Precision Farming or Convenience Agriculture

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Abstract
Profitability issues have constrained adoption of precision agriculture. Recently a question has been raised about role of management time in the adoption of precision agriculture. It has been hypothesized that producers prefer convenient technologies which economize on management time, to those which require more analysis and decision making. This paper provides an overview of the current status of precision agriculture worldwide, a summary of the economic studies of the technology and an examination of the convenience agriculture hypothesis.

Both availability and cost of management time appear to be issues for adoption of precision farming technology. Some precision farming technologies appear to use very little on-farm management time under U.S. conditions, either because they are usually out-sourced, or because they mainly affect logistics and do not require data analysis. Some stand-alone precision farming technologies yield low returns even without charging for management time and they would look even worse if management time were deducted. For the most profitable of precision farming practices returns seem to be high enough to pay average management costs. The willingness of traditional U.S. producers to undertake the computer analysis and decision making may be a greater constraint than the opportunity cost of the time because many producers chose agriculture for the active outdoor lifestyle and are reluctant to spend time in front of a computer. The unwillingness of U.S. producers to commit management time to precision agriculture may signal an opportunity for out-sourcing the data analysis and recommendation development.

Key Words
Precision agriculture, site-specific management, profitability, adoption, management time, variable rate

I. Introduction

Some aspects of precision agriculture are becoming standard practice in American agriculture. Around the world, commercial use of precision agriculture technology is occurring in most large scale, mechanized farming systems. But this technology is being adopted relatively slowly, compared to other innovations introduced about the same time (e.g. glyphosate resistant soybeans, Bt maize). This paper will explore the reasons for the relatively slow pace of precision farming adoption and in particular the role of management time in the precision farming adoption decision.

The specific objectives of this paper are to summarize the status of commercial use of precision agriculture around the world, to review economic studies of these technologies and to ask how the cost and availability of management time affects adoption of these technologies. This paper will focus on use of information technology for spatial management of field crops, but the principles can be applied to all types of site specific management, including horticultural crops, livestock, and forestry. These information technologies include: global positioning systems (GPS), geographic information systems (GIS), remote sensing, yield monitors, soil sensors, and variable rate application (VRA) of inputs. Sometimes “precision agriculture” and “site specific management” are used as synonyms, but site specific management is a broader concept which considers all types of spatial management, without or without the aid of electronics.

After this introduction the next section will provide an update on use of precision farming world wide. The third section will review economic studies of precision farming from both the public and private sectors. The fourth section outlines how management time would affect precision farming profitability and adoption. The final section has conclusions.

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II. Current Status

Since 1992, precision farming has attracted enormous media attention in North America from the farm press and beyond. Actual investment in precision farming has been promising in some areas, but considerably more modest than the media hype would suggest. The "killer application" of information technology for agriculture has been header yield monitors. Most previous computer technology applied to agriculture was for things that most farmers found dull and distasteful (e.g., accounting, tax preparation, payrolls). The monitors provide information on something that farmers are passionately interested in: crop yields.

From field testing of a few units in 1992, yield monitor use has grown rapidly (1). There now are roughly 30,000 headers in the U.S. equipped with yield monitors. In 2001 headers equipped with yield monitors were used on about 34% of all corn acres in the U.S. (2). For soybeans and wheat the most recent data is for 2000, when about 25% of soybean acres and 10% of wheat acres were yield monitored.

Yield mapping with GPS was done on about one third of the yield monitored area or about 11% for corn, 8% for soybeans and 2% for wheat. It should be noted that only about half of yield monitors in the U.S. and Canada are being used with GPS. Without GPS it is impossible to generate yield maps and to use the yield data effectively in spatial management. The economic benefits of yield monitors appear to come mainly from use of the information in diagnosing crop problems, and choosing hybrids and varieties (3).

Yield monitor use is substantially higher in the Corn Belt and on larger farms. A United States Department of Agriculture (USDA) study (4) indicates that while only 22% of U.S. farms are in the Corn Belt, almost 60% of farms using precision agriculture are in that region. An 1999 survey of farmers in Ohio found that only 6% of the 782 farmers participating used yield monitors, but 50% of the farmers with gross sales over $1 million used yield monitors (5). In that highest sales class, about 70% of the total acreage was harvested with a yield monitor in 1999. Another USDA study (6) found that while larger farm acreage is associated with higher probability of adopting precision agriculture, the highest probability of adoption is at the relatively modest farm size of 660 ha.

Outside of the U.S. and Canada there is substantial interest in yield monitoring, but adoption is lower. Stafford (7) indicated the following yield monitor numbers in northern Europe: United Kingdom, 400; Denmark, 400; Germany 150; Sweden, 150; France, 50; Holland, 6; and Belgium, 5. In Argentina there were about 560 yield monitors in 2001 and about 4% of the grain and oil seed area was harvested with headers equipped with yield monitors (8). Yield monitors are being used on some larger farm operations in Brazil and Mexico (9). Informal reports indicate that in Australia about 800 yield monitors were used for the 2000 harvest. Some fifteen farmers used yield monitoring in South Africa for the 1999-2000 crop season (10). There was virtually no use of any precision agriculture technology in Asia as of 1998 (11) and this also appears to be true for Eastern Europe and Africa outside of South Africa.

The original yield monitor devices were for grains and oilseed, but yield monitors are now being developed for a wide range of other crops, including sugar beets, potatoes, tomatoes, peanuts, and grapes. A recent USDA survey (2) indicates that about 8% of U.S. potato acreage is yield monitored, but only about 1% of sugar area. Methods are being developed to utilize GPS to provide spatial maps of hand harvested crops like apples and pears.

Variable Rate Fertilizer - The other high profile precision agriculture technology has been grid soil sampling and variable rate application (VRA). In 1996, 29% of farm retail dealers nationwide offered some grid soil sampling using global positioning systems (GPS) (12). By 2002, 50% offered this service (13). Controller driven variable rate application has seen similar growth. In 1996, 13% of fertilizer dealers offered controller driven variable rate application. By 2002, the percentage was 43%. Services offerings were higher in the Midwest and among large cooperatives and regional chains.

For some higher value specialty crops, like sugar beets, usage of variable rate spreading is quite high. Variable rate fertilizer is used on about 10% of potato area and 9% of sugar beet acres. In some specific areas use is even higher. In 1999 variable rate nitrogen was used on about 40% of the sugar beet acreage in the two states. (14).

For bulk commodities (e.g. corn, soybeans and wheat), the rate of intensive soil sampling and variable rate application has been substantially lower than dealer service offerings would indicate. A USDA survey (2) indicates VRT fertilizer was used in 2000 for 11% of corn area, 7% of soybean acres and 3% of wheat. Anecdotal accounts indicate that variable rate lime is the most common variable rate practice in the eastern Corn Belt.

Many U.S. producers of bulk commodities (corn, soybeans and wheat) are fascinated by the idea of site specific management of soil fertility. It is an intuitively appealing concept. But they have been plagued by continued questions about the profitability of the practice. The response of many growers has been to enroll part of their acreage in one of the site specific soil management programs offered by fertilizer retailers. For many farmers this is a low cost way to learn about precision farming without long term investment in equipment.

In Western Europe VRA seems to be driven mainly by environmental concern and regulation, in particular the limits on use of nitrogen to a total amount per farm. Given that limit some producers are using VRA to make sure the limited quantity of nitrogen goes to the places where yield response is the greatest. In Sweden for example there are 24 custom operators applying VRA nitrogen using the Norsk Hydro greenness sensor. Latin America and Australia there is experimentation with VRA, but relatively little commercial use. In Latin America the high cost of soil sampling limits the intensive soil sampling that is currently the basis of VRA decisions. Through the 1990s soil analysis in Argentina was about $70/sample. The development of new laboratories in Pergamino and in Buenos Aires has lowered that to about $25/sample, but this is still too high for the kind of intensive sampling practiced in the U.S. and Canada.

Other Precision Ag Technologies - In the U.S. and Canada, adoption of variable rate planting, variable rate pesticide application, remote sensing, vehicle guidance systems and other GPS technologies is more scattered. The USDA (2) found that variable rate seeding or pesticide was used on about 1% to 3% of grain acres. In 1999 a Purdue University researcher (15) found that about 5% of all custom application equipment in the U.S. and Canada was equipped with a GPS swathing system and that such systems are spreading rapidly among farmers producing non-row crops (e.g. wheat, drilled soybeans, canola). Whipker and Akridge showed that over 50% of custom applicators using ground based equipment used GPS guidance systems.

Several companies have test marketed aerial and satellite remote sensing to farmers. Primary uses have been identifying management zones, measuring crop injury (e.g. from herbicide drift, hail, wind), and early diagnosis of pest, nutrient deficiency and irrigation problems. Anecdotal accounts indicate that remote sensing companies have found repeat customers among the growers of fruits, vegetables and other high value crops. Most of the test marketing has used aerial photography, but long term plans are to use high resolution satellite images. One example of satellite use comes from sugar beet growers in Minnesota and North Dakota where in 1999 60% of the American Crystal Sugar Company growers used satellite images, mainly to help determine VRA nitrogen application zones (16). About 5% of corn and 4% of soybeans in the U.S. in 2000 were managed with the help of a remotely sensed image (2).

Adoption Projections - Surveys of producers and agribusinesses show an expectation that precision agricultural technology will soon become standard practice in the U.S. A survey (17) showed that producers in Iowa, Illinois, Indiana and Wisconsin expected yield monitor use and VRA of fertilizer to be over 45% of farms by 2001. Purdue University surveys (12, 13, 18, 19, 20) showed similar expectations among fertilizer and pesticide dealers.

Studies comparing precision agriculture to other agricultural technology suggest that the adoption pattern may be slow and uneven (1). Adoption of precision agricultural technology may be more like the spread of motorized mechanization in the U.S. in the first half of the 20th century or the adoption of no-till in the second half of the century, than it is like the adoption of hybrid corn in the 1930s or genetically modified seed in the 1990s. This is primarily because precision agriculture technology has come to the market in an immature form. The integrated systems needed for profitability do not yet exist. Many firms have used producers to beta test their technology and it takes time for the market to sort out winners and losers.

An additional problem is the relatively high adjustment cost of moving to a precision farming system. One of the easiest steps is starting to use a yield monitor and even that requires purchase or installation of unfamiliar electronic equipment, learning how to operate and calibrate the monitor, and acquiring yield map interpretation skills. In comparison, adoption of Bt corn is very easy. There is no change in planting or harvesting procedures.

Adoption patterns outside the U.S. and Canada have not been studied in depth, but there is some indication that local conditions will play an important role in the speed of adoption and on which components of the technology are used. For example, one study (21) suggests that because of the structure of agriculture in Argentina, yield monitors may be more valuable than they are in the U.S., but that VRA may be adopted even more slowly because of the overall economics of fertilizer use, the high cost of soil sampling, and relatively low level of management induced soil variability.

III. Previous Economic Studies

A substantial body of research has accumulated on the economics of precision agriculture. A Purdue University review of literature (22) found 108 studies in 2000, 63% of which found that the technology was profitable. Unfortunately, these studies use a wide range of assumptions and methods. Some studies omit significant costs, such soil sampling fees and VRA application charges. Other studies overestimate the yield benefits from precision agriculture. Several authors have summarized the common problems in estimating the profitability of site-specific management and outlined methods for obtaining reliable economic estimates at the farm level (3, 23).

Most economic studies of precision ag technology have focused on VRA of fertilizer because that was the first technology to be commercialized and it was also the one on which the most data was available for economic analysis. The published results on profitability of VR nutrient applications can be difficult to interpret, due to differences in experimental design and assumptions about included costs. Partial budgets on VR fertilizer application are driven by three elements: 1) increased cost of soil sampling information and VR application, 2) change in cost of fertilizer applied, and 3) change in revenue due to crop yield. The added information cost is central, yet it is omitted from some studies.

A recent article (3) examined profitability results from nine university field research studies of VRA fertilizer. It applied standard minimum cost assumptions to all studies where selected cost items had been omitted and found that the value of crop yield gains was especially important. High value crops that responded to VRA of fertilizer tended to do so more profitably than low-value crops, because the yield gains were worth more. VRA of fertilizer on wheat and barley was nowhere profitable, the results for corn were mixed, and VRA fertilizer on sugarbeet was profitable. By contrast, cost savings from reduced fertilizer application were much less important. The fertilizer inputs being managed are fairly low cost and only one study managed more than two of them. Given that soil testing is fairly costly, most of the crops are of fairly low value, and macronutrient fertilizers are relatively cheap, the cost of overfertilizing is fairly low.

VRA Simulation Studies - There is a similar group of studies using crop growth simulation to evaluate site specific soil nutrient management (3, 24, 25, 26). As for the VRA of fertilizer field studies, profitability results in the simulation studies are mixed, but they are more likely to show VRA profitability because they do not always include other yield limiting factors. For example, intensive soil sampling may show areas of low phosphorus in a field. Simulation may suggest a yield increase with VRA of phosphorus. The reality may be that these are areas in which water holding capacity is the most limiting factor and increasing phosphorous has little yield benefit.

This problem with simulation studies is compounded by the fact that even the most sophisticated crop growth process models often lack many of the factors that determine spatial variability. They were usually designed and calibrated to mimic small plot yields. Only now are efforts underway to include landscape factors, including topography, slope, aspect, hydrology, in crop process simulation models.

Other Technologies - Scattered studies have dealt with the economics of precision ag technology other than VRA fertilizer. In on-farm experiments a Kentucky researcher (27) showed that variable rate plant populations can be profitable in the Kentucky carst landscape, which are characterized by wide variation in yield potential. Another study (28) showed when management zones are determined by yield potential, variable rate seeding for corn is profitable only when some parts of the field have potentials below 63 q/ha. Illinois researchers and Pioneer Hi-Bred staff analyzed small plot data from 1987 to 1996 and found that there maybe small yield gains when plant population is varied by soil type, but the cost of determining optimal plant population by soil type probably exceeds the benefit in most cases (29).

Site specific management of perennial weeds is a classic “no brainer”. Producers can use scouting or the marker systems of header yield monitors to map locations for patch treatment. Annual weeds have proven more difficult. There are several simulations studies of site specific management of annual weeds (30,31). These studies tend to show some profit potential in site specific weed management, but like the soil nutrient management simulation studies it has been much more difficult to show benefits in field studies.

A 1999 study (15) budgeted the benefits of using GPS guidance to avoid skips and overlaps in pesticide application. The study found that use of GPS guidance is potentially profitable for custom operators and producers who already own a GPS with satellite differential correction. For producers who do not yet have GPS, the break even farm size in the U.S. Corn Belt is about 800 hectares.

Purdue researchers used a simulation model to analyze the profit potential of VRA of lime in Indiana (32). They found that VRA of lime was profitable under a wide range of circumstances, largely due to the fact that the optimal pH range is relatively narrow and there are negative effects of overliming (e.g. micronutrient tie up, increased damage from certain soil applied herbicides).

Currently, no published studies are available on the profitability of yield monitors, but researchers have identified the profit opportunities that are leading U.S. producers to invest in this technology (3, 33). Key benefits include:

- better information for diagnosis of crop production problems,
- cheaper on-farm experimentation (e.g. variety and hybrid trials),
- improved identification of management zones,
- quantitative evaluation of whole field improvements, such as drainage, land leveling, wildlife fencing and windbreaks,
- real time benefits at harvest through improved logistics (e.g. better scheduling of trucks, drying, storage) and through better marketing (e.g. taking advantage of early season price premiums because of confidence that later contract obligations can be met (34)).
- business management uses, such as in farm land rental or purchase negotiations, legal cases (e.g. evidence of crop herbicide damage), environmental management (e.g. establishing yields for determination of maximum manure application) and crop insurance claims.

Because many yield monitor benefits are at the whole farm level and may extend over several years, it has proven difficult to measure them. For example, if a producer uses yield maps to diagnose soybean cyst nematode problems, he may change the varietal choice and crop rotation on the whole farm, not just on the field where the pest was identified, and not just the next year, but for many years to come. Similarly, a variety or hybrid identified in an on-farm trial on one field may be used on many other fields. Measuring the whole farm benefits of yield monitoring would require whole farm information. Yield monitor benefits can not be measured adequately with the type of on-farm field trials used for VRA. With such whole farm information it would be possible to do “before and after” studies similar to those which have been done on adoption of swine management systems (35).

Yield monitors are often justified by using examples. For instance if a producer on a 1000 hectare farm would increase corn and soybean yields by one half quintal per hectare by better choice of hybrids and varieties, that would pay for an $8000 yield monitor and GPS in one year. Benefits other than hybrid and variety choice, and all benefits in the future, then come at very low cost because once the producer has the equipment and software the marginal cost of operation is very small.

No published studies are available on the economics of remote sensing in agriculture.

Integrated Systems - There are economies of scope in precision farming systems. Economies of scope occur when production costs fall because an enterprise includes a wider range of activities. In precision farming managing multiple inputs provides greater profitability than each input managed separately because of interactions between inputs can be fine tuned and because data collection, analysis and implementation steps can be combined for some inputs. The interaction of the right corn hybrid at the best population for that hybrid with the profit maximizing nitrogen rate for that hybrid and population, can yield better and may be more profitable than if each input were optimized separately. One example of combining steps occurs in soil sampling. The labor required to do grid soil sampling is the same whether that sample is tested for only pH, or also tested for phosphorus, potassium, CEC, and other characteristics. VRA costs will be lower if soil sampling costs can be spread over multiple inputs.

There are no truly integrated precision farming systems, but evidence from the Sauder farm trials (36) provides support for the idea that systems that manage multiple inputs are more profitable. These trials integrated variable rate management of NPK and planting rate on a 526 hectare acre farm producing a 50/50 corn soybean rotation in Central Illinois. Over three years the average benefit from the GPS based management for both corn and soybeans was US$34.35/ha. The experimental design did not allow researchers to identify which parts of the system contributed most to the benefit, but it was clear that a 9 q/ha increase in average corn yields played an important role. This is one of the only studies that has shown a statistically significant impact of site specific management on yields.

Risk - Given the data limitations, most precision agriculture profitability studies have focused on comparing average returns. In theory, precision agriculture could also reduce the variability of income within a year. A recent study of VRA of phosphorus and potassium suggests that management by soil type would be the strategy preferred by risk averse decision makers even though average net returns are about the same for both whole field and soil type approaches (37). Lowenberg-DeBoer (38) suggested that while precision agriculture has a modest potential in managing production risk, the benefits in marketing will probably be much more important.

Economic Synthesis - Precision agriculture is a young technology. Many aspects of the economics remain to be explored, but the general outlines of its economic characteristics are emerging:

- The profitability of precision agriculture is positively correlated with crop value. It is easier to create a profitable system on higher value crops.
- Integrated systems which manage multiple inputs tend to be more profitable because they can fine tune interactions and combine data collection, analysis and implementation steps
- In the long run most of the benefit of precision farming systems will probably come from whole farm management information uses, not from VRA.

Whole farm management information systems would include use of sensors, remote sensing, and telemetry to help:

- optimize spatial and temporal input application
- improve field operation logistics,
- supervise employees in the field,
- manage production risk,
- market differentiated products,
- provide “traceback” for food safety,
- document environmental compliance.

The push to use precision farming technology has been intensified by the food safety scares in Europe (e.g. Mad Cow Disease) and the awareness of bioterrorism in the U.S. after the anthrax attacks. If much of the data collection and analysis costs are covered by other uses, variable rate application may become a nice side benefit of whole farm information systems.

IV. Management Time

Management time is a scarce and expensive resource in all industries. A 2001 U.S. Department of Labor survey shows that the average compensation for managers is around US$60,000 annually (39). Experienced managers earn much more. Farm worker wages are around US$20,000 annually. A recent article (40) hypothesized that adoption of precision agriculture technology was relatively slow because of the management time require to implement this technology. This author labeled farming practices that economize on management time as "convenience agriculture".

The management time hypothesis could help explain some disparities in adoption of technology in agriculture. In particular it could help explain the difference between adoption of biotechnology products, which typically require little management effort, and information technology, which often requires substantial analysis and decisionmaking. The difference in adoption between glyphosate resistant soybeans and precision farming technologies such as yield monitoring or intensive soil sampling is a good example. Glyphosate resistant soybeans are planted on over 70% of U.S. soybean area in spite of the fact that there are marketing problems and they often do not show production benefits when compared to conventional soybeans. In many cases glyphosate resistant soybeans suffer from lower yields (i.e. yield drag) and may have higher weed control costs than conventional soybeans if glyphosate must be applied more than once. Many farmers say that they use glyphosate resistant soybeans because they are "so easy to grow". In other words, glyphosate resistant soybeans do not require as much management time as conventional soybeans. While their per unit area returns may be lower, they allow a producer to manage more area. In contrast, precision agriculture adoption has been relatively low, in spite of good evidence of profitability for some aspects.

One issue is that none of the economic studies of precision agriculture have explicitly accounted for the management time needed to implement these technologies. In fact very few of them have accounted for any additional time requirement (3). The most common practice has been to treat farm labor as a fixed resource that would not change with the technology and omit it from partial budget calculations. One of the key problems in trying to introduce charges for management time is that there is no good data on the amount of management time that various precision farming tools require. Some practices that are primarily outsourced (e.g. grid soil sampling, VRA fertilizer) probably require very little management time. Practices that primarily affect logistics or operations efficiency, but do not require data analysis or decision making (e.g. GPS guidance, lightbars), also do not require much management time.

Practices that must be implemented by the producer and those which require analysis and decisions probably require much more management time. In the U.S. Midwest, where it is common for farmers to own header harvesters, someone on the farm must usually invest time if yield monitoring is to show any benefit. They must learn how to operate and calibrate the equipment. They must learn how to make yield maps and how to use yield map data to diagnose problems or interpret on-farm trial information. It is common to hear first time yield monitor users explain that "I spent all winter going through those yield maps."

The charge for management time is difficult to determine in traditional U.S. farming operations in which producers provide both labor and management. It is common, even for producers with relatively large operations (> 2000 ha of row crops), to spend some time operating equipment. The value of time in bottleneck planting and harvesting periods can be estimated by the opportunity cost (e.g. shadow prices in linear programming models or the cost of hiring additional labor), but what is the value of the flexible time in the winter months used to study yield maps. Is it the US$10/hr that might be earned in seasonal work? Or is it the US$30/hour or more for management time?

The relatively low returns of most stand alone precision farming practices (e.g. VRA P & K, variable rate seeding of maize and soybeans) means that they could not support much management time. But what about the more profitable integrated precision agriculture practices? On the 526 ha Sauder corn and soybean farm, the GPS treatment would earn about US$18,000/year more than the conventional whole field management. This would pay for almost three full months of the average American managers time. Three months is probably more than enough to analyze the soil test data, to implement and interpret the on-farm trials that Sauder used to develop his farm specific soil fertility management plan, and to make the necessary decisions. This suggests that while including the cost of management time may mean that returns to precision farming technologies are somewhat lower than previously thought, it does not seem to entirely exclude adoption of the technology.

Management time is another reason to expect higher adoption of precision agriculture on larger farming operations. There are economies of scale in data analysis and decision making. Larger operations can spread the management time cost over more area.

A related issue is the availability of management time. Most U.S. producers did not become farmers in order to spend time in front of the computer analyzing spatial data. They became producers in part because they like the active, out door life that farming offered. This may mean that they are relatively unwilling to put time into management or equivalently that they must be compensated at a higher than average rate. Risk may also be an issue. Alternative uses of time for U.S. producers (e.g. seasonal off-farm work, livestock raising) have a more certain compensation than the relatively new, immature precision agriculture technology. The unwillingness of U.S. producers to commit management time to precision agriculture may signal an opportunity for out-sourcing the data analysis and recommendation development.

V. Conclusions

Precision agricultural technology is being adopted slowly in the U.S. and Canada. Some aspects, such as grain yield monitors and VRA of fertilizer on some higher value crops are moving toward becoming standard practice. Persistent questions about profitability have constrained rapid adoption of precision agriculture.

Most economic studies on precision agriculture have been done on VRA fertilizer and they show a clear link between crop value and profitability of the practice. In the U.S. VRA fertilizer is likely to be profitable on higher value field crops, like sugar beets, but often it is only a breakeven for bulk commodities like corn and soybeans. Results are similar for field and simulation studies, but many simulation models appear to overestimate the potential of precision agriculture, because the models do not include all limiting factors. Evidence suggests that integrated precision agricultural systems are more profitable than stand alone technologies because in integrated systems equipment, information and human capital costs can be spread over several inputs and because interactions between managed inputs can be fine tuned. The whole farm and off-farm benefits of precision agriculture are largely unstudied, but anecdotal information indicates that use of precision tools for logistics planning, monitoring crops and employees, marketing differentiated products, risk management, farmland purchase and rental, and other off-field uses may be much more profitable than field level use.

Both availability and cost of management time appear to be issues for the adoption of precision farming technology. Some precision farming technologies appear to use very little management time under US conditions, either because they are usually out-sourced (e.g. grid soil sampling and VRA P & K), or because they mainly affect logistics and do not require data analysis or decision making (e.g. GPS guidance). Some stand alone precision farming technologies yield low returns even without charging for management time (e.g. VRT seeding maize and soybeans), they would look even worse if management time were charged. Though little data is available on them, integrated systems seem to fare better. An example of the Sauder farm trials indicates that the annual benefits could support the average U.S. managerial salary for almost three month, probably enough time to handle the managerial tasks involved. The willingness of traditional U.S. producers to undertake the computer analysis and decision making is probably a greater constraint than the opportunity cost of the time because many of those producers chose agriculture for the active outdoor lifestyle that it offered and are reluctant to spend time in front of a computer. The unwillingness of U.S. producers to commit management time to precision agriculture may signal an opportunity for out-sourcing the data analysis and recommendation development.

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