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METHODOLOGY FOR ECONOMIC AND ENVIRONMENTAL ASSESSMENT OF CROPPING SYSTEMS: A MICHIGAN CASE STUDY

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ABSTRACT

METHODOLOGY FOR ECONOMIC AND ENVIRONMENTAL ASSESSMENT OF CROPPING SYSTEMS: A MICHIGAN CASE STUDY

By

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Since the Food Security Act of 1985, farmers' decision making environment has changed significantly. Farmers need more information on the economic and environmental tradeoffs of alternative cropping systems to make efficient decisions. This project developed a method for designing and simulating economic returns and environmental characteristics of alternative production systems. An interdisciplinary team, including a farmer, was active in all stages of project development. The SMART-FRMS system was used to simulate the environmental characteristics and a Net Present Value model was constructed for economic comparisons between systems. This case study included comparisons of conventional and no-tillage systems, hairy vetch and anhydrous as nitrogen sources, and the impact of including an alternative crop in a rotation. The no-till systems were found more profitable with less environmental impact than the conventional system. Anhydrous was determined to be the least expensive nitrogen source, and the alternative crop reduced the profitability of the system.

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TABLE OF CONTENTS

Chapter 1 Introduction

1.0 Problem statement and background

Since 1985, farmers have been faced with a new set of economic constraints for decision making. Given these changes, they need more information to make efficient decisions. The purpose of this project was to develop a method for designing and simulating economic returns and environmental characteristics of alternative production systems.

The pre-1985 decision making environment faced by farmers was distinctly different than the current situation. Before 1985, soil conservation measures were not imposed on farmers. The basic objectives of federal farm legislation during this period were to support farm income and to secure a stable and reasonably priced food and fiber supply (Reichelderfer, 1990). This was implemented by supporting commodity prices and farm income, and by controlling the quantities of the commodities produced. However, these policies had unintended consequences on environmental quality.

In 1984, the Environmental Protection Agency declared agriculture to be the largest non-point source polluter of surface water in the United States (U.S. Environmental Protection Agency, 1984). Surface and ground water were increasingly found to be contaminated with inputs to and byproducts of agricultural production, such as nutrients, sediments and agrichemicals. Farmers and nonfarmers began to question the amount and type of chemicals used in farming, as well as farming practices and their relationship to the safety of drinking water, pesticide residues on food and the rate of topsoil depletion. In response to these charges, the Food Security Act of 1985 introduced the strongest environmental components of any Farm Bill.

The Conservation Title in the Food Security Act of 1985, required farmers with highly erodible land to submit a farm plan of Best Management Strategies if they wanted to participate in the federal farm programs (Farnsworth, 1988). Certain states are supplementing the federal program with their own provisions. In Michigan, for example, the Right to Farm Act (1982, amended 1987) offers protection to farmers from liability for environmental damages under several state regulations if farmers follow state approved Best Management Guidelines for fertilizers, pesticides and manure. Other states are increasing the pressure to restrict and ban the use of some agrichemicals (Reichelderfer, 1990; Aiken, 1991).

Another venue that impacts farmers' decision making is environmental regulation. The Environmental Protection Agency's 1987 Water Quality Act provides voluntary guidelines that would restrict farmers' use of ground and surface water for waste disposal of farm chemicals and sediment from run-off (Reichelderfer, 1990). Currently, these guidelines are voluntary. However, some farmers anticipate that these may soon be required practices.

Public opinion about farmers has also changed. The public is concerned about erosion and associated surface water quality degradation. In a national survey with 604 respondents interested in public issues (Guither and Seibold 1990), 90 percent supported conservation compliance measures. In the same survey, 84 percent of the respondents supported increased regulation of certain farming practices and land use to reduce pollution of surface and ground water. Other public concerns from the survey include food safety and the structure of farming (corporate vs. the family farm).

In standard economic theory, the farm is analyzed as a profit-maximizing firm. However, we hypothesize that farmers are different because they live on the production unit and in the rural community. Hence, they share many of the public's concerns. Many farmers feel as though they are stewards of the land and worry about issues like erosion, worker health and food safety. Yet, unlike the general public, farmers and their families are personally dependent on both the economic and environmental viability of the farm. They worry that more restrictions on production may affect their family income. Consequently, farmers were analyzed as utility-maximizers, where income is only one component of their objective functions. Farmers were hypothesized to make decisions based on individual farm family objectives (Hildebrand and Waugh, 1986), which may include full employment of the family, worker safety and occupational choice.

1.1 Implications of these changes

The changing regulations and public opinion have had several impacts on farm production decisions. First, farmers are uncertain about the availability and price of production inputs (*e.g.*, fossil fuels, agrichemicals and labor). Second, farmers with highly erodible land, or land associated with vulnerable watersheds or groundwater supplies, may need to make changes in production methods. This may necessitate a change in the chemicals and tillage used, or the crops grown on the land. Production changes can be expensive especially if new machinery and training in its use are required to make the change. Finally, these new and complex regulations may discourage farmers from participating in the federal farm programs. Since commodity programs are coupled with environmental requirements, nonparticipants may have less incentive to comply with environmental provisions in the Farm Bill.

1.2 Objectives of this study

This study has three objectives. The primary objective is to develop a method for designing and simulating the economic returns from alternative production systems specified through farmer-researcher collaboration. This approach exploits the farmers' self-identified constraints, whether monetary or nonmonetary, without requiring explicit modeling of the constraints. The second goal is to provide this economic information to farmers to help address their changing decision making environment. The third objective is to assess the SMART-FRMS system, a farm-level environmental-economic planning software package, for use by extension educators and farmers.

To achieve the first objective, a farm in Michigan was selected for a case study and the farmer's input was solicited to develop hypothetical alternative cropping systems. These were characterized in economic and environmental terms. The economic characterizations were done with a net present value model that permitted ranking the alternatives as intertemporal investments. The alternatives were compared using the annuity equivalent of their cash flows.

The environmental attributes of the systems were characterized using the experimental SMART-FRMS (Center For Farm Financial Management, 1990b) software package. The environmental indicators were expected soil loss and potential for run-off and leaching. This component is important because environmental factors may alter farmers' production methods. Finally, economic and non-economic tradeoffs between the alternatives were evaluated. This approach implicitly addresses both economic and noneconomic factors that enter the farmer's objective function, as determined by the farmer.

Under the second objective, the farmer was provided with the results of the comparative analysis and encouraged to select the best system based on these characterizations and his/her internal constraints. Internal constraints are farm objectives that may be difficult or impossible to quantify and incorporate into a typical profit-maximization model.

The third objective, to assess the SMART-FRMS system for use by extension educators and farmers, was accomplished by testing it throughout the project. Data needs and collection methods were developed and the software was evaluated for ease of use. A final section in Chapter 6 discusses this in detail.

1.3 Sustainability defined

In this study, sustainability was analyzed from the farmer's perspective. In this context, sustainable agriculture was defined as:

"farming that ensures an adequate net farm income to support an acceptable standard

> of living for farmers while also underwriting the annual investments needed to improve progressively the productivity of soil, water, and other resources." (Benbrook p.12, 1991)

This definition was used because it can be interpreted to include both monetary and nonmonetary farm objectives. An acceptable standard of living depends on income and other farm objectives, such as worker safety and full employment of family labor. Environmental concerns, such as erosion and water quality, are also implicit in this definition and important considerations in this project.

1.4 Introduction to the study

This study was part of an interdisciplinary research project designed to analyze sustainable agriculture in Michigan. The (environmental-economic) analysis occurred as agronomic field studies were being conducted by other members of the research team in Michigan State University's Crop and Soil Sciences Department.

The economic component of the research project focused on a field level analysis of alternative rotations selected by the participating farmer in collaboration with researchers. Actual field data was collected and organized into a computerized field record keeping system owned by the farmer. More detailed economic and financial information for the farm was collected and put into the SMART-FRMS system. Next, a present value model was constructed and used to simulate budgets for the hypothetical cropping systems to make intertemporal comparisons of the alternative rotations. Then, the environmental characterizations of the rotations were derived using SMART-FRMS simulation capabilities. Finally, the results were summarized for presentation of alternatives to the farmer.

1.5 What is unique about this approach?

There are several factors that make this approach unique when it is compared to other economic studies of farm production. Most notably, this model is non-optimizing.

Optimization models are restrictive because they usually do not account for farmers' internal constraints. Nonmonetary considerations may be difficult to quantify, but may be significant in farmer decision making. If not captured by the model, these internal constraints may limit the usefulness of optimization approaches.

The economic model used in this study explicitly recognizes the transition period, often referred to as the "start-up" period. This is the time it takes to reach a biological and management equilibrium after converting to a new production system. Simulation and optimization models of alternative farming systems usually assume this equilibrium has already been reached. By including the transition period in the analysis, more realistic economic results for the intertemporal comparisons are possible.

This analysis provides foundations for a whole-farm system on a field-by-field basis that closely resembles the actual decision making process for a farmer. This incremental approach is often adopted by farmers because it reduces the economic risk of a transition from one system to another. This is particularly true in Michigan where soil type varies widely across fields, thus results across the farm may be mixed.

Environmental factors are used to characterize the rotations and the on-farm cost of erosion is included in the present value model. Rausser (1980) argues for a model that includes the on-farm, economic tradeoffs associated with erosion. He also states that such measures "should be generated endogenously." In this project, the type of farming practice dictates the amount of the erosion penalty[1] ($/acre) which is included in the variable production costs. This expands the costs, usually considered in systems comparison, beyond simply production cost components.

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[1] The erosion penalty is calculated by multiplying the physical quantity of expected erosion (tons/acre) by the value of the nutrients lost in a ton of erosion. In this study, we assumed the value to be $6.00/ton (discussed further in Chapter Four).

Finally, there was significant farmer-researcher interaction and interdisciplinary effort among agricultural economists and agronomists in the development, planning and analysis of the alternatives. Farmer participation is rarely solicited in research design, since the objective of typical agricultural research is to develop recommendations.

1.6 Outline of the thesis

Chapter Two describes the literature reviewed in the course of this project: computer based information systems, optimization models, present value analysis and participatory research. Chapter Three presents the net present value model used for the intertemporal simulation of the rotation budgets. It also includes the derivation of the annuity which is used for the economic comparisons. In Chapter Four, the data collection process is discussed. This includes the techniques developed to aid in the collection and organization of the data, and a discussion of the computer based tools used throughout the project. Chapter Five outlines the results of the analysis on a field-by-field basis. This chapter also includes tables that summarize the economic and environmental results of the analysis. Finally, Chapter Six includes the summary, a discussion of the major conclusions of the project, and areas of future research.

Chapter 2 The Literature Review

2.0 Introduction to the chapter

The four main bodies of literature that were relevant in the development of this project are computer based information systems (economic and agronomic), optimization models in agricultural production, present value analysis, and participatory research. Each is treated separately in the following sections.

2.1 Computer based information systems

Computer based information systems have historically been designed for farm level use and have been problem specific. They usually answer either an economic question, or an agronomic/biological question and are used as inputs to the farmer decision making process. FINPACK (University of Minnesota) and TELFARM[2] are examples of programs that answer farm level economic questions. FINPACK conducts short and long-run financial analysis that helps farmers make production decisions. It does this from a strictly economic perspective, without consideration of environmental or agronomic impacts on the system. TELFARM is an accounting and financial record keeping system used for general business analysis. It was not developed for long-run planning and it also fails to provide an environmental analysis of the system.

FIELD MANAGER (Horizon Computer Systems) is an example of a field record system. It is a data base used to hold all production information on a field-by-field basis. It is designed to receive both economic and agronomic information, such as the costs and quantities of inputs used and crop yields. It does not calculate or record any environmental information.

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[2] Organized by: The Department of Agricultural Economics, Michigan State University, East Lansing, MI. Serviced through the Cooperative Extension Service.

Other types of problem specific computer programs designed for farmers include PIG PLAN, SOYSTEM, SOYHERB, CORNSTEM and CORNHERB (all developed at Michigan State University). Each of these programs calculates important information for farmers, such as feeding and seeding rates given specific biological parameters and farm goals. However, these programs do not conduct financial analysis or alert the farmer to potential environmental problems given the cropping systems chosen.

There are several computer programs that analyze chemical movement in the soil. Two examples of these are GLEAMS (Leonard *et al.*, 1987), and LEACHMP (Wagenet and Hutson, 1987). GLEAMS simulates pesticide transport and LEACHMP simulates pesticide leaching in the soil given specific environmental parameters. These are important environmental indicators; however, neither of these programs do any type of economic analysis or erosion calculation given a cropping system or rotation.

The problem specific approach fails to answer some of the most difficult questions that farmers face. Farmers want and need information on the simultaneous impact of their decisions on several aspects of their farm operations. They need information on the economic effects, the agronomic effects, and the environmental effects of their decisions. Once they have this information, they can utilize problem specific information systems to answer questions about particular options.

The SMART-FRMS system is different from the problem specific systems previously mentioned. It can be used to show the tradeoffs between alternative cropping systems in economic and environmental terms. It measures the components of a system by multiple criteria, allowing the farmer to make an informed decision using multiple farm goals. The SMART-FRMS program was selected for use in this study because it provides this information.

2.2 Optimization models

The optimization models discussed in this section are nonclassical models, also referred to as mathematical programming models (Chiang, 1984). They are used to maximize a specified objective function subject to a set of constraints and may include stochastic elements. Optimization models in this context use mathematical programming to simulate the effects of alternative production decisions and select the choice that best meets the objective function and constraints.

In farm level applications, these models generally assume that the objective of the decision maker is to maximize profits, and that all constraints and objectives can be quantified and included in the model or are summarized in stochastic unknown error terms. The more elements of the objective function that are unknown, the greater the error in the results of the optimization.

There are several types of mathematical programming. Linear programming has linear constraints and objective functions. Nonlinear formulations may require quadratic, separable, or nonlinear programming methods (Pfaffenberger and Walker, 1976). Multiple goal programming allows more than one known criteria to be specified as an objective. Dynamic programming is used to account for changes over time. It separates a problem into a sequence of interrelated subproblems, each of which may be solved from the knowledge gained by solving its predecessors in the sequence (Pfaffenberger, 1976; Kennedy, 1986). If elements of the objective function or constraints are not deterministic, stochastic optimization methods may be specified.

All these categories of mathematical programming select a "best" choice, based on optimization of the objective subject to constraints. Researchers use these outcomes to describe recommended strategies. Examples in agricultural production include El-Nazar and McCarl (1986), Burt (1981) and Kennedy (1986).

According to Ellis *et al.* (1991), firm-level programming models have difficulty predicting producer behavior. They attribute this to two main factors: there are alternative producer goals or constraints that cannot be incorporated into the model, and that the relevant resource constraints are incorrectly specified. These goals and constraints are often excluded from the analysis because of modeling difficulties. As a result, profit maximization becomes the objective of the analysis by default. Mathematical programming techniques offer a single optimal solution, usually without explicit consideration of noneconomic goals and constraints (*e.g.* environmental).

This analysis is based on a hypothesized objective function, but does not use an optimization model because the goal is to provide information about the alternative production systems rather than a recommendation. It is assumed that the farmer makes the best decision given his/her constraint set. This avoids specification errors by researchers trying to model the farmers' decision process, yet still provides an important role for the research process. This approach facilitates decisions, rather than dictating them.

2.3 Net present value analysis

Net present value analysis is a procedure widely used for intertemporal investment analysis (Robison, unpublished). It was developed because decision makers needed a systematic procedure for valuing cash flows that occur at different times in the life of an investment. The mechanism designed for this valuation is discounting. Discounting is based on the assumption that $1.00 today is worth more than $1.00 received one year later (this reflects the opportunity cost). Net present value analysis uses discounting, via a discount rate[3], to convert future cash flows into current dollars. If a decision maker is considering two (or more) investments of equal duration, their cash flows (revenue less variable costs) can

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[3] The discount rate is not equivalent to the interest rate. In this context it refers to the risk-free investment rate, or the best alternative use of funds for the farmer.

be discounted and their net present values (NPV) can be compared. The investment with the largest NPV is the one that provides the highest return on the investment. In this sense, NPV analysis is an optimization tool.

This discounting effect is particularly important when analyzing alternative cropping systems. When converting to a new production system there is often a significant initial cost incurred[4]. For reasons discussed above, the selection of the discount rate could determine whether an alternative system is more profitable than a conventional system.

If a decision maker is interested in comparing investments of unequal length, NPV analysis can still be applied. One technique is to repeat the investments an infinite number of times, extending the cash flows into perpetuity, and then comparing their annualized NPV. Otherwise, the longer investment is likely to have an inherent advantage over the shorter investment, since, if net returns are positive in each period of the investment, more periods will accrue to the investment with the longer duration. If both investments are repeated an infinite number of times and their cumulative NPVs annualized, it is possible to avoid errors in conclusions due to summing NPVs across unequal numbers of years.

NPV analysis can be readily applied to investments that meet criteria other than profit-maximization as an objective of the decision maker. The NPV model in this study was applied to an intertemporal comparison of alternative rotations to provide information rather than recommendations.

2.4 Participatory on-farm research

As the agricultural production industry becomes more complex, there is an increasing need for participatory on-farm research teams. Francis *et al.* argue that a "team" approach is

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[4] The fixed costs of converting to a new system are not included in the model (Chapter Three). However, a section in Chapter Six discusses how they can be incorporated into future analyses.

needed for objectives that are "too broad for solution by a single scientist or discipline." (1982, p.43). Laughlin (1991) comments that "[b]y posing problems and solving them together, we have the opportunity to reach a new level of progress." Participatory on-farm research is defined here as a research project with significant farmer-researcher interaction and interdisciplinary collaboration in the development, planning and analysis of the research problem.

Lockeretz and Anderson (1990) argue that this approach is particularly important for research on alternative production systems and sustainable agriculture because many of the innovations used in alternative production systems originated with farmers. Consequently, farmers help researchers ask the right questions and better specify the research model. Also, sustainable agriculture is commonly thought to involve more active and sophisticated information management by farmers. If so, the greater the degree of farmer involvement the more empowered he/she becomes (Laughlin, 1991).

Other models of participatory research, (Tripp, 1982; Harwood, 1973; Rhodes and Booth, 1982; and Chambers and Ghildyal, 1985)[5], have different objectives, but as a group, they differ from traditional laboratory models of farm research. The participatory research models include a farm level research component and are characterized by sharing values and information (Laughlin, 1991).

2.5 How this study incorporated these ideas

This study used an integrated computer information system to compare crop rotations at the field level. Field budgets were constructed with the BUDGETOR component of the experimental SMART-FRMS software and a NPV model was used for intertemporal comparisons of the alternative production systems. The environmental impact assessment was

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[5] These models were cited in Laughlin (1991).

done with the PLANETOR component of the SMART-FRMS program. This produced information for simultaneous consideration of economic and environmental factors to aid in selecting a production system.

This study does not implement an optimization model in order to derive an optimal solution. Instead, it provides a characterization of the alternative rotations so that the farmer can make the best decision given his/her internal and external constraints. An underlying hypothesis of producer utility maximization is suggested, but only as a basis for the economic model.

Active farmer participation and a cohesive interdisciplinary team were expected to be key to the success of this project. The farmer and the interdisciplinary team collaborated in the development, planning, implementation and analysis of the alternative cropping systems.

Chapter 3 The Model

3.0 Introduction to the chapter

This chapter presents a theoretical model of farmer decision making consistent with the hypothesis that internal constraints play a major role in the process. The basis of decision making was assumed to be utility maximization, rather than profit maximization. It was also assumed that the individual farmer can identify the preferred alternative production system using information about economic returns and environmental indicators, as well as his/her own internal constraints.

The economic-environmental information was generated from a net present value model of alternative cropping systems and from the SMART-FRMS simulation software. The NPV model is developed in this chapter, with discussion of the computer simulation deferred to Chapter 4.

3.1 Farmer decision making

As discussed in Chapter 2, most models of farmer decision making assume optimization of deterministic or stochastic objective functions specifying maximization of net revenue or expected net revenue. This approach assumes the farmer is a firm manager operating under neoclassical profit maximization. We hypothesize that the farmer is maximizing utility, and that monetary returns are only one component of that utility specification. In addition, the farmer considers nonmonetary factors that are difficult to quantify, but influence the choice of alternatives. The implicit form of this model is:

$$\begin{aligned} \max \quad & E(U) = f(M;N) \\ s.t. \quad & M \geq I \end{aligned} \tag{1}$$

where: E(U) is expected utility
M is a vector of variables representing monetary returns from farming

N is a vector of variables representing nonmonetary returns from farming
I is a minimally acceptable level of income from farming.

This model states that the farmer maximized expected utility, which is a function of both monetary and nonmonetary considerations, subject to a constraint on income from farming. The level of I is determined by family income needs and other sources of income available to the family.

Taking total derivative of E(U) yields the first-order condition for maximization of expected utility:

$$\frac{\partial E(U)}{\partial f}\,\frac{\partial f}{\partial M} + \frac{\partial E(U)}{\partial f}\,\frac{\partial f}{\partial N} = 0 \qquad (2)$$

The monetary component is hypothesized to be the traditional net revenue formulation, with the inclusion of on-farm costs of environmental degradation, in this case, erosion. The nonmonetary component is assumed to be known only to the farmer. In this case, it included considerations such as full employment of family members on the farm, lack of availability of skilled labor, interest in collaboration with university researchers and desirability of practicing good land stewardship.

By assuming that only the farmer is capable of assigning weights to the nonmonetary considerations, it is not possible to specify the explicit form of the objective function and to optimize it. Therefore, this study focussed on generating economic and environmental information for the farmer to use in making a decision among cropping alternatives. To this end, a net present value model was formulated and simulated for each production system option.

3.2 Net revenue specification

A net present value (NPV) model was developed to facilitate intertemporal analysis of the alternative cropping systems selected in this project. The basis of this model is the net revenue, defined as total revenue less costs, that accrues in each period.

Consider a single-year crop model where net revenue is defined as:

$$\begin{aligned} &\textit{Net Revenue} = (P_m) Y - C_v - C_f \\ &\qquad \textit{where} \quad C_v = C_n + e\, C_e \end{aligned} \tag{3}$$

where:

P_m is the market price of the crop (\$/unit)
Y is the yield of the crop (units/acre)
C_v is the variable cost associated with producing the crop (\$/acre)
C_f is the annual fixed cost associated with producing the crop (\$/acre)
C_n is the variable input cost of production (\$/acre), excluding erosion
C_e is the on-farm cost of erosion (\$/ton) in lost nutrients
e is the physical amount of erosion (tons/acre)

Total revenue is equal to the product of market price (P_m) and yield (Y), and is measured in dollars per acre. Variable input costs (C_n) are not assumed to be a function of yield. They include all costs association crop production, such as seed, fertilizer, fuel, repairs, *etc.*

The on-farm cost of erosion, C_e, is measured in terms of the value of nutrients lost with the soil, in dollars per ton. This cost is multiplied by the quantity of soil lost (measured in tons per acre), to generate cost in dollars per acre for a specified cropping system. Although soil loss may have negative effects on long-term field productivity, there are not reliable indicators of the correlation between erosion and productivity changes over time. Rausser (1980) noted that economic tradeoffs should have relevance to farmers, so nutrient loss was used to represent year-to-year effects of soil loss from the farmer's perspective. The soil loss measure was generated endogenously in the environmental simulation used for this study, and depended on soil characteristics and cropping practices selected, as suggested by Rausser (1980).

By incorporating on-farm erosion costs, the monetary component of the utility function in the previous section includes a visible effect of productivity loss, that is, nutrient reduction. This is an externality of production that is internalized by the farmer. Nonmonetary private externalities, including stewardship considerations and desire to improve the farm for heirs, were assumed to be calculated implicitly by the farmer, and were not specified in the net revenue model.

The total variable costs, C_v, are composed of the sum of production input costs, C_n, and on-farm erosion cost, C_e. If the level of erosion increases, so do the total variable costs of production. However, variable input costs are independent of the quantity of erosion. The production input costs are assumed to change only with the crop and production methods used, not with changes in soil loss. The annual fixed costs (C_f) are the payments to debt reduction and overhead made each year. These might include payments on capital equipment specific to a desired production system.

To do an intertemporal analysis of net revenue, the NPV model was used.

3.3 Introduction to the net present value analysis (NPV)

The NPV approach was chosen because it allows for an intertemporal comparison of the cash flows associated with alternative cropping systems. This project treats cropping decisions as a series of investments with multiple-year planning required for some alternatives. NPV models convert future cash flows into current dollars, so that the net revenues over the entire planning period may be counted. The mechanism for this conversion is discounting.

When principal is invested at a given interest rate, it accumulates value according to the period of compounding. If interest is compounded annually, then each year the principal grows by an amount equal to the interest rate multiplied by the principal that existed at the end of that period. In subsequent years, the interest is based on this accumulated principal.

Discounting is the reverse of compounding. The relationship between the two for a one-period investment is given by:

$$V(1 + r) = P$$

$$\frac{P}{(1 + r)} = V \qquad (4)$$

where: V is the present value of the investment
P is the principal accumulated

r is the market interest rate in the first equation and the private discount rate in the second. As mentioned, the interest rate and the discount rate are not always equal. However, unless an individual provides information about his/her discount rate, the rate is usually assumed to be close to the market rate of interest. As a simple example, suppose principal equal to $100 were invested at a market interest rate of 5 percent, compounded annually. In one year, the investment would be worth $105. The present value, $100, in addition to the accumulated interest, 5 percent multiplied by $100, gives the principal, $105. Conversely, suppose at the end of next year, $100 in principal would have accumulated as a result of an investment made now at the same market interest rate. At a discount rate of 5 percent, the investor would value that principal at $95.24 now. The principal at the end of the year, $100, is divided by (1+r),a sum representing the investor's time value of money, 105 percent (1.05 in decimal terms), to get the present value.

For multi-period investments, compounding and discounting may be accumulated by summing across all periods, allowing for the increase in principal (compounding) or decrease in present value (discounting) that occurs as the time period increases. With discounting, the farther into the future the analysis is extended, the greater the accumulation of discount factors:

$$\begin{aligned} &\textit{One period:} && \frac{P_1}{(1+r)} = V \\ &\textit{Two periods:} && \frac{P_1}{(1+r)} + \frac{P_2}{(1+r)^2} = V \\ &\textit{n periods:} && \frac{P_1}{(1+r)} + \frac{P_2}{(1+r)^2} + \ldots + \frac{P_n}{(1+r)^n} = V \end{aligned} \tag{5}$$

where the subscripts on P and the superscripts on (1 + r) represent the period being discounted, relative to the current decision period. The general form for the present value model is:

$$\sum_{i=1}^{n} \frac{P_i}{(1+r)^i} \tag{6}$$

where all terms are as previously described. This model was adapted for use in this analysis.

The alternative cropping practices specified by the farmer-researcher team relied on crop rotations. A rotation is a sequence of annual crops planted on the same field over a period of years. Farming in rotations using different crops has advantages in terms of breaking up pest cycles and improving nutrient availability. Disadvantages may include greater year-to-year income variation, relative to a monoculture, and greater management and equipment demands. When the entire sequence is completed, it is repeated.

Typically, one thinks of an entire farm being divided into as many parcels as there are years in the rotation, with the sequence being repeated across the farm as well as on the individual parcels over time. Thus, all years in the rotation are represented on the farm in the same year. For the single-field approach adopted for this study, the field was assumed to be entirely planted to a single crop, following the rotation sequence.

Present value analysis can be done with either discrete or continuous discounting. The discrete method is used in this model because discounting is done annually. In Michigan, fields produce only one crop per year; subsequently, there is one cash flow accounting period per year, rather than a continuous change in investment value. In this case, the discrete model more accurately represents the system. However, in mathematical terms, discrete models can always be converted to continuous models (Chiang).

3.4 The basic NPV equation

The basic net present value equation used to analyze the alternative cropping systems is shown below:

$$NPV = \sum_{i=0}^{\tau} \frac{(P_{m_i})\, Y_i - (C_{n_i} + e_i\, C_{e_i} + C_{f_i})}{(1 + r)^i} \tag{7}$$

where:

i marks the year in the rotation sequence
τ is the length of the rotation sequence
P_{m_i} is the market price of the crop in the i^{th} year (\$/unit)
Y_i is the annual yield of the crop in the i^{th} year (units/acre)
C_{n_i} are the variable input costs in the i^{th} year (\$/acre)
e_i is the amount of erosion per year, in the i^{th} year (tons/year)
C_{e_i} is the on-farm erosion cost of lost nutrients, in the i^{th} year (\$/ton)
C_{f_i} is the annual fixed cost payment in the i^{th} year (\$/acre)
r is the farmer's discount rate

This equation represents the net present value of one complete rotation on a single field.

The cash flow each period is calculated by subtracting total cost from total revenue. This is divided by the discrete discounting factor shown in the denominator. The cash flows are discounted each year of the rotation and their discounted values are summed over the length of the rotation.

This model can be used to compare rotations of equal length. The rotation with the highest NPV offers the highest accumulated dollar return in discounted terms. If one rotation is longer than the other, and if net revenue is positive in each period, the longer rotation may have an implicit advantage over the shorter rotation because the accumulation of net revenue occurs over a longer period.

3.5 A model for rotations of unequal length

In the basic equation, where discounted revenue is summed over the length of the rotation, the longer rotation may appear more profitable than the shorter rotation. One way to compensate for this advantage is to extend the rotations into perpetuity and then compare their NPVs. The single rotation model may be extended into perpetuity by modeling infinite repetition of the rotation crop sequence. The net revenue for the i^{th} year of the rotation, R_i, is:

$$Let\ R_i = (P_{m_i} + P_{d_i})\ Y_i \ - \ (C_{n_i} + e_i\ C_{e_i} + C_f) \tag{8}$$

Where all terms are as previously defined. For a single rotation, the discounted net revenue, NPV, is:

$$NPV = \sum_{i=1}^{\tau} \frac{R_i}{(1+r)^i} \tag{9}$$

Where r is the farmer's discount factor, and τ is the number of years in the rotation sequence. When this rotation is repeated into perpetuity, the discounted net revenue may be compared to other rotations, whether of equal or unequal rotation length. If repeated an infinite number of times, the net revenue obtained from the rotation is:

$$NPV = \sum_{n=0}^{\infty} \left[\sum_{i=1}^{\tau} \frac{R_i}{(1+r)^i} \right] (1+r)^{-n\tau} \tag{10}$$

Equation (10) describes two steps: 1) the annual cash flows are discounted and summed for the single rotation, and 2) the net present value of each complete rotation is discounted and summed over the infinite series of repetitions.

The discount factor for the infinite series, $(1 + r)^{-n\tau}$, has the same form as the discount factor for the single rotation, $(1 + r)^i$, except for the exponents. For the single rotation, the discount factor is applied to cash flows at the end of each crop year in the rotation, $i = 1,\ldots,\tau$, since net returns are accrued once in each period, when the crop is harvested and sold. When the rotation sequence is repeated, the NPV for the complete crop sequence is discounted at the end of the rotation, in year τ, and is summed over perpetuity, $n = 0\tau, 1\tau, 2\tau,\ldots,\infty\tau$.

Expanding the sum in equation 10 gives:

$$NPV = \left[\sum_{i=1}^{\tau} \frac{R_i}{(1+r)^i} \right] \left[1 + (1+r)^{-\tau} + (1+r)^{-2\tau} + (1+r)^{-3\tau} + \cdots \right] \tag{11}$$

The infinite series converges to:

$$NPV = \left[\sum_{i=1}^{\tau} \frac{R_i}{(1+r)^i} \right] \left[\frac{1}{1-(1+r)^{-\tau}} \right] \tag{12}$$

Or, by substitution:

$$NPV = \left[\sum_{i=1}^{\tau} \frac{(P_{m_i})\, Y_i - (C_{n_i} + e_i\, C_{e_i} + C_f)}{(1+r)^i} \right] \frac{1}{1-(1+r)^{-\tau}} \tag{13}$$

Equation (13) allows rotations of unequal length to be meaningfully compared. However, this model assumes the rotation has reached a steady state equilibrium. That is, penalties in yield or cost due to agroecosystem adjustments or management errors while learning new practices are not explicitly accounted.

3.6 The transition period and the NPV model

When a new cropping system is adopted, it is expected to take some time to reach a steady state equilibrium. This period, before an equilibrium is reached, is referred to as the transition period. The two main reasons for this transition period are natural perturbations from weed and pest populations, as they adjust to the new cropping pattern and management errors while learning the new system.

The transition period may be any length of time required to reach equilibrium. The steady state may be achieved within a single rotation, or may require more than one rotation. Once the transition is completed, all subsequent complete rotations are assumed to be identical, and are discounted from that point in time to perpetuity, as in Equation (13). Prior to equilibrium, from the beginning to the end of the transition, each rotation in the transition period is separately discounted, to account for the changing yield and cost penalties as pest populations stabilize and as farmers learn more about the cropping system. To accurately represent the cropping systems, the transition period was incorporated into Equation (13).

For this study, the main changes from existing production systems were the institution of rotations of varying lengths and crop sequences, and the planned used of no-till cultivation. With little agronomic data to support a hypothesis about the length of transition period, the farmer estimated steady state could be achieved within one rotation.

In the following equation, the transition period is assumed to be one complete rotation, of τ years. Once equilibrium is reached, the transition period is never repeated. The model with a one-rotation transition period is:

$$
\begin{aligned}
NPV = {} & \sum_{j=1}^{T} \frac{(P_{m_j})\, Y_j - (C_{n_j} + e_j\, C_{e_j} + C_f)}{(1+r)^j} \\
& + \sum_{i=1}^{T} \frac{(P_{m_i})\, Y_i - (C_{n_i} + e_i\, C_{e_i} + C_f)}{(1+r)^i} \; \frac{(1+r)^{-T}}{1-(1+r)^{-T}}
\end{aligned}
\tag{14}
$$

where *j* marks the year in the transition rotation, *i* marks the year in the equilibrium rotation, extended into perpetuity, and all other terms are as previously defined. The lengths of the rotation in both the transition and equilibrium periods are the same, as is the crop sequence.

Although aggregate yield effects of similar production changes on all farms could alter the market price for the crop, this analysis focussed on the field level so prices were exogenous to the model. Costs were also assumed to be independent of yield, since the farmer was assumed to follow the same input use patterns whether the field was in the transition period or the equilibrium period. In reality, with the cropping systems used in this model, input use should be sensitive to pest pressures and management expertise. However, without modelling these changes explicitly in a dynamic system, it is not possible to model responses to them. The erosion rate, e, depends on the cropping system selected, and changes with the year in the rotation, since crops and tillage may differ by year. The erosion rate was generated exogenously by the SMART-FRMS simulation of environmental impact.

Costs and prices were assumed to be constant over time. This assumption was due to inability to predict prices and costs though the next Farm Bill, let alone through perpetuity, rather than because it is a maintained hypothesis. Since the goal of this project was comparison of alternative cropping systems, and all systems were subject to the same relative price and cost differences, this was a reasonable simplification for analysis.

3.7 Calculation of the annuity: the basis for rotation comparisons

Equation (14) can be used to compare rotations of unequal length while accounting for the influence of the transition period on NPV. The rotation with the highest cumulative NPV is the one that offers the highest discounted net return.

Although this is often calculated in economic analyses of alternative projects, the NPV of a cropping sequence is not commonly used in farm analysis. Farmers are used to thinking about a cropping system in terms of the expected annual cash flows. To make the analysis more familiar to the farmer, the annualized value of the NPVs were calculated for the comparison. An annuity approximates a constant cash flow equivalent to the NPV.

The annuity does not represent the actual discounted net returns that accrue in each year, or in each rotation. Annual returns differ as various crops are grown, and rotational returns differ when the system moves from the transition period to the equilibrium period. However, the analytical approach is still valid, because it provides a mechanism for comparing the alternative cropping systems in terms with which the farmer would be more familiar, namely, annualized returns. Recognizing the simplification being made, the annuity, was calculated as the NPV over all rotations to infinity, multiplied by the discount rate used to determine the NPV. This annuity equivalent was used to make economic comparisons of the alternative cropping systems.

3.8 Summary of the NPV model

NPV analysis was used to address the monetary component of farmers' expected utility which was assumed to be only one of the criteria for decision making. The other component of the utility function depends on nonmonetary returns from farming which were assumed to be known only by the farmer, therefore; they could not be included in an optimization model.

The NPV model is needed to do an intertemporal comparison of the rotations. The

SMART-FRMS system helps organize and simulate much of the data used in the NPV model but it does not provide information to make an economic comparison of the alternative cropping systems.

The standard equation (7) can be used to compare rotations of equal length. However, it might bias results in favor of a longer rotation over a shorter one when comparing rotations of unequal length. Equation (13) compensates for this by extending the rotations into perpetuity before comparing their NPVs. The transition period is incorporated into the model with equation (14). This period only occurs once as the system is being established, and was assumed to be one rotation long in this analysis.

Finally, the NPV was converted into its annuity equivalent for comparison with other rotations.

Chapter 4 Data Collection

4.0 Introduction

This chapter describes the project environment, the selection and description of fields and cropping systems for study and data collection. The project setting, farm characteristics and farmer objectives were in large part determined the study design. Two separate software programs were used to collect data and simulate partial budgets for the fields and cropping systems, as well as environmental impacts.

4.1 The project setting

The study site for the project was Ingham County, Michigan. The U.S. Census Bureau, (Census, 1987) reported that in this county there are 859 farms with harvested cropland. This accounts for 48 percent of the total county acreage (Michigan Department of Agriculture, 1990). The average farm size in the county is 152 acres and 50 percent of the farmers there are full time farmers (Census, 1987).

In 1987, 89 percent of the harvested cropland was planted to four main crops: corn (42 percent), hay (20 percent), soybeans (17 percent), and wheat (10 percent). There are yearly fluctuations in the crop mix due to price expectations, and structural changes every five years due to the commodity provisions in the Farm Bills.

The soil in this region is highly variable across farms and across fields. The topsoil is generally considered loamy with 27 to 35 percent clay in the subsoil (Hicks, 1992). The predominant soil in the region is Capack Loam at 58,000 acres.

4.2 Farm characteristics

The farm that was the subject of this study has over 1000 acres, a trait shared by less than 10 percent of the farmers in the county (Census, 1987). Three family members, including the owner-operator, work full-time in farming with some of the labor applied to a beef cattle operation that is not part of this study.

The main crops grown on the farm are similar to the county profile. In 1992, corn was grown on 58 percent of the tillable land, soybeans on 25 percent, alfalfa 10 percent, canola 3 percent, and 4 percent of the land in set aside. Currently, rotations of corn, soybeans, and alfalfa are being established; however, before 1991 rotations were not used.

The predominant soils on the fields selected for the analysis are typical of the county. They are Capack Loam, Marlett Fine Sandy Loam and Owosso Marlett Sandy Loam. Capack Loam has land use classification code IIw and is in management group 2.5B. Its average slope is 0 to 3 percent with average slope length of 100 feet. This soil is limited by excess water. The U.S. Soil Conservation Service recommends tiling this soil for better drainage as it tends to be wet. Marlett Fine Sandy Loam is the third most common soil type in the county and is classified as a moderately-, to well-drained soil. Its land use capability class is IIe, management group 2.5A. The average slope is 2 to 6 percent, with average slope length of 100 feet. This soil is limited by erosive conditions. Owosso Marlett Sandy Loam is the seventh most common soil in the county and is considered to be a moderately- to well-drained soil. Its land use capability is IIe, management group (3/2)a. The average slope is 2 to 6 percent with average slope length of 100 feet. This soil is also subject to erosion problems.

4.3 Field and cropping system selection

The fields and cropping systems used in the analysis were selected in a group meeting before the 1992 planting season. This interdisciplinary group was made up of the farmer, his private consultant, three representatives from Michigan State University's (MSU) Department of Agricultural Economics and three representatives from MSU's Crop and Soil Sciences Department. From Agricultural Economics, there was a farm management specialist, an environmental and public policy specialist and a graduate researcher. From Crop and Soil

Sciences there was a sustainable agriculture and nutrient specialist, a field technician, and a graduate researcher.

The interdisciplinary team was assembled to provide recommendations and answer questions that the farmer may have had in deciding on the systems for the analysis. The agronomic and economic-environmental analyses were to proceed simultaneously, so field and cropping system selection needed to meet requirements for the farmer, the economists and the agronomists. However, the farmer was the final decision maker.

Existing fields were reviewed for possible inclusion in the study. There were three major considerations in the field selection, all related to potential influence on environmental quality. First, the fields were selected to represent different environmental conditions (potential for run-off and leaching) that are typical of the farm. Second, they were to represent various levels of erodibility. This potential was estimated by considering soil type, average slope and average slope length on each existing field. The final consideration in field selection was proximity to the cattle operation and possible nitrate problems. Originally, the study planned to integrate the fields and cattle operation; however, this component was cancelled because there was a delay in the cattle purchase.

The farmer expressed substantial interest in crop rotations and "no-till" farming as alternative system attributes. Logan (1990) defines no-till as a production system where the soil is left undisturbed prior to planting. Planting is completed in a narrow seedbed about 2 to 8 centimeters wide. Given the farmer's interest in the economic and environmental viability of no-till systems, the rotations designed for analysis were no-till; one conventionally tilled system was included as a control.

There were five criteria for selecting the rotations for the analysis. First, they represented rotations that the farmer was interested in comparing in economic and environmental terms. Second, they answered questions the farmer had about new practices or crops. Third, they reflected the research needs of the researchers and farmer. Fourth, they represented rotations of crops common in mid-Michigan. Finally, they were feasible given the farm's labor and equipment constraints. Three fields and eight different rotations were selected for analysis: three rotations for field I, five rotations for field II, and two rotations for field III. Some rotations on these fields included the same crop sequence, but different assumptions about nitrogen carryover.

4.4 Field descriptions

Two tables summarize the field and rotation descriptions described in this section. Table 1 describes the attributes of the three fields selected for this study, including size, predominant soil series, percent organic matter, average slope, average slope length and available field history. Field I is 24 acres, while field II is about 124 acres and field III is 60 acres. The field boundaries followed the farmer's existing designations. The soil types represent the major soil series present on the farm. As discussed, drainage is a restriction on the Capack Loam, which is the main soil on field II, while erosion may limit practices on the Owosso Sandy Loam and the Marlett Fine Sandy Loam making up fields I and III, respectively.

Organic matter is important in this study because it influences plant growth in many ways.

> "The greatest benefits of organic matter in soil are its water-holding capacity; the manner in which it alters soil structure to improve soil tilth; its high exchange capacity for binding and releasing some mineral nutrients; and its mineralization to nitrogen, phosphorus, and sulfur. The cycling of mineral nutrients between living organisms and dead organic components of the soil system provides an important reservoir of the elements needed in plant growth." (National Research Council, p.143, 1989)

This attribute is varied across the three fields. Field I has the highest level at 3.3 percent. Field II has 2.8 percent organic matter and field III was estimated to have 1.5 percent, based on default information contained in the SMART-FRMS data base.

Table 4-1. Description of the Fields Selected for the Analysis

	Size (acres)	Soil Type (series name)	Organic Matter (percent)	Average Slope (percent)	Average Slope length (feet)	Field History (crop & yield)
Field I	24	Owosso Sandy Loam (OwB)	3.3	4.0	100	8 years in alfalfa
Field II	124	Capack Loam (CaB)	2.8	3.0	100	1989 set aside 1990 corn 1991 corn
Field III	60	Marlett Fine Sandy Loam (MaB)	1.5	4.0	100	1990 corn 1991 set aside and seeded to alfalfa

---

[a] Default value from soil data base. Actual field test to establish organic matter has not been conducted for this soil.

Average slope and slope length are similar across the three fields, with the format ranging from three to four percent, and the latter estimated at 100 feet. The steeper and shorter the slope, the more likely a field is to experience erosion problems. The three fields in this study are not very steep on average, but have fairly short slopes. However, these values are typical for the county Michigan (Hicks, 1992).

The field history gives an idea of soil condition and of the nutrient and pest carryover that may be expected for the transition rotation. Field I was in alfalfa for eight years prior to the study. Field II was set aside in compliance with federal commodity program requirements in 1989, then planted to corn in 1990 and 1991. Field III was in corn in 1990, and was set aside and seeded to alfalfa in 1991. There could be nitrogen carryover from Fields I and III where alfalfa, a legume, was previously grown. Field II may be easier to plant into, but is likely to have lower, if any, nitrogen carryover, and potentially greater insect problems if corn is planted for a third year. These considerations affected the rotation selection and input decisions.

4.5 Rotation descriptions

Table 2 shows the cropping sequences selected for the rotations on each field. As mentioned, the rotations selected were primarily no-till systems. The corn, soybeans, and wheat are no-till and the canola and the alfalfa are conventionally tilled. Crop sequences were selected for comparison of environmental and economic objectives, as well as for agronomic interest.

Field I: The first rotation assumed for field I was a six-year rotation - corn, corn, soybeans, and three years of alfalfa - designated IA. The second rotation, IB, was identical to the first one except that the first-year corn was inter-seeded with hairy vetch. This legume was assumed to provide a 20-pound nitrogen that substituted for chemical fertilizer as an available source of nitrogen. The third rotation, IC, was the same as the second except that

Table 4-2. The Cropping Sequences Selected for the Rotations

	Rotation	Year 1[a]	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Field I	IA	Alfalfa	Corn	Corn	Soybeans	Wheat	Alfalfa	Alfalfa	Alfalfa	
	IB	Alfalfa	Corn w/ vetch (20lb.)	Corn	Soybeans	Wheat	Alfalfa	Alfalfa	Alfalfa	
	IC	Alfalfa	Corn w/ vetch (90lb.)	Corn	Soybeans	Wheat	Alfalfa	Alfalfa	Alfalfa	
Field II	IIA	Corn	Soybeans							
	IIB	Corn	Corn	Soybeans	Wheat					
	IIC	Corn w/vetch (20lb.)	Corn	Soybeans	Wheat					
	IID	Corn w/vetch (90lb.)	Corn	Soybeans	Wheat					
	IIE	Corn	Corn	Soybeans	Wheat	Canola				
	IIZ[b]	Corn	Soybeans							
Field III	IIIA	Alfalfa	Alfalfa	Alfalfa	Corn	Corn	Soybeans	Wheat	Alfalfa	
	IIIB	Alfalfa	Alfalfa	Alfalfa	Corn	Corn	Soybeans	Wheat	Canola	Alfalfa

---

[a] The first year in these rotations represents the transition year.

[b] Conventional tillage methods were assumed for this rotation.

the hairy vetch was assumed to provide a 90-pound nitrogen credit.

The objective of designing these rotations was a comparison of the effects of including hairy vetch in the rotation as a nitrogen source and a soil cover under differing assumptions about nitrogen value (IB vs. IC). Exclusion of the legume (IA) provides a baseline for the comparisons.

Field II: The first rotation designed for field II, designated IIA, was a traditional two-year corn, soybean rotation. The second rotation, IIB, was corn, corn, soybeans, wheat. The third rotation, IIC, was identical to IIB except that hairy vetch was interseeded into the first-year corn and assumed to provide a 20-pound nitrogen credit. The fourth rotation, IID, was the same as IIC except that the vetch was assumed to give a 90-pound nitrogen credit. Finally, The fifth rotation, IIE, was corn, corn, soybeans, wheat, canola, and was designed to explore the use of canola as part of a rotation system. A final rotation on this field, IIZ, included only corn and soybeans. It differed from rotation IIA in that it assumed a conventional tillage system. This crop sequence and tillage method are common in southern Michigan.

The objectives of these alternative systems were; 1) to evaluate an alternative crop (canola) and its affect on the rotation (IIB vs. IIE), 2) to examine the economic and environmental effects of including hairy vetch in the rotation at varying nitrogen credit levels (IIC vs. IID), 3) to compare rotations typical of the region under different tillage systems.

Field III: The first rotation on field III, designated IIIA, was a seven year rotation: corn, corn, soybeans, wheat, alfalfa, alfalfa, alfalfa. The second rotation, IIIB, was the same except canola followed the wheat in year eight: corn, corn, soybeans, wheat, canola, alfalfa, alfalfa, alfalfa. The objective of this comparison was to evaluate the potential benefits of including canola in a relatively long rotation (IIIB vs IIIA).

4.6 Other assumptions

Since production methods may vary by region, assumptions had to be made about specific systems used in this region and study. In Michigan, only one crop is harvested from a field in a given year due to weather constraints. Corn and soybeans were assumed to be planted in the spring and harvested in the fall. Wheat and canola were considered frost seeded and harvested mid-summer. In this system, we assumed that the alfalfa was seeded in the spring, which allows for two cuttings in the establishment year and three cuttings in the two post-establishment years.

Timing of production activities was assumed to fall within optimal windows of activity. For most crops, planting and harvesting activities are weather dependent, so yield penalties for lateness could result. Lack of information on rotations prevented analysis of these timing effects. Weed and insect pressures were assumed to be those of an average year.

Hairy vetch is not typically included in rotations in this region. However, it was included in the four rotations in this study because researchers in the MSU Crop and Soil Sciences Department believe that it may be a valuable source of nitrogen and soil conditioning agent. Assumptions about hairy vetch were based on existing literature and expert opinions, as data on performance in these rotation systems was not available.

Hairy vetch was assumed to be aerial seeded at 30 lbs per acre into 12 to 14 inch first year corn. The seed cost was assumed to be $31.50 per acre, plus $5.58 per acre for the application fee (Lohr *et al.*, 1991). The nitrogen it produces and fixes in the soil benefits the second-year corn. Expert opinion is divided on the amount of nitrogen credit attributable to the vetch. As result, the only difference between rotations, IIC and IID, and IB and IC, is that the nitrogen credit from the vetch was assumed to be 20 pounds per acre for IB and IIC and 90 pounds per acre for IC and IID. This credit reduces the amount of anhydrous ammonia application on a nitrogen-equivalent basis at side-dressing time.

By including hairy vetch in the rotation, the herbicide program that the farm used was also assumed to change. In the first-year corn, one banded application of pre-emergence herbicide was assumed at a cost of $6.12 per acre and one mechanical cultivation for weed control at $8.30 per acre (Woods, 1992). The following year, before the second-year corn is planted, the vetch must be killed with a contact herbicide.

The C-factor, calculated for use in the Universal Soil Loss Equation (USLE), is also affected by the hairy vetch. Since hairy vetch was assumed to remain on the field after the corn was harvested, it added to the field cover over the winter (the C-factor is higher). This helped reduce erosion, included here as an on-farm variable cost of production.

Finally, it is critical to note that in this study, hairy vetch was valued only as a nitrogen source. There may be other benefits of including hairy vetch in a rotation, such as its contribution to organic matter, and soil nutrients. However, until those benefits can be measured and quantified, they are difficult to incorporate into an economic analysis.

4.7 Collecting the data

The Period, 1987 through 1990, immediately preceded this research project. During this time, production and financial records were kept by the farmer on a series of ledger sheets. Gaps in the information were filled in by personal interviews with the owner, the farm manager and the farmer's consultant.

The production and financial data for the period, 1991 to 1992, was collected during the course of this project. The primary venues for data collection from the farmer and bookkeeper were planning meetings, telephone interviews, personal interviews, collected field notes, and FIELD MANAGER, a computerized record keeping system, which was maintained by the farm after assistance from MSU.

Some of the information needed to construct the budgets for the cropping systems was not available from existing farm records. When this occurred, estimates of this information was gathered from experts familiar with the project and with the farm's production history. Expert opinion based on existing literature and personal experience, was used when empirical data was not available. The method of collecting the expert opinion relied heavily on the cooperation of the interdisciplinary team and specialists in other departments at MSU.

Six main subjects required expert opinion for completeness: soil attributes, field treatments, nitrogen credits, yields, prices and variable costs. The soil information was the only topic not supplemented with a form specifically designed to aid in data collection. At least one expert research collaborator was selected to provide information in each of the six areas requiring supplemental data. When opinions differed, a third collaborator was consulted and the more conservative estimates were used. This approach avoided exaggerated claims for the hypothetical systems. Some of the forms were used in an interview setting; others were mailed to the collaborators with a letter of explanation. When necessary, follow up telephone contacts were used to clarify descriptions.

4.8 Soil information

The soil information came primarily from a personal interview with the District Conservation Officer (DSO) for Ingham County. The DSO was familiar with specific soil information on this farm and in the fields used in this project. He provided the necessary information on the predominant soil type, the average slope and slope length, and the drainage characteristics for each field. He also calculated the C-factors for all the rotations used in this study, based on accepted SCS methods (Hicks, 1992).

The DSO also provided a figure for the on-farm costs of erosion. Based on his discussions with farmers in the county, the cost of erosion to the farmer in terms of lost nutrients was assumed to average $6.00 per ton. This value could fluctuate depending on soil characteristics and carryover nutrients available in the soil at the time the erosion occurred.

4.9 Field treatment information

The field treatment information was collected in a personal interview with the acting farm manager. The objective of this interview was to determine inputs used, by practice applied, in order to allocate field treatment costs on a per-acre basis. This required information on the basic components of production: seedbed preparation, planting, weed control, insect control, harvest and drying, where applicable. The information targeted by the interview was the specific tillage, the seeding rates, the application rates for fertilizer, herbicides, and pesticides, the type of labor used for each activity, the specific farm machinery used for each operation, and the expected time required to complete a treatment.

A sample of the form designed for use in this interview is shown in Figure 4-1. The form listed the crop of interest (corn), the field name used by the farmer (GR-12), the size of the field (24 acres) and the type of tillage assumed (no-till). The collaborator was requested to allocate the costs for each activity among machinery, labor and material inputs. Information was also requested on special treatments necessary due to the previous crop, such as when corn follows corn or alfalfa, as in rotations IA, IB and IC. This information was necessary for all of the crops proposed in the alternative rotations. The acting farm manager received this form as well as information on the order of the crops in the rotations and the field history, including previous yields.

Where actual field data was limited, estimates were received and discussed with the farmer's crop consultant. He provided specific information on seeding and chemical application rates, based on field history, and assuming an average farming year. The fertilizer recommendations were based on actual field tests when possible. This information was used to generate per acre field level budgets.

CORN
BUDGET FOR GR-12 24 ACRES
NO-TILL

ACTIVITY	MACHINERY	LABOR		MATERIALS	
		HRS.	$/HR.	QUANTITY	$/UNIT
Seedbed Preparation					
Planting					
Weed Control					
Insect Control					
Harvest					
Dry					

SPECIAL TREATMENTS FROM ROTATION

Corn-Corn

Alfalfa-Corn

Figure 4-1. Sample field treatment form

4.10 Nitrogen credit information

The nitrogen credit information was solicited from two research collaborators using a form which described the rotations and the fields' history. The collaborators, a field technician in MSU's Crop and Soil Sciences Department and the farm's private consultant, were sent the form with a letter of explanation. The goal was to get expert opinion on the amount of nitrogen carryover to expect in the soil given the previous crop, soil type and tillage regime. Figure 4-2 shows a sample form for collecting data on nitrogen carryover. A definition of nitrogen credits was provided, reminding the collaborators that both green manure and previous nitrogen-fixing crops were to be included and that the value should reflect leaching and runoff losses prior to planting. The three study areas were described using the farmer's field names and the crop sequence in each rotation (examples given). Collaborators were asked to estimate nitrogen credits in pounds per acre under both no-till and conventional tillage systems. This information was then used to estimate the potential for excess nitrogen in the system.

4.11 Yield information

The yield information was solicited from two research collaborators using a form which described the rotations and the fields' history. The same collaborators who responded to the nitrogen credit request were sent the form with a letter of explanation. The goal of this form was to get expert opinion on how the tillage and rotation would affect crop yields. The collaborators were asked to give an estimate of the expected yield, the optimistic yield and the pessimistic yield based on tillage, crop and yield history.

A sample of the form used to collect yield data is shown in Figure 4-3. Estimates of three yield levels were requested: expected, percent above and percent below. Since the data was to be used in the SMART-FRMS simulation, the definitions provided in the SMART-FRMS software manual were provided for the collaborators (Center for Farm

Nitrogen Credits from the previous crop includes both green manure and credits from a previous nitrogen fixing crop. The amount entered should be a net value adjusted for losses from leaching and runoff that might occur before planting time.

PLEASE ENTER THE NITROGEN CREDITS (lbs. of N) FROM PREVIOUS CROP

FIELD GR-12 A,B,C Rotation one: alfalfa, corn, corn, soybeans

NITROGEN Field history: 8 yrs in alfalfa.	Year 1 Hay alfalfa	Year 2 Corn	Year 3 Corn	Year 4 Soybeans	Year 1-Alfalfa This begins the rotation again
No-Till.					
Conventional Till.					

FIELD GR-12 A,B,C Rotation two: alfalfa, corn, corn (inter-seeded with vetch), soybeans

NITROGEN Field history: 8 yrs in alfalfa.	Year 1 Hay alfalfa	Year 2 Corn inter-seeded with vetch	Year 3 Corn	Year 4 Soybeans	Year 1-Alfalfa This begins the rotation again
No-Till.					
Conventional Till.					

FIELD HO-02 Rotation one: corn, soybeans

NITROGEN Field history: 1989 set aside 1990 corn 1991 corn	Year 1 Corn	Year 2 Soybeans	Year 1-Corn This begins the rotation again
No-Till.			
Conventional Till.			

Figure 4-2. Sample nitrogen credit form

SMART Rotation Budgets

Definitions (according to the SMART-BUDGETOR system):

Expected Yield - This is the average or "normal" yield expected based on tillage.

% Above - This is the *percent above the expected yield* you would likely achieve one year out of six. It is not the highest yield ever experienced.

% Below - This is the *percent below the expected yield* you would likely have in one year out of six. It is not the lowest yield ever experienced.

PLEASE ENTER THE YIELD INFORMATION BASED ON THE ROTATION AND TILLAGE REGIME

FIELD GR-12 A,B,C (24 acres) Rotation One: alfalfa, corn, corn, soybeans

TILLAGE REGIME	YIELD Field History: 8 yrs. in alfalfa	Year 1 Hay Alfalfa (Tons.)	Year 2 Corn (Bu.)	Year 3 Corn (Bu.)	Year 4 Soybeans (Bu.)	Year 1-Hay Alfalfa This begins the rotation again
NO-TILL.	Expected Yield					
	% Above (optimistic)					
	% Below (pessimistic)					
CONVENTIONAL TILL.	Expected Yield					
	% Above (optimistic)					
	% Below (pessimistic)					

FIELD GR-12 A,B,C (24 acres) Rotation Two: alfalfa, corn, corn (inter-seeded with vetch), soybeans

TILLAGE REGIME	YIELD Field History: 8 yrs. in alfalfa	Year 1 Hay Alfalfa (Tons.)	Year 2 Corn (Bu.)	Year 3 Corn inter-seeded with vetch (Bu.)	Year 4 Soybeans (Bu.)	Year 1-Hay Alfalfa This begins the rotation again
NO-TILL.	Expected Yield					
	% Above (optimistic)					
	% Below (pessimistic)					
CONVENTIONAL TILL.	Expected Yield					
	% Above (optimistic)					
	% Below (pessimistic)					

Figure 4-3. Sample yield form

Financial Management, 1990a). Field names, sizes, field history and crop sequences were listed for each site. The tillage regimes included no-till and conventional. The yield figures implicitly included an element of probability in that the percent above and percent below categories requested an estimate of the percentage below expected yield that would be likely in one out of six years, or about 17 percent of the time the crop was planted. The integrative effects of yield due to preceding crops were explicitly considered in estimation of yields. This information was used in all calculations of revenues.

4.12 Price information

The price information was solicited from one research collaborator, a farm management specialist in Agricultural Economics. He used a MSU price simulation model to predict the market prices of the crops in the rotations, in appropriate years matching rotation lengths in real terms. The purpose of this form was to obtain price expectations incorporating expected market changes.

Figure 4-4 shows a sample form for collecting expected price information. Estimates of prices for each crop, for each year of the rotation were requested. In addition, the collaborator was asked to suggest percent above and percent below the expected price that would be likely one out of six years. The definitions of expected price, percent above and percent below were taken from the BUDGETOR manual (Center For Farm Financial Management, 1990a).

Expected prices are perhaps the most difficult data to estimate, because they rely on market responses to price changes, both on the supply and demand sides. Several of the crops in the rotations are eligible for price support under federal commodity programs in the 1990 Farm Bill, but future policy changes may alter these programs. Since all of the crops except alfalfa are traded on international markets, prices may fluctuate in response to world production and market conditions.

Definitions (according to the SMART-BUDGETOR system):

NOTE: For program crops use either the target or the market price, depending on which price will be higher.

Expected Price - This is the long range average price for the commodity.

Optimistic Price - This is not the highest price ever experienced. Rather, a price this high or higher would be expected one out of six years. Express the optimistic price as a percentage of the expected price. For example, if the optimistic price is 110% of the expected price, then enter +10%.

Pessimistic Price - This price is not the lowest price ever experienced. Rather, a price this low or lower, would be expected one out of six years. Express the pessimistic price as a percentage of the expected price. For example, if the pessimistic is 90% of the expected price, then enter -10%.

PRICE: CORN	**1990** Year 1	Year 2	Year 3	Year 4	Year 5	**Farm Bill** **1995** Year 6	Year 7	Year 8	Year 9
Expected									

% Above_________ (Optimistic price) % Below_________ (Pessimistic Price)

PRICE: SOYBEANS	**1990** Year 1	Year 2	Year 3	Year 4	Year 5	**Farm Bill** **1995** Year 6	Year 7	Year 8	Year 9
Expected									

% Above_________ (Optimistic Price) % Below_________ (Pessimistic Price)

Figure 4-4. Sample price form

The model used by the collaborator accounts for some of these effects.

It was recognized that actual prices might be quite different from those predicted. After considering the implications for incorrect valuation of perpetual rotations using this data, it was decided that constant 1992 prices would be used. While perhaps less realistic, this approach avoided the problems inherent in predicting prices beyond the current Farm Bill. Table 4-3 shows the prices assumed for outputs, in 1992 dollars. These prices were used in all calculations of revenue.

4.13 Other input information

This information was solicited directly from the participating farmer using a form during an interview. Two weeks before the interview, the form was sent to the farmer to give him an idea of the information needs and allow him time to access records required. At the interview, specific questions were answered by the farmer and the form was completed by the graduate researcher. The object of this form was to collect data needed to calculate the per acre costs for items such as repairs, supplies and miscellaneous expenses.

A sample form for collecting input information not described in the field treatment forms is shown in Figure 4-5. For a list of materials and expenses, the per unit cost and the description of the units were requested. The farmer was asked to quantify production acres (land actually being farmed) for comparison with tillable acres (land that could be farmed). This permitted allocation of the variable input costs to be made on the same basis as the costs quantified on the field treatment forms.

The information received was actual values for 1991 and predicted values for 1992. This information was used to complete the description of per acre costs.

4.14 Summary comments on the data collected

Ideally, actual field and cost data for all of the categories above would have been collected. However, since the rotations had not been established on the farm, estimates

Table 4-3. Prices used in the budgets and economic analysis, in 1992 dollars

CROP	PRICE ($/unit)
Corn	2.25/bushel
Soybeans	5.50/bushel
Wheat	2.75/bushel
Canola	0.09/pound
Alfalfa	62.00/ton

OTHER CASH OPERATING COSTS-FOR CROP PRODUCTION
Inputs for PLANETOR

UNITS	**$/UNIT**	**PHYSICAL**
Drying Fuel	________	____________
	________	____________
	________	____________
Direct Crop Labor	________	____________
	________	____________
	________	____________
	________	____________
Fuel	________	____________
	________	____________
	________	____________
Repairs	________	____________
-annual repair costs/machine	________	____________
-includes oil changes etc.	________	____________
	________	____________
	________	____________
Supplies	________	____________
-variable costs (e.g. tires)	________	____________
	________	____________
	________	____________
Miscellaneous	________	____________
	________	____________
	________	____________
	________	____________
Operating Interest Expense	______________________________	
	______________________________	
	______________________________	

Total Production Acres ______ **Total Tillable Acres** ______

* Operating Interest Expense refers to the interest expense per acre on operating loans for the above expenses as well as expenses from seed, fertilizer, crop chemicals, and scouting. Enter the estimated operating loan interest (or interest on accounts payable) that would be paid on loans incurred to pay the listed expenses. For example, if it is estimated that $80 will be borrowed per acre for 10 months at 12% interest, the operating interest expense will be: $80 x 10/12 x .12 = $8.00

Figure 4-5. Sample variable cost form

were needed in several areas. In every case, the estimates were taken from the farmer, experts in the appropriate areas, or the best alternative information source.

In some cases where actual farm data was not available, or where farm data was not believed by the farmer or farm consultant to represent a typical year on the farm, information was collected from published sources for similar farm conditions. Two such sources of information were crop and livestock budgets generated by MSU (Nott *et al.*, 1992) and machinery cost estimates from the University of Minnesota (Fuller, *et al.*, 1992). Both of these sources are considered reliable sources of costs estimates for the parameters specified. These published sources complemented actual data and expert opinion. Taken together, these sources provided the data for the study.

Chapter 5 Simulation Methods

5.0 Introduction to the chapter

This chapter describes the simulation methods used to compile financial and farm data and generate budgets and environmental impact information for the analysis. Three software packages were used for this project. FIELD MANAGER (Harvest Computer Systems, 1986), a farm record keeping system, was used to organize existing farm data. SMART-FRMS (Center For Farm Financial Management, 1990a) was used to generate budget information and produce measures of potential for chemical leaching and soil erosion. QUATTRO PRO (Borland, 1991), a spreadsheet package, was used to simulate the NPV for each field.

SMART-FRMS is an experimental program being evaluated by the University of Minnesota for use by extension agents and farmers. Testing this program was one of the objectives of this research. Although it contains several modules, only two - BUDGETOR and PLANETOR - were needed for this project. These modules, as well as FIELD MANAGER, are discussed in the following sections.

5.1 FIELD MANAGER

FIELD MANAGER is a computer based record keeping system that was owned by the farmer before the research project began. It keeps detailed records of each field's production history including soil tests, yields, costs, and application rates of other farm inputs. FIELD MANAGER can also determine the costs of production on a field-by-field basis and conduct breakeven analysis using actual or projected figures. Prior to this project, the software was not in use. Though the farm wanted the program running, the time constraints of implementation were too great given their available labor.

One of the first steps of this research project was assisting the farm's bookkeeper in setting up FIELD MANAGER for farm use. Records from the previous four years for all fields were converted for inclusion in the FIELD MANAGER database at MSU. The program and files were then installed on the farm's computer for corrections and additions by the farm's bookkeeper.

This process accomplished two ends. First, it permitted the researchers to become familiar with previous field treatments and farm activities. Second, it established a rapport with the farmer and farm support staff, and demonstrated to them the commitment to provide research that could be of use on the farm. Compilation of records for input to the program required substantial effort on the part of the farmer and his office staff, as previous records had been kept on paper and tapes in several locations. The farmer, not the researchers, decided that use of FIELD MANAGER would be beneficial to his operation.

5.2 Introduction to SMART-FRMS

The SMART-FRMS system is an experimental software program developed by the University of Minnesota, and funded jointly by the Extension Service and the Cooperative State Research Service of the U.S. Department of Agriculture. The acronym stands for "Sustaining and Managing Agricultural Resources for Tomorrow-Farm Resource Management System." (Center for Farm Financial Management, 1990c) The goal of the software was "simultaneous consideration of resource conservation, environmental protection, productivity and profitability,.." (Ikerd p.104, 1991). This ultimately leads to multiple goal planning.

SMART-FRMS, version 1.4, was chosen for this research project because it informs farmers of the economic and environmental implications of selecting a production system. This helps farmers make decisions on the tradeoffs between economic and environmental objectives. In this study, it was used to simulate budgets and environmental impacts of the alternative rotations. The main components of the system are BUDGETOR, the budgeting component, and PLANETOR the whole farm planning component, which simulates the environmental effects of different rotations.

5.3 BUDGETOR

BUDGETOR was used to develop the budgets for the rotations selected for this project. Actual economic and environmental farm data were used to complete the simulation. Default values, generated annually by MSU researchers (Nott *et al.*, 1992), were used only when necessary.

Most of the data came from files compiled for FIELD MANAGER. Other data was collected from collaborators or taken from published sources, as described in the last chapter. The level of detail required by BUDGETOR necessitated an extremely time consuming data collection process, even with a farm as well staffed as the one in this study. The input - output table shown in Figure 5-1. lists the information needed for this part of the project and the output generated.

Actual field data was preferred for all of the items listed in Figure 5-1. However, estimates provided by extension or university researchers were used when necessary. This was particularly relevant for items such as nitrogen credit from the previous crop, soil type, and organic matter.

The BUDGETOR outputs shown in Figure 5-1 include excess nitrogen, highest chemical rating, value of expected yield, labor requirements and total cash operating costs, or variable costs of production. BUDGETOR calculates these values based on the inputs provided, some of which are qualitative, like chemical names, and some of which are quantitative. The following definitions are paraphrased from the BUDGETOR manual (Center for Farm Financial Management,1990a).

"Excess nitrogen" (pounds per acre) refers to the average nitrogen (N) available (pounds per acre), minus the average N removed (pounds per acre). Average N available is the

INPUT[a]	OUTPUT
Credit green manure (lbs/acre) Credit other sources (lbs/acre) Applied nitrogen (lbs/acre) Expected yield (units/acre) Optimistic yield (units/acre)	Excess nitrogen (pounds) with expected yield with optimistic yield
Herbicides used on the field Pesticides used on the field	Highest chemical rating (High, Medium, Low) as measured by: toxicity leaching potential run-off potential
Expected yield (units/acre) Expected price ($/unit)	Value of expected yield ($/acre)
Total labor hours required (hours/acre)	Labor requirement (hours/acre)
Costs/acre for: Seed Fertilizer Crop chemicals Crop insurance Drying fuel Irrigation energy Water assessment Custom hire Direct crop labor Fuel Repairs Packaging Supplies Miscellaneous Operating interest expense	Total cash operating costs ($/acre) (variable costs)
Total return ($/acre) Total direct cost ($/acre)	Return over direct costs ($/acre)

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[a] There is other information that can be processed by BUDGETOR. The information shown here is what was actually used in this study.

Figure 5-1. BUDGETOR - input/output table

N available in the soil, plus N from other sources, such as manure and chemical applications. Average N removed is the amount of N the crop removes per unit of production (pounds per unit), times the yield (units per acre).

"Highest chemical rating" is an overall rating that indicates the potential for off-site transportation of farm chemicals. There are three possible ratings (High, Medium, and Low) that depend on three major sub-components: leaching potential, run-off potential, and toxicity. BUDGETOR assigns the rotations a rating for each of the sub-components which are averaged to obtain the overall rating (highest chemical toxicity). The inputs required to obtain these ratings are the chemicals used on the fields and the excess nitrogen in the system. These ratings are independent of the soil type to which the chemical is applied, but do rely on cropping practices. Interpretation of these ratings is more accurate when using the ratings in the PLANETOR component, described in the next section, which includes the influence of soil type in the analysis.

The "value of expected yield" ($ per acre) is per acre value, or total revenue, of the crop assuming a typical yield. It is calculated by multiplying the expected price of the crop ($ per unit) and the expected yield of the crop (units per acre).

"Labor requirement" (hours per acre) shows the labor requirements per acre for all field activities on a monthly basis. this output is useful in planning labor needs throughout the year.

"Total cash operating costs" ($ per acre) are the variable costs of production calculated on a per acre basis. This measures the cost of seed, fertilizer, crop chemicals, repairs, labor, *etc.*

"Return over direct costs" ($ per acre) is net revenue, per acre return minus the variable costs. It is calculated by multiplying the expected yield by the expected price and then subtracting the variable costs.

Other outputs produced by BUDGETOR were not used in this research project. These include diesel (gallons) and BTU (millions) requirements per year, total return risk factor (+/-), corn equivalents produced (bushels), hay equivalents produced (tons), silage equivalents produced (tons) and Animal Unit Months (AUM) produced. For more information on these other areas the reader is referred to the BUDGETOR manual (Center for Farm Financial Management, 1990a).

5.4 PLANETOR

PLANETOR was designed to be the whole farm planning instrument of the SMART-FRMS system. However, since this project is not a whole farm planning exercise, it was used to simulate the environmental impacts of certain fields and provide the environmental characteristics of the field-rotation combinations. PLANETOR's environmental information combines crop and soil information to describe the rotations in terms of erosion, water quality and pesticide toxicity.

In this version of PLANETOR the environmental information was provided as "High", "Medium" or "Low" ratings of a potential problem in the given area. These ordinal rankings are not assigned a specific probability of risk in this version of the program. Instead, they refer to physical characteristics of the chemicals, the soil, and the cropping system. Erosion and excess nitrogen are the only environmental indicators that are calculated in both qualitative and quantitative terms. For example, the Soil Conservation Service has determined a tolerable annual soil loss, or T-value (tons per acre per year) for soil types in the United States. If the soil loss predicted by the Universal Soil Loss Equation (USLE), in tons per acre, for a given field-rotation combination is less than 90 percent of the T-value for that soil, the combination gets a "Low" soil loss rating. If the predicted level is between 90 percent and 200 percent of the T-value the combination rates "Medium". Likewise, if the predicted level is over 200 percent of the tolerable level the system receives a "High" rating.

Figure 5-2. shows an input/output table of the information needed to run the PLANETOR component of the SMART-FRMS system and the results generated. Erosion is calculated with the USLE. The specific field information required for the calculation includes soil type, organic matter, average slope and slope length on the field, the type of practice (contour plowing, terracing, standard), and the C-factor. The C-factor is a measure of the cover remaining on a field throughout the year. It is calculated by the Soil Conservation Service based on the crop grown and the tillage system used on the field. Each rotation has a unique C-Factor.

The water quality rating is the overall rating based on three factors; excess nitrogen, chemical leaching, and chemical run-off. PLANETOR determines the rating by assessing the soil characteristics (organic matter and soil depth) to determine leaching and run-off potential. It combines this information with the leaching and run-off characteristics of the chemicals (soil adsorption, water solubility, persistence) used in production to determine an overall water quality rating. The information needed to run this simulation includes soil type, organic matter, total nitrogen available, yield and crops grown, total nitrogen applied, and the herbicides and pesticides used on the fields. This rating is independent of weather factors that affect the probability of environmental problems.

Figure 5-2. shows that all of the information required to determine pesticide toxicity is already in the program through the BUDGETOR component. Pesticide toxicity measures the human toxicity of a chemical. The ratings come directly from the chemical labels rating, stored in a database prepared by the Agricultural Research Service. This information is independent of the soil type and handling practices.

Other output provided by PLANETOR but not used in this research project include: gross farm income, total farm expenses, net worth change, monthly labor balance, energy

INPUT	OUTPUT
Soil type (series name) Organic matter (%) Average slope length (feet) Average slope in the field (%) Practice (contour, terrace, *etc.*) C-factor	Erosion (tons/acre)
Soil type (series name) Organic matter (%) Total nitrogen avail. (lbs/acre)[a] Total nitrogen applied (lbs)[a] Crop planted[a] Expected yield[a] Herbicides used on the field[a] Pesticides used on the field[a]	Water quality (High, Medium, Low) as measured by: excess nitrogen chemical leaching chemical runoff
Herbicides used on the fields[a] Pesticides used on the fields[a]	Pesticide toxicity (High, Medium, Low)

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[a] This information was already put into the program via BUDGETOR. It does not need to be re-entered in PLANETOR.

Figure 5-2. PLANETOR - input/output table summary, water summary, manure summary and the production summary. This information is relevant for a whole farm study; however, it is not appropriate for a field level study of alternative rotations.

5.5 Concluding comments on the SMART-FRMS system

What separates SMART-FRMS from traditional farm software packages is that it facilitates simultaneous consideration of the economic and environmental implications of alternative cropping rotations. A field can be analyzed with any number of rotations to see which one best satisfies the farmers objectives. This type of information is extremely important given the changing parameters that farmers have to operate within.

However, there are three specific areas of the program that are troublesome. The first concerns the water quality indicators. These indicators (High, Medium, Low) do not change as the amount of the chemical used on the field changes. Thus, a farmer who uses two quarts of Roundup per acre will generate the same rating, as a farmer who uses four or even ten quarts per acre.

Second, the ratings are not correlated with a quantified probability related to erosion, water quality or pesticide toxicity. Similar systems tend to get the same ratings which makes ranking similar systems very difficult without using an external model that simulates chemical movement such as GLEAMS (Leonard, 1987) or LEACHMP (Wagenet, 1987).

Finally, there is no component in the system for an intertemporal comparison of rotations. Without an intertemporal comparison it is difficult for a farmer to decide which system offers the highest economic return over time. This is the reason for using the output from SMART-FRMS in a NPV simulation. The NPV analysis was conducted using a spreadsheet package and the discounting methods explained in Chapter 3. Output from BUDGETOR and PLANETOR were used to obtain net revenue, accounting for the on-farm cost of erosion, for each period in the rotations outlined in Chapter 4. The results of the analysis are presented in the next chapter.

Chapter 6 Results of the Simulations

6.0 Introduction to the chapter

As stated in Chapter 3, the rotations were extended into perpetuity before the annuities of their NPVs were calculated. The discount rates used in the analysis were three, five and seven percent. These rates are close to current interest rates for Treasury bills (about three percent) and for consumer credit (about seven percent).

The economic basis of comparison was the annuity value of the rotation. The annuity, including the transition period, was calculated for the rotations with the on-farm erosion costs equal to $6.00 per ton in lost nutrient value (Hicks, 1992).

Prices and costs used, correspond to those outlined in Chapter 4. The environmental basis of comparison was erosion, water quality and pesticide toxicity. The systems were assumed to be primarily no-till. Corn, soybeans, and wheat are no-tilled in this project while canola and alfalfa remained conventionally tilled. Each of the fields and their rotations are discussed in subsequent sections. The focus was on the economic and environmental characteristics of the field-rotation combinations, including the annuity values calculated at all discount rates, with erosion valued on-farm, and the environmental indicators used in this study.

For comparison, an extra rotation was included in field III's analysis. This rotation, "Z", was a conventionally tilled corn-soybean rotation typically used in Michigan. The variable costs for this rotation were taken directly from the 1992 Michigan Crop Budgets (Nott *et al.*, 1992). The yield was assumed to be 120 bushels per acre and the same prices were used as for the other rotations.

6.1 Field I

Field I had three alternative cropping systems developed for it, including two rotations that differed only by the nitrogen carryover assumptions from hairy vetch. The rotations were shown in Table 4.1. As mentioned, the objective of designing these rotations was a comparison of the effects of including hairy vetch in the rotations as a nitrogen source and soil cover under differing assumptions about nitrogen value (IB vs. IC). The vetch was excluded from IA to provide a baseline for the comparisons.

Table 6-1 shows the variable production costs for the three rotations on field I. Fixed costs were not included in the NPV analysis due to the difficulty in determining which assumptions to use about the state of existing production-specific equipment. A discussion of this problem is included in Section 7.4. As mentioned, variable production costs consist of actual farm data, expert opinion and published data. Due to confidentiality, the costs for individual inputs were not included here.

The summary costs showed that there were slight differences between the rotations for all years, except two and three, which corresponded to corn production. Rotation IA, which acts as the control, was assumed to have constant costs across both years of corn production ($119.08 per year). Rotation IB and IC had higher first year corn costs because of the hairy vetch establishment; however, their second year costs were lower than the first year due to the nitrogen benefits of the vetch. The summary table shows that including the vetch costs an additional $39.00 per acre, in year one, and saves between $2.00 and $15.00 per acre in year two.

Table 6-2 shows the annuity of the NPV calculated for each rotation, at each discount rate. Rotation IA had the highest annuity at $140.00 per acre. This was $4.00 per acre more than IB which includes hairy vetch and assumes a 90 pound nitrogen credit. Rotation IC had an annuity of $133.00 per acre assuming a 20 pound nitrogen credit. The annuity figures

Table 6-1. Variable Production Costs for Field I ($/acre/year)

Rotation	Year 1[a]	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
IA	44.14	119.08	119.08	74.87	122.17	44.14	44.14
IB	44.62	157.73	117.00	75.35	122.65	44.62	44.62
IC	44.62	157.73	103.79	75.35	122.65	44.62	44.62

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[a] The first year in these rotations represents the transition year.

Table 6-2. Annuity Equivalent of NPV for Field I ($/acre/year)

Rotation	r = 3%	r = 5%	r = 7%
IA	139.52	138.30	137.21
IB	132.83	131.44	130.17
IC	135.06	133.68	132.43

imply that including the hairy vetch in the rotation, given current prices, costs the farmer between $4.00 and $7.00 per acre per year. This difference was related to the relative price differences of a pound of nitrogen fertilizer provided by hairy vetch and by anhydrous ammonia.

If application costs were assumed equal for anhydrous ammonia and hairy vetch, the cost of a pound of nitrogen from the vetch was $1.53 per pound when a 20 pound nitrogen credit was assumed, and $0.35 per pound when a 90 pound nitrogen credit was assumed. In contrast, a pound of nitrogen from anhydrous cost approximately $0.13 per pound. So even with an optimistic assumption on hairy vetch's actual contribution, it was still three times more expensive than anhydrous. Factors that may cause their relative prices to change include; state regulation on chemical fertilizers, a fertilizer tax, or a significant increase in the price of fossil fuels.

Table 6-3 shows the environmental indicators for field I. These indicators - erosion, water quality, and pesticide toxicity - were described in Chapter 5. The rotations on field I each achieved an overall rating of "Low" potential for erosion problems. PLANETOR predicted that IA would generate, on average, 0.43 tons of erosion per acre per year. This was higher than the rotations that included the vetch as a cover crop, 0.35 tons. Vetch helped reduce erosion by maintaining a cover on the field after the other crops were harvested. The tolerable soil loss for this field was 5 tons per acre per year, significantly higher than predicted values.

The potential threat to surface and groundwater from agricultural chemicals and nitrogen was described by the water quality indicator in PLANETOR. Each rotation was given a "High" rating based on soil and chemical characteristics of the field-rotation combinations. The current version of the program generated the ratings independent of the

Table 6-3. **Environmental Indicators for Field I (High, Medium and Low)**

Rotation	Erosion tons/acre	Water Quality	Excess N lbs/acre/yr	Pesticide Toxicity
IA	Low 0.43	High	Medium 46	Medium
IB	Low 0.35	High	Medium 44	Medium
IC	Low 0.35	High	Medium 44	Medium

amount of the chemical applied or the application method. Subsequently, it was difficult to distinguish between similar rotations based on the overall water quality rating.

The excess nitrogen component of the water quality rating was one way to distinguish between similar rotations. For example, rotation IA produced an average of 46 excess pounds of nitrogen per acre per year, and rotations IB and IC produced 44 excess pounds. This result was probably due to the assumed nitrogen carryover from the previous crop.

The pesticide toxicity indicator gave each of the rotations a "Medium" rating. The nature of this indicator, that is, label-dependent, makes it somewhat unreliable as a measure of actual health benefits.

6.2 Field II

Field II had six alternative cropping systems, including the conventional corn-soybeans rotation. The rotations were shown in Table 4-1. As mentioned, the objectives of this comparison were: 1) to evaluate an alternative crop (canola), 2) to examine the economic and environmental effects of including hairy vetch in the rotation at varying nitrogen credit levels, and 3) to compare rotations typical of the region under different tillage systems.

Table 6-4 shows the variable production costs for all rotations in field II by year of the rotation. Fixed costs were not included in the NPV analysis due to the difficulty in determining which assumptions to use about the state of existing equipment. A discussion of this problem is included in Section 7.4. As mentioned, variable production costs consist of actual farm data, expert opinion and published data. Due to confidentiality, the costs for individual inputs were not included here.

The summary costs show that rotation IIZ has significantly higher variable costs than the other rotations. This was largely attributed to differences in labor, fuel and erosion costs between tillage systems. The most interesting tillage comparison was between IIA and IIZ

Table 6-4. Variable Production Costs for Field II ($/acre/year)

Rotation	Year 1[a]	Year 2	Year 3	Year 4	Year 5
IIA	118.48	74.27			
IIB	119.20	119.20	74.99	53.89	
IIC	157.01	116.28	74.63	53.53	
IID	157.01	103.07	74.63	53.53	
IIE	119.98	119.98	75.77	54.67	72.04
IIZ[b]	174.19	123.64			

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[a] The first year in these rotations represents the transition year.

[b] This is the conventionally tilled rotation.

because they were both two year corn-soybean rotations. Labor costs were $43.00 per acre higher for corn production in rotation IIZ, than IIA. Most of this difference was caused by the increased seedbed preparation needed in rotation IIZ. The extra tillage also caused an increase in fuel and erosion costs, $7.00 and $11.00 per acre, respectively. These higher costs make rotation IIZ less profitable than rotation IIA, especially since herbicide costs were assumed to be approximately the same across tillage systems.

Rotations IIB, IIC, IID compared the use of hairy vetch in the rotation. Where rotation IIB's costs are constant across the two-year corn cycle, the costs in rotation IIC and IID are higher in the first year as the vetch was established, and then lower in the second year as the vetch provides nitrogen to the system. Otherwise, the costs between the two rotations were the same. Canola was analyzed in rotation IIB and IIE. Production costs were the same in the first four years of the rotation then, in year five, IIE's costs were lower than IIB's costs. This occurred as IIB began its rotation again with corn. Differences in variable costs for the same crop across rotations were due to assumptions made about nitrogen credits and other integrative effects discussed in Chapter 4.

Table 6-5 shows the annuity of the NPV calculated for each rotation, at each discount rate. Rotation IIA had the highest annuity at $122.00 per acre. This was $18.00 higher than Rotation IIE which was the rotation with the next highest annuity. Rotations IIB and IIE, which differ only by canola, had almost the same annuity value, $104.00 and $105.00, respectively. The five-year rotation (IIE) that included canola provided $1.00 per acre more than four year rotation (IIB) without the canola. Depending on commodity programs and world markets, inclusion of canola could be profitable.

The economic value of including hairy vetch in the rotation was analyzed by looking at Rotations IIB, IIC, and IID. Rotation IIB did not have hairy vetch in the rotation and had a annuity of $104.00. Rotation IIC assumed a 20-pound nitrogen credit for the vetch and had

Table 6-5. Annuity Equivalent of the NPV for Field II ($/acre/year)

Rotation	r = 3%	r = 5%	r = 7%
IIA	120.92	120.79	120.68
IIB	101.62	102.22	102.81
IIC	92.66	92.99	93.30
IID	96.01	96.37	96.71
IIE	101.84	102.30	102.75
IIZ	96.08	96.08	96.08

an annuity of $95.00. Rotation IID, with a 90-pound credit for the vetch, had an annuity of $98.00. Including hairy vetch in these rotation as a N-source cost the farmer between $6.00 and $9.00 per acre, depending on the assumed nitrogen credit. This difference may be attributed to the relative prices of buying and applying hairy vetch seed and anhydrous ammonia, the chemical nitrogen source. If fossil fuel prices increased, the hairy vetch might become competitive as an N-source.

Rotation IIA and rotation IIZ were both corn-soybean rotations. However, rotation IIA was assumed to be no-till and rotation IIZ was conventionally tilled. Rotation IIA returned an annuity of $121.00 per acre, while rotation IIZ generated $90.57 per acre, a difference of $20.32 per acre. A significant portion of this difference was due to the labor and fuel requirements of the systems. No-till requires less of each if the timing of chemical applications is optimal, as was assumed for this analysis. Nonoptimal management could result in conventionally tilled systems being more profitable.

Table 6-6 shows the environmental indicators for field II. These indicators - erosion, water quality and pesticide toxicity - were described in Chapter 5. All rotations on field II achieved an overall erosion rating of "Low". PLANETOR predicted that rotation IIA would produce, on average, 0.25 tons of erosion per acre. Rotation IIB would produce 0.37 tons, rotation IIC and IID would generate 0.31 tons, rotation IIE, 0.5 tons, and rotation IIZ would produce 2.04. By comparing IIB, IIC, and IID, it was apparent that the rotations that included vetch produced less erosion than the same rotation without the vetch. Vetch performs a soil-retaining function.

The tolerable soil loss for this field was five tons per acre per year. This explains why all the rotations received a "Low" rating. As expected, the conventionally tilled rotation produced significantly more erosion than the rotations that were no-tilled. The no-till effect

Table 6-6. Environmental Indicators for Field II (High, Medium and Low)

Rotation	Erosion tons/acre	Water Quality	Excess N lbs/acre/yr	Pesticide Toxicity
IIA	Low 0.25	High	Medium 35	Medium
IIB	Low 0.37	High	Medium 41	Medium
IIC	Low 0.31	High	Medium 41	Medium
IID	Low 0.31	High	Medium 41	Medium
IIE	Low 0.50	High	Medium 42	Medium
IIZ	Low 2.04	High	Medium 46	High

over shadowed the soil holding contribution of the hairy vetch. The vetch effect might be more important in a conventionally tilled system. The effect of valuing erosion on-farm was to make conventional tillage less profitable.

The potential threat to surface and ground water from chemicals and nitrogen was described by the water quality indicator. Each of the rotations received a "High" rating for potential water quality problems. PLANETOR determined these ratings based on the soil and chemical characteristics of the rotation-field combinations. The current version of the program does not distinguish between chemical application rates and techniques, or the effect they have on the potential for water quality problems. Subsequently, it was difficult to distinguish between the rotations based on the overall water quality rating.

The excess nitrogen component gave each of the rotations a "Medium" rating for the amount of expected excess nitrogen. Rotation IIA had the lowest average excess nitrogen at 35 pounds per acre and Rotation IIZ had the highest average at 46 pounds per acre. This result was probably due to the assumed nitrogen carryover from the previous crop.

The pesticide toxicity indicator assigned rotations IIA, IIB, IIC, IID, and IIE a "Medium" rating and rotation IIZ "High" rating. The "High" indicator in IIZ was triggered by an insecticide not needed in the other rotations. The nature of this indicator, that is, label-dependent, makes it somewhat unreliable as a measure of actual health effects.

6.3 Field III

Field III had two alternative cropping systems developed for comparison. The rotations were outlined in Table 4-2. As mentioned, the objective of this comparison was to evaluate the potential benefits of including canola in a relatively long rotation.

Table 6-7 shows the annual variable production costs for rotations IIIA and IIIB. Fixed costs were not included in the NPV analysis due to difficulty in determining which assumptions to use about the state of existing machinery, discussed in section 7.4. The variable production costs consisted of actual farm data, expert opinion and published data. The costs for individual inputs were not included here to maintain farm confidentiality.

The summary variable costs show little annual difference between the rotations, although IIIB was slightly higher in every period. This difference was directly equal to the difference in annual on-farm erosion costs. Since canola was assumed to be conventionally tilled in these rotations, its inclusion in the rotation increases annual expected erosion.

Table 6-8 shows the annuity of the NPV calculated for both rotations at each discount rate. Rotation IIIA has the highest annuity at $135.00 per year, which was $3.00 per acre more than rotation IIIB. This difference was probably caused by the additional erosion costs associated with rotation IIIB, and by timing changes. For example, adding canola to the rotation delays, by one period, the beginning of the second repetition of the rotation. In this rotation, it means delaying a return to the crop with the highest net revenue, which could cause a lower annuity value.

Table 6-9 shows the environmental indicators for field III. These indicators - erosion, water quality, and pesticide toxicity - were described in Chapter 5. PLANETOR assigned both rotations a "Low" rating for the potential for erosion problems. The tolerable soil loss for this field is 4.0 tons per acre per year, which is significantly higher than rotation IIIA, 0.29, and rotation IIIB, 0.50. Though they both receive "Low" ratings, IIIB produces almost twice as much erosion as rotation IIIA.

PLANETOR's water quality indicator estimated the potential threats to surface and ground water contamination from agricultural chemicals and nitrogen. Both rotations received a "High" rating by the program based on the soil and chemical characteristics of the field-rotation combinations. As mentioned, the current version of the program generates the ratings independent of the amount of the chemical applied or the application method. This

Table 6-7. **Variable Production Costs for Field III ($/acre/year)**

Rotation	Year 1[a]	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
IIIA	121.66	43.78	43.78	118.72	118.72	74.51	53.41	
IIIB	122.92	45.04	45.04	119.98	119.98	75.77	54.67	72.27

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[a] The first year in these rotations represents the transition year.

Table 6-8. Annuity Equivalent of NPV for Field III ($/acre/year)

Rotation	r = 3%	r = 5%	r = 7%
IIIA	135.44	135.92	136.30
IIIB	131.01	131.65	132.20

Table 6-9. Environmental Indicators for Field III (High, Medium and Low)

Rotation	Erosion tons/acre	Water Quality	Excess N lbs/acre/yr	Pesticide Toxicity
IIIA	Low 0.29	High	Medium 44	Medium
IIIB	Low 0.50	High	Medium 42	Medium

makes it difficult to distinguish between similar systems based on the overall water quality rating.

The excess nitrogen estimates provided actual estimates and can be used to distinguish the rotations. Though both of the rotations received a "Medium" rating, they produced different amounts of excess nitrogen. Rotation IIIA generated 44 pounds of excess nitrogen per acre and rotation IIIB generated 42 pounds of excess nitrogen. These differences are likely caused by the assumed nitrogen carryover from the previous crop in the different rotations.

The pesticide toxicity indicator assigned both of the rotations a "Medium" rating. As mentioned, the nature of this indicator, that is, label-dependent, makes it somewhat unreliable as a measure of actual health effects.

Chapter 7 Conclusions

7.0 Introduction to the chapter

The primary objective of this project was to develop a method for designing and simulating the economic returns and environmental characteristics of alternative productions systems, specified through farmer-researcher collaboration. This approach exploited the farmers' self-identified constraints, whether monetary or nonmonetary, without requiring explicit modeling of these constraints. The second goal was to provide this economic and environmental information to farmers to address their changing decision making environment. The final objective was to assess the SMART-FRMS system, a farm-level environmental-economic planning software package, for use by extension educators and farmers.

This chapter comments on the results of the hypothetical alternative cropping systems and factors that affected these conditions, farmer participation in interdisciplinary university research, the experimental SMART-FRMS software package, and suggests several areas for future research.

7.1 Alternative cropping systems

The economic and environmental ranking factors included the annuity, erosion, excess nitrogen, water quality, and pesticide toxicity. These factors were used to account for a range of conditions simulated on the three fields. However, only the first three distinguish the alternative cropping sequences because water quality and pesticide toxicity are the same across rotations. Two of the cropping sequences are ranked first, in two of the three factors. Rotation IIA is the most profitable and produces the least excess nitrogen on field II, and rotation IIIA is the most profitable and generates the least erosion on field III. These results would be expected to differ if erosion was not incorporated into variable cost analysis.

The primary comparisons across the three fields were between vetch and anhydrous ammonia as nitrogen sources, no-till and conventional as tillage systems, and rotations with and without canola as an additional crop in the sequence. The three fields differed in size and soil type, among other factors, representing a variety of conditions on the farm.

The rotations that included hairy vetch as a nitrogen source were found to have lower annuities than the same rotation fertilized with anhydrous. This can be attributed to the significant difference in the cost of a pound of nitrogen supplied by vetch and by anhydrous. The results indicate that even with an optimistic assumption on hairy vetch's actual contribution, it is still three times more expensive than anhydrous. However, several factors could cause the relative prices to change.

Some states have considered banning, taxing and/or limiting the amount of inorganic fertilizer (*i.e.*, anhydrous) that can be used on agricultural land. If any of these restrictions occur, hairy vetch and other nitrogen fixing organic compounds would have to be re-evaluated to determine the most profitable fertilization technique. The price of fossil fuel could also influence the relative prices of the vetch and the anhydrous, since inorganic fertilizer's production and distribution depend on fossil fuel.

Finally, hairy vetch could become profitable if it had measurable value in addition to being a nitrogen source. Many soil scientists believe that organic nitrogen (*i.e.*, hairy vetch) has benefits beyond nitrogen contribution, such as adding to soil tilth, soil biota[6], and organic matter. If these benefits could be reliably measured and valued in terms of their contribution to yield and/or the variable costs of production, then hairy vetch may be profitable given existing prices. Agronomists are conducting research to determine these relationships.

No-till rotations were consistently determined to be more profitable than the conventional system. The no-till systems had significantly higher annuity values, as well as,

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[6] Soil biota is defined as all species and plants occurring in the soil.

lower potential environmental risks than the conventional system. In reaching this conclusion, the assumption of optimal herbicide application was critical. This assumption is probably realistic in the equilibrium period of the rotation; however, it is less realistic during the transition period. Little scientific data exists on how yields are affected by slight deviations from the optimal spraying time. Although, observations suggest the potential for significant financial losses.

The environmental conditions of the no-till system will almost always be better than the conventional system assuming that herbicides are correctly applied. Fewer nutrients leave the field in a no-till system since there is significantly less erosion than in a conventional system.

Finally, fixed costs are important in analyzing the no-till system. As mentioned, the fixed costs were not included in the NPV analysis in Chapter 5. Farm size and the state of the farmer's machinery, have significant influence on the annual fixed cost payments per acre, and thus, profitability. A decision maker must analyze the fixed cost requirements based on farm size and existing machinery before making a production decision. This is discussed in section 7.4.

Canola is a relatively new crop in mid-Michigan. After it became subsidized under the federal farm programs, the participating farmer wanted information on its profitability and environmental impact. The rotations of field III were designed for this analysis. As previously mentioned, the rotation without the canola, IIIA, had a higher annuity than with the canola, IIIB. However, canola was the last crop in a 8 year rotation. Since all future benefits are discounted to the present, canola may have been disadvantaged by being placed 8 years in the future.

7.2 Farmer participation in university research

As mentioned in earlier chapters, there was significant farmer-researcher interaction and interdisciplinary effort among agricultural economists and agronomists in the development, planning and analysis of the alternative rotations. This level of cooperation and collaboration was successful only because it was well planned and executed.

From the initial planning stages, team members, including the farmer, acknowledged that a inter-disciplinary team was crucial for a successful research project. Individuals were selected from all appropriate areas of expertise to build a strong human resource base. This created efficiency in research as the interdisciplinary members relied on one another for information outside their respective disciplines. For example, the economic-environmental analysis relied on information from several team members, as mentioned in the text. When the information needs were extensive, as in the hypothetical budgets, forms were designed to facilitate information exchange between members. These forms effectively and successfully collected relevant information from the other team members.

The participating farmer had previous experience with researchers and was familiar with the research process. This experience better enabled him to participate in all stages of project development. In group discussions, he stated that his interest in sustainable and alternative agriculture grew as environmental awareness increased, and as environmental regulation of agricultural production seemed more likely. In fact, he initiated contact with researchers in sustainable agriculture about a potential on-farm research project, hoping to gradually convert to more sustainable farming practices. He attributed his involvement in interdisciplinary on-farm research to two main reasons: access to information on alternative production methods relevant for his farm, and that he and his family enjoy working in a research environment. He felt that on-farm research kept him in contact with the most current farming research, and gave him credibility with other researchers and extension educators.

7.3 SMART-FRMS as a practical tool

The SMART-FRMS system is important because it was developed in response to farmers' changing needs. It recognized that farmers needed more information about production systems in order to make the best decision. Specifically, farmers needed a system to simultaneously analyze economic and environmental objectives through farm simulation. This version provides farmers with valuable planning information on the consequences of their production systems from both perspectives.

The environmental component of the program is relatively easy to manipulate and provides useful information on important environmental indicators; however, more sophisticated analysis will be needed in the future. As mentioned in Chapter 5, the water quality indicators are triggered by chemical and soil properties, independent of the application rate. The application rate should be tied into the environmental analysis to more accurately model the system. Another weakness of the program is that it only calculates water-related erosion for comparison with the SCS determined "tolerable level" of erosion. Since the tolerable level is a measure of both wind and water erosion (Hicks, 1992), the erosion ratings of the rotations are skewed downward.

The economic information calculated with the program applies only to a whole farm analysis. It is also easy to manipulate and understand once the crop budgets are established. However, the time and effort required to establish the budgets is potentially prohibitive. The current version of the program requires that extension educators construct soil specific, default budgets, for a given region. In Michigan, where soil types are highly variable, hundreds of budgets would need to be developed for all of the crop-soil combinations. The budgets used in this study were developed for three fields on a specific farm. Eighteen budgets had to be constructed to account for the crop-soil combinations. Hypothetical budgets were developed for cropping sequences not yet implemented on the farm. Finally, a component for intertemporal analysis of the rotations would aid farmers in selecting among rotations. It is difficult to select the most profitable rotation when comparing unequal cash flows received in different time periods. The present value model constructed for this analysis was designed to meet this need.

Many of these suggestions were being addressed in the next version of the program. In particular, researchers were trying to incorporate a chemical transport model into the program which would provide more specific information on the risks to water quality from specific farming practices. Other work was being done to assign probabilities to the environmental ratings.

The experimental SMART-FRMS computer system was an important step forward in decision support programs. It addressed farmers' changing information needs. Once the system is established, farmers can easily compare different cropping systems across their farm or on a single field.

7.4 Areas for future research

The economic and agronomic analysis occurred simultaneously over the course of this project. This was important in the overall project design; however, the data for economic analysis was limited as field trials were still underway. There were two areas of agronomic research that would be helpful in further analysis of these alternative cropping systems: nitrogen credits from the previous crop, and the effects of no-till on soil properties and crop production.

Conclusive information on nitrogen credits from one year to next, and their relationship to tillage, has important implications on variable production costs and water quality. At the farm level, nitrogen credit data could change farmer's variable costs as they substitute nitrogen carryover for chemical fertilizer. Off-farm changes in water quality are possible as existing resources (*i.e.*, organic nitrogen) are used more efficiently.

Agronomists know that no-till production changes soil properties in ways that affect plant growth (National Research Council, 1989). However, the direction and magnitude of these changes are ambiguous, and need to be quantified so they can be included in economic analyses of alternative cropping systems. Three specific areas are listed. First, research is needed to investigate hypothesized yield penalties associated with no-till production, in both the transition period and the equilibrium period of the system. Next, more information is needed on the potential yield variability of no-till systems. This should address the impact of timing and herbicide applications on yield, and downside yield risk (Harwood, 1992). Finally, research is needed to determine the effect of tillage on herbicide and pesticide applications which effect both the economic and environmental components of the system. The agronomists at MSU are conducting field studies that address many of these issues. Carefully constructed experiments on farms and research plots will eventually provide important information for economic analyses of alternative cropping systems.

A whole farm economic study is needed to fully understand the implications of alternative systems on profitability and environmental quality. This would require more information on equipment and labor scheduling across the farm, risk from weather and management errors, and fixed cost analysis. For example, fixed costs were included in the model in Chapter 3 but were not used in the actual calculations. This was due to difficulties in determining which assumptions to use about the state of existing production-specific equipment. In agricultural production, a change in production will cause a change in annual fixed cost payments, as different equipment is required for different systems. The magnitude and direction of the change in annual fixed cost payments depends on the state of existing production-specific equipment. If the farmer's existing equipment is new, the annual fixed cost payments of converting to a new system will be higher than if the existing equipment is fully amortized with zero salvage value. This difference can be attributed to the additional cost to the farmer of idling new equipment over old equipment. Further studies on fixed costs are needed to determine an optimal conversion point for farms of all sizes at various discount rates.

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