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THE FARMER'S DECISION

Balancing economic agriculture production with environmental quality

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Weeding out Economic Impacts of Farm Decisions

CHAPTER 4

D.W. Archer

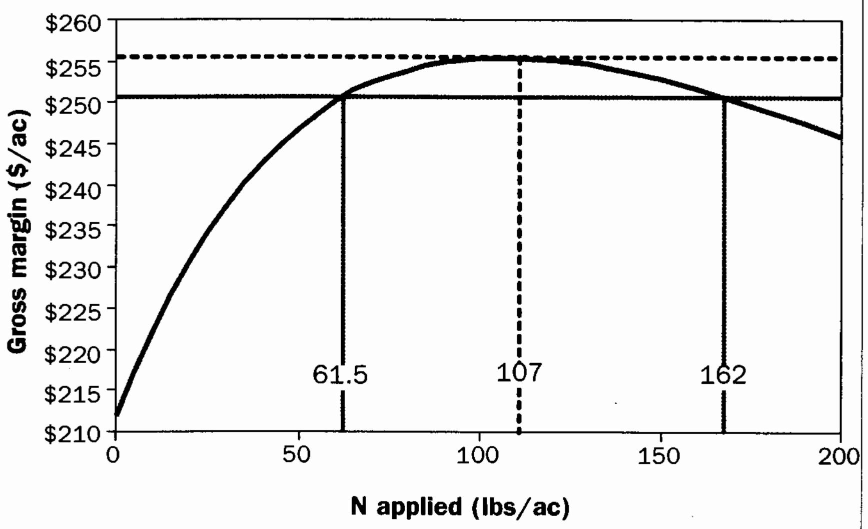
Decisions made at the farm level are heavily influenced, if not driven, by farm-level economic impacts. Producers make a myriad of decisions throughout the season, and even if they are not driven strictly by profit maximization goals, profit needs to at least be considered in order for the operation to remain economically viable. As a consequence, this paper will focus primarily on the relationships between management decisions and farm-level profit. What follows is a discussion of some of the factors that affect farm profitability, with the idea of providing insights into how management decisions may be influenced by economic considerations, and conversely, providing a broad overview of how enhanced decision making might affect farm profitability.

Basic production processes. The most direct economic impacts at the farm-level represent a summation of impacts occurring at the field or smaller scales relating the use of purchased inputs to crop outputs. This "crop response function approach" is one of the oldest and most widely used tools in agricultural economics (Heady and Pesek, 1954), and has seen renewed interest in the area of precision agriculture and variable rate applications (Bongiovanni and Lowenberg-DeBoer, 2001; Bullock et al., 2002; Mamo et al., 2003). An example of this approach is the relationship between nitrogen fertilizer applications and crop yield. If we know the functional relationship between the quantities of nitrogen fertilizer applied and crop yield, as well as nitrogen and crop price, it is quite easy to identify the amount of fertilizer to apply in order to maximize net returns. However, in reality producers only have a general idea about the relationship between the quantity of fertilizer applied and crop yield. In addition, factors acting between the times the fertilizer is applied and when the crop is harvested result in uncertainty about yields and prices that will be realized. For example, yield is affected by nitrogen availability, weather, availability of other nutrients, pest pressures, etc. It is costly to gather more information about the relationship between the quantities of fertilizer applied and crop yield. Even with extensive information gathering, it is unlikely all of the uncertainty will be resolved. The important question is how much information is it worth collecting?

In many cases, the relationship between net return and applied nitrogen is relatively flat over a range of application rates, implying there is little economic benefit to gathering more information in order to fine tune rates. Figure 1 shows the gross margin for the nitrogen production function used by Mitchell (2003). The optimum nitrogen application rate in this example is 107 pounds per acre, resulting in a gross margin of $255.42 per acre. However, the nitrogen application rate can range anywhere from 61.5 to 162 pounds per acre, and gross margin will be within $5.00 per acre of the optimum. This has often been observed to be the case with other inputs (Hutton and Thorne, 1955; Anderson, 1975) and for other economic decisions including land use allocation decisions (Pannell, 2004). This "flat payoff function"

Figure 1

Gross margin response to applied nitrogen fertilizer in corn.



has some potentially positive implications in that producers have a wide margin for error in their production decisions which lends a degree of flexibility to their management options. This flexibility is a key issue in farm-level economics that will be discussed in more detail later. Focusing on a single input decision, this flat payoff function may lead one to conclude that there is potential to reduce input levels with little negative economic impact. For the nitrogen example, application rate could be reduced by over 40 percent with only a $5.00 per acre reduction in net return. In one of the examples provided by Pannell (2004), herbicide doses ranging from 60 percent of the optimum to 170 percent of the optimum would yield profits within 95 percent of the optimum. Even though the economic benefits to fine tuning rates may be small, it does not necessarily follow that environmental consequences would be small.

The nitrogen example shown in Figure 1 is admittedly a simple example in that it is based on a single location and single year response, so it does not include the risk and uncertainty (hereafter the terms risk and uncertainty will be used interchangeably, referring jointly to imperfect knowledge and uncertain consequences) faced by producers. Uncertainty can affect producer decisions in many ways, depending upon the source of the uncertainty. Motivated by the common idea that farmers apply "a little extra fertilizer just in case it is needed," Babcock (1992) showed that uncertainty regarding soil nitrate concentrations and potential yields could lead producers to increase nitrogen applications rates to maximize expected profits. In a simulation analysis of nitrogen application to corn in Iowa, Babcock showed that uncertainty could increase application rates by as much as 25 to 36 percent. This result is not generalizable to other production technologies. Pannell (1990; 1991) showed in many cases expected pesticide application

rates decline with increases in uncertainty.

At the whole-farm level, basic production processes include interactions among production activities. Crop rotation sequences can affect crop yields through effects on weed and disease pressures, nutrient cycling, and water use dynamics. Integration of crop and livestock production can affect profitability by reducing input costs and increasing productivity. As an example, Pannell (1999) discusses the importance of accounting for interactions in estimating the farm-level impacts of introducing lupins to a Western Australian farm. In the analysis, Pannell included the effects of lupins on fixing nitrogen, improving soil structure, reducing cereal disease levels, and use of lupin grain and residues as sheep feeds. He also included effects on efficiency of machinery use. Comparing the analysis to the case where no interactions were included showed that the economic benefits from lupins would be greatly underestimated without interactions.

Timeliness. As basic production processes are brought up to the farm scale, timeliness becomes important. Many farming activities must be carried out at specific times in order to be most effective. Crops need to be planted to make full use of the growing season, herbicide applications need to be timed to minimize yield loss due to weed competition, and crops should be harvested when they have reached maturity, but before yield loss or damage occurs. However, producers have limited equipment and labor to carry out these operations. Critical times may occur simultaneously at several locations around the farm making it impossible to reach all of the locations in a timely manner, or weather conditions may delay field operations. When these operations can not be completed at the appropriate time, there is generally a direct effect on crop productivity and therefore economic returns.

Producers make decisions to manage the economic effects of time constraints. They may select crop mixes or tillage practices to reduce the potential for conflicts to occur. They may purchase more or larger equipment and hire additional labor to increase their capacity to complete operations in a timely manner. These types of decisions can have significant farm-level economic effects. Because of the potential for significant farm-level economic effects, machinery selection has been the impetus behind the development of several software decision aids (Siemens et al., 1990; Ellinger, 2003) that include effects of timeliness. In addition, time constraints are an important part of comprehensive whole-farm optimization models (e.g. Doster, 2000; Pannell, 1996).

Flexibility. Flexibility in management options has long been conjectured to have significant economic impacts at the farm-level, but has received relatively little formal study. Schultz (1939) went so far as to say that individual farms are not necessary except in the face of change, writing:

> The criterion that measures entrepreneurial success is to be found in adjustments which may be looked upon as consisting of two interrelated parts: (a) correctly anticipating the type of adjustments that are needed; and (b) the best way or method for making the adjustment.

The idea is that producers have flexibility to make tactical adjustments in response to new information, and that these tactical adjustments can have significant farm-level economic impacts. It is this response to new information that distinguishes flexibility in decision making from timeliness issues.

Techniques and a theoretical basis for analyzing management flexibility have been available for quite some time (Rae, 1971; Antle, 1983b). However, application of these techniques has only become practical with advances in computer technology. Management flexibility was first studied for decisions involving a single enterprise or a single input (Mjelde et al., 1989;

Thornton, 1984; Harper et al., 1994; Mitchell, 2003). Studies evaluating whole-farm impacts of tactical adjustments are more recent and more limited (Kingwell et al., 1992; Kingwell et al., 1993; Kingwell, 1994; Etyang et al., 1998; Dorward, 1999; Ekman, 2000). In some cases the availability of tactical adjustments can have large farm-level economic effects. Kingwell et al. (1993), in a study of a representative Western Australia farm system, found the inclusion of tactical adjustments increased expected net return by 22 percent compared to the best inflexible strategy. In addition, the largest benefits of flexibility occurred in the most extreme seasons. This would indicate that producers who can make tactical adjustments, particularly in extreme conditions, may have a competitive advantage. However, Ekman (2000) showed only a three percent increase in expected net return using a flexible strategy compared to a fixed strategy for a representative Swedish farm. The differing impacts are likely due to the uncertainty effects considered in the alternative models. Kingwell et al. considered adjustments to seasonal weather observations that have direct and potentially large impacts on production, while Ekman considered adjustments to uncertain field-time availability which had generally indirect and marginal impacts on yields and were partially offset by reductions in cost. A challenge for both farm managers and economists is to recognize a *priori* when tactical adjustments are likely to have significant farm-level economic effects.

In some cases, timeliness and management flexibility may be the primary reasons producers use a specific technology. Bouzaher et al. (1992) modeled choices among herbicide strategies based on the time periods when specific herbicides could be applied and be effective. Herbicide strategies that allowed longer time periods for successful application at the lowest cost resulted in the highest expected net returns, and would be selected by profit maximizing producers. Similarly, Archer and Gesch (2003) evaluated the potential for a temperature-sensitive seed coating to be adopted by producers in the U.S. northern Corn Belt based on the added flexibility in planting time that the coating would provide. The analysis showed the new technology could increase whole-farm expected net returns by three to four percent with expected use on as much as 45 to 79 percent of the total crop acres. Note this benefit occurs for a technology *that has no direct effect on crop productivity*.

Several recent analyses have included the concept of "real options." The idea is that with some types of decisions, there is a value to waiting rather than taking immediate action. Real options can be used to assess the value of management flexibility. This approach has been used by Saphores (2000) to evaluate pest control decisions where "the farmer has to balance expected pest damages with the cost of applying the pesticide *plus the loss of flexibility* which comes from using one of its possibilities to reduce the density of the pest population by spraying the pesticide" (emphasis added). The approach has also been used in evaluating the decision to adopt new technologies. In analyzing the decision to invest in site-specific crop management, Khanna et al. (2000) showed that it may be more profitable for producers to delay adoption even though immediate adoption appears to be profitable. This situation occurs because payoffs are uncertain, investments in the technology are irreversible and costs of the technology are declining. In this analysis, adoption of site-specific crop management was shown to have environmental benefits due to reduced nitrogen runoff, so delaying adoption also delays environmental benefits. In a related study, Isik (2004) showed that uncertainty about the availability of cost-share subsidies for improved nutrient management (including site-specific technologies) can delay adoption when cost-share is not currently available but there is an expectation it may become available. The real options approach accounts for the possibility of producers delaying decisions into the future.

Information acquisition. Because tactical adjustments are made in response to new information, this has naturally lead economists to analyze the value of information. Hennessy and Babcock (1998) observed "there is wide spread belief that modern manufacturing emphasizes flexibility in accommodating new information," and "information technology is being used to enhance flexibility." The implicit recognition is that businesses not only utilize flexibility to make adjustments as information becomes available, but they make investments to increase flexibility by acquiring information. Information can be used to make management decisions as the season progresses (reducing temporal uncertainty) and/or information can be used to adjust management across the landscape (reducing spatial uncertainty).

Anderson et al. (1977) identified a method for estimating the value of information as the difference between the certainty equivalent value of the optimal strategy with the information and the certainty equivalent value of the optimal strategy without the information. (Note: certainty equivalent value is the amount of money that an individual would have to receive to be indifferent between a certain payoff and a given gamble. This is used to account for differences in individual risk preferences. For a risk-neutral producer, certainty equivalent is the same as expected profit.) Chavas and Pope (1984) outlined a theoretical model for the value of information in sequential decisions, where the decision maker can revise plans as new information becomes available. The model showed that the ability to revise future plans tends to make the decision maker better off, indicating the value of flexibility in management. Antle (1983b) indicated the potential pitfalls of not including sequential decision making in economic analysis. The importance was confirmed by Mjelde et al. (1989) who showed a four to 10 percent increase in profits for a farm utilizing information to adjust nitrogen applications versus a farm that does not update applications based on weather conditions.

Applying the Anderson et al. approach, Pannell (1994) evaluated the value of information in weed-control decisions based on information about potential yields (via weather information) and weed densities. He showed that the expected value of information could reach as high as 15 percent of the expected gross margin. He also showed that expected herbicide applications should decline for a producer who adjusts herbicide applications based on weather observations and weed densities.

In evaluating the value of information, it is important to be clear about the assumptions being made about both the initial level of information producers have and the level of information that will be attained. In evaluating the value of information on late-spring soil nitrate levels, Babcock and Blackmer (1992) assumed producers initially know the probability distribution of soil nitrate levels, but not the actual values. They compared this to a state of "perfect information" where soil nitrate levels are known with certainty. Their analysis showed values of perfect information ranged from $6 to $22 per acre and expected total nitrogen applications were reduced by as much as 38 percent compared to the no soil test information case. Note, these values represent upper bounds on what producers would obtain if they either had better baseline information than assumed or if soil test information is imperfect.

Babcock and Blackmer's example

showed how, at least for nitrogen, information might serve as a substitute for purchased inputs. Uncertainty leads producers to apply higher nitrogen application rates, but information can allow producers to respond tactically, reducing uncertainty, and thereby reducing application rates. Unfortunately, this result is dependant on the underlying production relationship, so it is not necessarily generalizable.

Regarding spatial uncertainty, Hennessy and Babcock (1998) developed a theoretical model to evaluate how acquiring information about spatial variability affects both profitability and input use. For the case of perfect information, that is, moving from a condition of unknown variation across a field to known spatial variation across a field, Hennessy and Babcock showed that the value of information increases as variability increases. This supports the common finding that the economic performance of site-specific application technologies is positively related to spatial variation across a field (Forcella, 1992; Babcock and Pautsch, 1998; English et al., 2001). This also explains the observations of Olson and Elisabeth (2003) that adoption of precision agriculture technologies was positively related to soil variability for farms in southwestern Minnesota. Hennessy and Babcock could not identify a general relationship between information and input use without a more detailed understanding of the specific technology involved. However, in an applied analysis, Babcock and Pautsch (1998) found that soil test information could result in reducing fertilizer application rates by five to 32 percent. Even though Babcock and Pautsch showed positive economic values for perfect spatial information in variable rate nitrogen applications, it should be noted that the value of the information was relatively small, ranging from $1.53 to $7.43 per acre.

Of course, the assumption of perfect information is a limiting case. In reality, it is unlikely that all of the uncertainty will be resolved prior to making a decision. Mitchell (2003) extended the theoretical model of Hennessy and Babcock to include the possibility of imperfect information. He showed that the value of imperfect information about spatial variability is higher when it increases the efficiency of input use, and when the information is "good" in that it correlates well with the underlying stochastic factor and exhibits low variability. In an applied analysis, Mitchell showed that imperfect information could decrease nitrogen application rates by four to nine percent depending on the quality of the information. However, the economic value of the information was again relatively low, ranging from $1.07 to $1.38 per acre. In a similar analysis, Babcock et al. (1996) showed that nitrogen application rates might be reduced by 15 to 40 percent, with the value of the information ranging from $3 to $10 per acre.

This leads to the larger question of how producers strategically position themselves to take advantage of tactical opportunities. Investments in information acquisition are one tool producers can use. As Pannell et al. (2000) observed the key to maintaining an economically viable farm enterprise is getting the big decisions right, and that those who made incorrect major adjustments are the ones who are most likely to be under financial stress.

Financial considerations. Financial considerations often get overlooked in farm-level economic analyses. As Malcolm (2000) observed "financial feasibility is as important a criteria as economic returns" in farm management economic analysis. Several studies have looked at how farm investment and borrowing decisions are affected by year-to-year changes in production (Lowenberg-DeBoer, 1986; Featherstone et al., 1990; Atwood et al., 1996; Escalante and Barry, 2001; Atwood and Buschena, 2003); however, these generally lack detail in production practices. Consequently, interactions between production decisions and investment and borrowing decisions have not been analyzed in detail. However, it is these investment and borrowing decisions that are the "big decisions" Pannell et al. (2000) say are important for producers to get right. In order to get these decisions right, it is important to understand how they might constrain or be constrained by management options at a finer level. Escalante and Barry (2001) showed that the availability of share leasing arrangements might lead to a substantial increase in farm size due to effects on increasing cash flow. For a representative risk-neutral Illinois farm, they showed that both farm size and net farm income more than doubled with the availability of share leasing arrangements. However, because the model did not include other constraints related to production practices, it is unclear whether this response is realistic.

Whole-farm models often include financial constraints (Pannell, 1996; Dorward, 1999), but these don't include detail on the dynamics of year-to-year adjustments in investment and borrowing decisions that may be important for capturing the effects of financial considerations on farm-level decisions. Dorward (1999) showed an interaction between access to credit markets and benefits to on-farm tactical responses to risk, indicating that tactical responses may become less important when farms have access to effective credit markets. Understanding these types of interactions is important in understanding how financial considerations affect farm-level decisions.

Producer attributes. The preceding discussion neglects any consideration of differences among producers. Producers have individual tastes and preferences. They are part of a community and have social goals and environmental goals; and they have different mixes of skills, abilities,

and interests. While these attributes will not be discussed in detail here, it is important to illustrate some pertinent relationships to economic performance.

The most common tool for including individual preferences in economic analysis is the utility function. In most cases utility is used only to account for individual's aversion to risk. While there has been considerable research indicating that producers tend to be risk-averse, risk aversion is often included in economic analysis with little regard for whether it is economically important (Pannell et al., 2000; Just, 2003). In addition, considerable research has shown that behaviors often attributed to risk-averse preferences can be explained by appropriately capturing other aspects such as financial transaction costs (Atwood and Bushena, 2003) and production technologies (Antle, 1983a; Babcock and Shogren, 1995; Pannell et al., 2000). Pannell et al. (2000) argue, "Often, better representation of the biology, production alternatives, technology, taxation ramifications, resource endowments, weather-year and price conditions, and tactical opportunities will yield more valuable information about change at the farm-level than sophisticated inclusion of risk-aversion." For soil nitrate uncertainty, Babcock and Shogren (1995) showed that the direct effect of uncertainty on production accounted for 40 to 85 percent of the total premium producers would be willing to pay for risk reduction, with risk aversion accounting for the rest of the premium. This is not to deny that producers are risk-averse, but simply to point out that, depending on the situation, risk aversion may or may not play an important part in farm-level decisions compared to other factors.

Besides having different preferences, farmers have different mixes of skills and abilities. These differing levels of human capital affect both the sources of information farmers utilize and the usefulness of that information (Just et al., 2003). Griffin et al. (2004) identified human capital costs as one of the barriers to adoption of precision-agriculture technologies. They also observed that, although human capital costs appear to be a barrier to adoption, producers "seem to be skeptical of 'closed-loop' approaches that automate decision-making." It may be this skepticism of "closed-loop" approaches is an implicit recognition that these approaches do not contribute to building the human capital farmers rely on in making daily management decisions, and therefore are not as valuable to them.

Emerging technologies. What are the implications of the foregoing factors for farm-level economic impacts of emerging technologies? The "flat payoff function" phenomenon has been identified as a potential barrier to the adoption of precision-farming technologies (Pannell, 2004). Specifically looking at technologies in which inputs are varied based on site-specific conditions, commonly called variable rate technology, Pannell observed that flat payoff functions implies there are diminishing marginal returns to the benefits of more precise application of inputs. That does not necessarily mean that precision farming technology will not be adopted. As the hardware, data acquisition and processing costs decrease, even small payoffs should lead to increased adoption and this can have significant environmental effects. However, as noted earlier, Khanna et al. (2000) showed that declining costs can also serve as a barrier to adoption when producers decide it is better to wait for lower costs. There is some limited evidence to suggest that systems that manage multiple inputs are more profitable (Finck, 1998). However, unless precision farming technology results in substantial changes in input levels, the direct production function effects on profit are likely to be low.

There are some situations in which substantial changes in input use are known to occur. One is in "patch management" of perennial weeds, where herbicides are only applied to discrete patches where weeds have been identified. Indeed, Lowenberg-DeBoer (2003) identified this as the "no-brainer" in site-specific management. However, Pannell and Bennett (1999) indicate, even in this case, there are some complexities that can reduce the economic benefits. Specifically, Pannell and Bennett (1999) identified the importance of including the costs of weed competition where weeds occur at densities below the economic threshold for spraying or are missed in mapping, and therefore are not sprayed. Substantial changes in input use might occur in other situations as well. Babcock et al. (1996) showed that taking advantage of soil test information in variable rate nitrogen applications may require farmers to vary rates from 0 to 172 pounds per acre. Even if average rates do not change substantially, this can have significant economic and environmental effects.

Looking at the broader range of "precision-agriculture" technologies, are there opportunities for larger farm-level economic impacts? Lowenberg-DeBoer (2003) suggested that yield monitors may provide opportunities for whole-farm economic benefits through such things as diagnosis of crop problems, on-farm experimentation, improved logistics, land rental negotiations, legal documentation, environmental management, and crop insurance claims. Global positioning system (GPS) guidance is a technology that has multiple potential economic impacts. A direct impact is in the reduction of overlaps and skips, and potentially an increase in speed of field operations. Analysis for a representative 1800 acre Indiana farm (Watson and Lowenberg-DeBoer, 2002) indicated that lightbar guidance technology would be profitable based on these field efficiency improvements alone. Watson and Lowenberg-DeBoer (2002) also indicated that GPS guidance may allow farmers to expand farm size with the same set of

equipment, which made all types of GPS guidance profitable for the representative Indiana farm. Other uses for GPS guidance include farming practices that require driving accuracy and the ability to return to the same place for subsequent operations. This includes controlled traffic and strip tillage farming systems. In a simple farm budgeting analysis, Watson and Lowenberg-DeBoer (2002) showed a $44,000 increase in annual whole-farm net returns for an 1800 acre Indiana farm using GPS auto guidance to switch to a controlled traffic system.

Remote sensing is a precision agriculture technology for which the farm-level economic impacts are not yet clear. Used as a tool for adjusting input rates, the economic impacts are again limited by the flat payoff function problem. This is confirmed by Tenkorang and Lowenberg-DeBoer (2004) in a preliminary review of studies which include estimated economic impacts. Even in the absence of image processing and analysis costs, returns to remote sensing were typically low. Possible exceptions were for high-valued crops such as sugar beets and cotton. However, because remote sensing is technology that can help resolve both temporal and spatial uncertainty, its potential value in information acquisition and making tactical adjustments should not be overlooked.

Bullock and Bullock (2000) argued that agronomic information has become more valuable with the advent of precision agriculture technology. In their discussion, they are careful to separate the value of precision agriculture technology from the value of the information needed to make use of the technology. For example, they separated the value of variable rate applications from the value of site-specific production functions needed to determine appropriate application rates. They argued that precision agriculture technology and information are complements, so the availability of one increases the value of the other. Continuing the example, variable rate technology is not particularly useful without site-specific production function information, and conversely, site-specific production function information is not as useful without the technology for varying site-specific application rates.

Information and the flexibility to adapt as information becomes available are important drivers of farm-level economic performance. This means producers need to be able to utilize information to make the appropriate adjustments, and perhaps more importantly, they need to be able to analyze the potential impacts of the "big decisions" that really constrain how they can react to changing conditions. These two types of management decisions will be discussed separately.

First, regarding the ability to utilize information to make appropriate adjustments, as Pannell (1996) noted, producers do a pretty good job with their day-to-day management decisions. However, that is not to say that improvements cannot be made, particularly as farms increase in size, and as technologies for collecting more and more detailed raw data proliferate. Technologies that help with recordkeeping and processing data into useable information become more important. These include the use of single-issue decision aids that either provide a specific recommendation or provide information that producers can use in making adjustments (Freebairn et al., 2004; Archer et al., 2001; Archer et al., 2002). In order to be adopted, these decision aids must be quick and easy to use and must use readily available inputs. In some cases, decision aids have now been incorporated into web-delivered information services that automate input retrieval, eliminating the need for user data entry (e.g. Growth Stage Consulting; North Dakota State University). As precision agriculture technology improves, automated procedures for converting site-specific data into readily useable information or even application prescriptions are becoming available (Fridgen et al., 2004). These technologies offer the potential to provide incremental improvements in economic returns, but it is important to recognize that these improvements can be overshadowed by one "big" mistake.

Regarding the ability to analyze the potential impacts of big decisions, budgeting techniques remain standard tools that have stood the test of time (Malcolm, 1990). A survey in 1996 of U.S. Great Plains' producers, showed that of those using computers, 89 percent reported using word processing software at least once a year followed by accounting/recordkeeping software (85 percent), tax software (74 percent), spreadsheets (73 percent), production records (57 percent), financial planning (56 percent), and production decision aids (25 percent) (Ascough et al., 1999). This indicates that a fair number of producers are already using spreadsheets and financial planning software, which have applications in farm-level management. Financial recordkeeping software is a core component of farm business education programs in the United States, and financial planning software has been used successfully in conjunction with extension consultation to assist producers in evaluating dairy management alternatives (Robb et al., 2001).

Malcolm (2000) indicated that there is a reasonable chance farmers will adopt spreadsheet farm budgeting tools in the future. Stochastic budgeting, which is an extension of traditional budgeting techniques that allows the inclusion of uncertain variables, has seen considerable recent use in economic analysis (Lien, 2003; Archer et al., 2003). Recent introduction of commercial spreadsheet add-ins for stochastic budgeting will make stochastic budgeting tools available to producers. However, it is likely that this will increase the chances of misuse as with standard budgeting techniques (Ferris and Malcolm, 1999).

In addition to budgeting tools, whole-farm simulation modeling has long held promises for helping farmers improve strategic decision making. However, the sheer amount of data and skills needed to build, maintain, and run these models have limited their use by individual farmers. Recent applications of simulation modeling in a participatory setting have shown promise (Attonaty et al., 1999; Meinke et al., 2001; Keating and McCown, 2001; Carberry et al., 2002). This approach relies critically on the interface between what has been called the "hard" scientific systems approach and the "soft" social systems approach. As Keating and McCown (2001) observed, it is this interface that presents the greatest challenges and opportunities for successful farming systems analysis.

Concluding Remarks

The objective of this paper was to provide a broad overview of the mechanisms by which farm management decisions affect economic returns. Economic impacts of farm-level decisions can range from very simple impacts affecting a small part of a single enterprise to very complex impacts affecting every part of the farm operation. Impacts are inextricably tied to resource endowments (including natural and financial resources), production technologies and personal skills, abilities, and goals. As such, impacts are difficult to generalize. This also represents a challenge in providing tools and information that producers can use to improve decision-making. Recent research has shown that the use of information in making management decisions and flexibility in adapting to changing conditions can have substantial farm-level economic impacts. However, there is a need for better understanding about how farms can position themselves strategically to best respond to changing conditions.

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