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EXAMINING TRADEOFFS BETWEEN THE ECONOMIC AND ENVIRONMENTAL COSTS OF INCREASED CROPPING DIVERSITY

By

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ABSTRACT

EXAMINING TRADEOFFS BETWEEN THE ECONOMIC AND ENVIRONMENTAL COSTS OF INCREASED CROPPING DIVERSITY

By

Wayne Stuart Roberts

Increasing cropping diversity through rotations, manure, and cover crops can improve soil quality. However, some observers perceive a conflict between preserving the resource base and maintaining farm profitability. This research tests the hypothesis that alternative production systems employing manure and cover crops in corn-based crop systems can reduce environmental contamination while maintaining farm profitability.

This study reviews empirical methods used in forty-eight recent studies comparing alternative production systems with respect to profitability, financial stability, and environmental impact criteria. These studies indicate that balanced environmental-economic analysis is most likely to arise from integrating biophysical simulation with economic optimization.

Analysis of variance on 34 Michigan fields and a whole-farm optimization analysis show nitrate leaching and phosphorus runoff can be reduced while maintaining profitability in corn-based crop systems. Gross margins are increased by crop rotation and manure use; cover crops reduce nonpoint source pollution without significantly reducing net returns.

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Win-win is primarily a way of thinking. Most of us approach situations with the win-lose mentality. "Winning" means somebody else loses. We're scripted with a scarcity mentality by win-lose athletics, academic distribution curves, and forced ranking systems. We look at life through the glasses of win-lose. . . . Contrary to most of our scripting, "to win" does not mean somebody else has to lose; it means we accomplish our objectives. In the interdependent reality, win-win is the only long-term viable option. It's the essence of abundance mentality-there's plenty for both of us; plenty in our combined capacity to create even more for ourselves and everyone else. By working together, learning from each other, helping each other grow, everyone benefits, including society as a whole.

-Covey et al. 1994 (p. 212)

Chapter 1

INTRODUCTION

Introduction

Since 1798 when Thomas Malthus wrote his *Essay on Population* developing the idea that populations increase faster than the food supply and that it was probable that some people would die of starvation, the debate has continued on whether food production can meet demand. Of course, in the eighteen century, Malthus and others were unaware of the tremendous effects technology would have on crop yields. It is amazing to realize the increased production available today compared to the past.

This growth has not been without its tradeoffs, the most controversial being agriculture's contribution to environmental contamination. Agriculture is the largest single non-point source of water pollutants, including sediments, salts, fertilizers, pesticides, and manures (National Research Council 1989). Agriculture makes up to 64% of the non-point source pollution of U.S. rivers, and 57% of U.S. lakes (Carey 1991). Concern over the fate of agricultural chemicals surfaced in the 1960s, but has intensified within the last ten years.

While some concerned citizens and special interests groups have pushed for stricter regulation on agriculture, other farmers and researchers have begun to develop alternative practices with the goals of reducing input costs, preserving the resource base, and protecting human health.

Many of these alternative crop production systems use animal or crop residues along with legume and green-manure crops in rotation to reduce chemical inputs and environmental hazards. Soil quality indicators such as organic matter content and biological activity have been shown to increase with these alternative systems (Doran et al. 1987; Reganold et al. 1993). These increases in organic matter and biological activity can result in reduced soil erosion, increased efficiency of nitrogen utilization, and retention of water in the soil (Karlen et al. 1992). However, while these new technologies may improve soil quality, little information is available about the potential multi-year benefits or costs associated with nutrient and soil quality management. Despite environmental successes with these systems, economic considerations are important to farm managers in deciding upon cropping systems.

The purpose of this thesis is to explore avenues of creating win-win solutions for both farm profitability and resource preservation. It is the guiding hypothesis of this work that opportunities exist for both "sides" to accomplish their objectives, rather than one objective being accomplished at the expense of the other. Agriculture is only sustainable when production remains sufficiently profitable to ensure its continuance and the resource base is sufficiently preserved to ensure that it will be available for future generations. Even if the argument is accepted that farm managers maximize profits and operate along the production possibilities frontier so that no further gain can be made without tradeoffs, the frontier itself can be expanded by changes in technology. Malthus was confident that production was being maximized given the current production of his time, but he could not foresee how the production possibility frontier itself would be radically changed. This is the promise of alternative production systems.

Objectives

The underlying problem motivating this research is the potential conflict that exists between improving farm profitability and preserving the resource base among corn-based cropping systems. Organic agriculture has been defined as the absence of synthetic chemicals and the presence of rotation, cover crops, and other biological control mechanisms. However, it has been suggested by Harwood that crop and cover crop diversity (including the use of manure), which help determine organic matter diversity, are the primary "conditioning" factors which drive the organic conversion process.* These determinant effects are only marginally influenced by the use or absence of chemical inputs. Most benefits of organic management (farming practices which rely on non-synthetic nutrients like animal manure and plant residues, avoiding the use of synthetic chemicals) could therefore be realized on a broad scale in integrated production systems. From an economic perspective, the hypothesis states that as soil quality increases, operating costs will decline due to 1) a reduction in fertilizer use as N is carried over from legumes grown in rotation with any cereal grain and 2) in some cases a decline in

* Richard Harwood 1993: personal communication.

insecticide control of corn rootworm as crop rotation eliminates risk of damaging rootworm infestation. Yields would also increase directly with soil quality, resulting in increased farm profitability with attendant reductions in environmental contamination. Therefore it is hypothesized that alternative production systems employing manure and cover crops in corn-based rotations with other crops will reduce environmental contamination while maintaining farm profitability.

The research objectives involved in testing this hypothesis are:

1)To identify an appropriate methodology for a joint economic and environmental comparison of alternative cropping systems.

2)To review the agronomic relationship between improved soil quality and reduced environmental contamination from agriculture. Important in this discussion is the relative profitability of these systems designed to improve soil quality.

3) To test the hypothesis in Central Michigan corn-based cropping systems with a small paired comparison of adjacent farmer fields employing different levels of crop diversity.

4)To evaluate the hypothesis more generally by simulating different crop production systems and letting a mathematical programming model identify the optimal crop mix that satisfies economic objectives given environmental constraints..

The structure of the thesis follows the sequential order of the research objectives. Chapter Two consists of a detailed review of previous economic comparisons of alternative cropping systems to identify the appropriate criteria of interest and associated methodology most suited for a joint economic and environmental comparison. Chapter Three provides a justification of the agronomic issues motivating the hypothesis, particularly the role of substrate diversity in improving soil quality. The relationships between increased substrate diversity and improved management of the nitrogen and phosphorus nutrient balances are also addressed.

Chapters Four and Five provide the empirical contribution of this research. The first part summarizes 36 enterprise budgets from 15 south central Michigan farms, comparing yields, costs, and gross margins by crop rotation, and the use of manure or cover crops. The budgeting analysis is combined with analysis of variance to assess if means for management practices are statistically different.

Chapter Five incorporates the enterprise budgets into a linear programming (LP) model to determine the optimal mix of cropping enterprises that maximize financial returns subject to environmental constraints fixed at varying levels. Site-specific environmental models based on the enterprise budgets provide the marginal environmental impact of an additional acre for each cropping activity considered in the LP model. The sensitivity of the optimal solution to changes in prices is then examined.

While legislation, penalties, and restrictions are the most common tools used to solve conflicts between profitable production and environmental improvements, it is the hope of this research to facilitate the effort to find creative third-alternative solutions. "It's not compromise. It's not 1+1=1½. It's the creation of third alternatives that are genuinely better than solutions individuals could ever come up with on their own. . . where

1+1=3 or more" (Covey et al. 1994).

Chapter 2

ECONOMIC METHODS FOR COMPARING ALTERNATIVE CROP PRODUCTION SYSTEMS: A REVIEW OF THE LITERATURE[2]

Introduction

In response to growing concern over environmental contamination and consumer resistance to food perceived as tainted by pesticides, many farmers and researchers have begun developing alternative crop production systems. Typically, these systems are neither more profitable nor higher yielding than the systems they replace. However, they may result in less contamination of ground and surface waters, less pesticide residue on the marketed product, or better soil quality. Having been designed to address these environmental objectives, these systems cannot be evaluated fairly on productivity criteria alone.

Until recently, productivity was the primary criteria used by most economists and agronomists for evaluating agricultural technology. Since World War II, most U.S. crop research has focused on reducing labor requirements and increasing yields per unit of land (Hayami and Ruttan, 1985). Economic evaluations of new crop

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2 Roberts, W.S., and S.M. Swinton. American Journal of Alternative Agriculture. 11(Winter, 1996): Forthcoming.

technology have focused on profitability. Yield increases by themselves raise profits, so the primary issue considered was whether the value of the yield increase justified the cost incurred to obtain it.

Three factors complicate comparisons between the new alternative cropping systems and "conventional" ones: expanded performance criteria, the diversity of the technologies, and production of multiple products. Comparisons are most complicated when more than one performance criterion is desired and different systems excel at different criteria. Different performance criteria may be transformed into a general index (see, e.g., Higley and Wintersteen 1992; Kovach et al. 1992; Teague et al. 1995a,b,c) or compared one-by-one using some dominance criterion (e.g., Bouzaher et al. 1992; Hoag and Hornsby 1992). How closely the technologies are related determines whether a "nested" statistical evaluation can be conducted. That is, if one technology is inherently contained within another (such as a lower fertilizer rate within a higher rate) the comparisons are direct and simple. On the other hand, if two technologies are very different, the comparison may be much more complicated, such as annual application of inorganic nitrogen (N) fertilizer compared with organic soil amendments which may take years to reach the desired equilibrium level of N mineralization. Most farms produce many products, yet standard economic comparisons treat individual outputs as if they were unrelated. A particular complication is how much weight should be assigned to undesirable side effects of production (see Beattie et al. 1974).

This chapter reviews recent literature comparing alternative and "conventional" cropping systems on the field and farm level. This review builds on the previous literature review by Fox et al. (1991) by identifying important criteria for comparison and developing a topology for economic analyses of North American cropping systems. Methods used to compare crop systems are evaluated with the goal of identifying those best suited for specific kinds of comparisons.

Criteria for Comparison

Profitability and environmental impact are the two performance criteria of greatest interest for contemporary comparisons, with profitability the main criterion in financial comparisons. Profit refers to the net financial return after the farm operator has paid all fixed and variable expenses. Many studies reviewed here used gross margin as a proxy for profit. Gross margin is the return over specified variable costs.

However, average profitability is an inadequate criterion by itself, since it ignores risk. As Conway (1994) notes, a measure of profit stability is required as well. From an economic perspective, income stability is the interesting measure. It is inherently dynamic, since stability cannot be measured in a single period. The number of production periods sufficient for a reliable evaluation remains an empirical issue tied to the type of comparison.

Any crop technology has environmental consequences, which may involve air, land, water, and the health and ecological status of living organisms. The focus here is on direct effects from using technology on the farm. The effects of greatest interest will vary with the technology, but important ones include energy use, labor requirements, soil erosion, and chemical runoff and leaching. As with profitability, it is not just the average environmental effect that matters, but also its stability.

Systems and Technology Types

The economic literature on cropping systems typically starts from a baseline called "conventional." To this are compared alternative systems that typically use less tillage, mineral fertilizers, or pesticides. The alternative systems may use lower amounts of existing technology at reduced input levels, or they may introduce new technology. The latter category includes such practices as flex cropping and integrated pest management (IPM), which substitute information for physical inputs. Alternative crop nutrition technologies include combining rotations, cover crops, and manure applications to substitute or reduce the need for mineral fertilizers.

Most alternative systems are designed primarily to reduce a specific environmental impact, especially soil erosion or contamination by fertilizers or pesticides, with reducing costs as a secondary objective. More than one environmental criterion may be needed to compare systems, since alternative systems designed to meet one environmental objective, such as reduced soil erosion, may be inconsistent with a different one, such as reduced chemical leaching (see Crowder et al. 1985; Painter et al. 1992; Foltz et al. 1993). Ironically, the most elusive system to characterize seems to be the "conventional" benchmark. Since conventional farming practices are always evolving, the benchmarks used should be typical of common practices for the time and location of the study.

System Characteristics Important in Designing the Analysis

Several characteristics are important in designing a comparative analysis of alternative systems. The dynamic features of many alternative systems, such as rotations and biological pest control, imply that comparisons should allow sufficient time for the system to adjust to biological changes and for the operator to learn how to manage the new system (see Dabbert and Madden 1986; Hanson et al. 1990; Lockeretz et al. 1978). Resource degradation, such as soil erosion, occurs gradually, and remedial practices like conservation tillage and crop rotations take years to make a difference (Baffoe et al. 1987; Crowder et al. 1985; Goldstein and Young 1987; Helmers et al. 1986; Lesoing and Francis 1993; Sahs et al. 1988; Zentner et al. 1988).

A second important system characteristic is responsiveness to shocks from weather, product prices or input costs. Systems with lower investments in purchased inputs tend to be less susceptible financially to input price shocks. Some crop systems tend to yield more reliably in the face of unusual rainfall levels (Mends et al. 1989; Sahs et al. 1988; Shearer et al. 1981). Both economic and physical characteristics affect the income stability criterion, though separating cost, price, and yield effects is analytically important (see Helmers et al. 1986).

The level of aggregation is a third characteristic needing to be identified. This paper is focused on the farm level, but when many farms make a change, it can have additional effects on both profitability and environmental impacts for an individual farm. For example, widespread adoption of an alternative system can change the supply of a crop and thereby change its price (see Knutson et al. 1990; Langley et al. 1983; Olson et al. 1982). The profitability of an alternative system, especially an organic system, may depend on premium prices; a significant increase in the supply over demand can substantially reduce the premiums received (Batte 1993).

The environmental resource endowment is a fourth characteristic that should be explicitly incorporation into most comparisons. All else being equal, systems that reduce soil erosion will offer greater benefits on highly erodible soils or where surface water quality is highly valued (Faeth 1993). Similarly, heavy soils with poor water infiltration are less likely to allow chemical leaching into groundwater than light, sandy soils (Cox and Easter 1990). Systems are designed to meet environmental objectives for specific settings, so the setting is important in designing system comparisons (see McQueen et al. 1982; Schoney and Thorson 1986).

Cropping systems are also characterized by different demands for labor, capital, and management skills. Alternative systems may call for more knowledge and labor from the farm manager, but less equipment and chemical inputs. These differences need to be accounted for in the analysis.

Finally, some cropping systems may have environmental side-effects which diminish their appeal. An example is an organic or low-chemical system that relies on increased tillage, with a corresponding increase in soil erosion; conversely, a conservation tillage system may rely on increased herbicide use for weed control (Crowder et al. 1985; Dobbs 1994; Zentner et al. 1988). Important side-effects should be incorporated explicitly into system comparison, especially when there are environmental externalities that exist beyond the farm boundary.

Methods for Comparing Systems

The choice of analytical method largely depends on the performance criteria of interest. Table 2-1 matches analytical methods to performance criteria for most of the 57 studies from the United States and Canada that are reviewed here. The performance criteria are divided into average profitability, average environmental impact, and stability of profits and environmental impact. However, environmental stability was analyzed only by Carriker (1995) and Teague et al. (1995a,b).

Enterprise budgets are the predominant method for comparing profitability, providing a focus for evaluating the costs and returns of alternative systems. (See Table 2-1 for a list of studies using them for this purpose.)

Table 2-1: Classification of literature by performance criteria and analytical methods.

	Criteria		
Method	Profitability	Stability (fin/env)	Env. Impact
Enterprise budgets	Berardi		
	Chase & Duffy		
	Diebel & Williams		
	Dobbs (93, 94)	Dobbs et al.	
	Dobbs et al.		
	Faeth		Faeth
	Goldstein & Young		
	Hanson et al.		
	Helmers et al.	Helmers et al.	
	Ikerd et al.		Ikerd et al.
	Lazarus et al.		
	Legg et al.		
	Lockeretz et al.(78, 81)		
	Mends et al.		
	Moffitt et al.	Moffitt et al.	
	Painter et al.		
	Sahs et al.	Sahs et al.	
	Shearer et al.		
	Smolik et al.	Smolik et al.	Smolik et al.
	Teague et al.(c)	Westra & Boyle	
	Westra & Boyle		
	Young & Painter		
	Zentner et al.		
Break-even analysis	Diebel et al.		Diebel et al.
	Mends et al.		
	Painter et al.		
	Schoney & Thorson		
Whole farm analysis (not LP)	Diebel et al.		
	Dobbs et al.		
	Hanson et al.	Hanson et al.	
	Ikerd		Ikerd
	Irwin-Hewitt & Lohr		Irwin-Hewitt & Lohr
	Klepper et al.		
	Mends et al.		
	Smolik et al.		

Linear programming	Baffoe et al.		Baffoe et al.
	Crowder et al.		Crowder et al.
	Dabbert & Madden		
	Domanico et al.		Domanico et al.
	Faeth		Faeth
	Foltz et al.		
	Johnson et al.		
	Langley et al.	Langley et al.	
	Lazarus et al.		
	Lazarus & White		
	McQueen et al.		McQueen et al.
	Olson et al.	Olson et al.	
	Swinton & Clark		Swinton & Clark
	Taylor et al.		
	Teague et al. (a,b)	Teague et al. (a,b)	
	Xu et al.		
Dynamic programming	Bole & Freeze		
	Johnson et al.		
	Schoney & Thorson		
	Van Kooten et al.		Van Kooten et al.
	Young & van Kooten		
Biophysical Simulation		Bole & Freeze	Crowder et al.
			Foltz et al.
			Johnson et al.
			Taylor et al.
		Teague et al (a.b,c)	Teague et al. (a,b,c)
			Xu et al.
Dominance	Bouzaher et al.		Bouzaher et al.
	Carriker	Carriker	Carriker
	Hoag & Hornsby		Hoag & Hornsby
	Xu et al.		Xu et al.
Index of env. impact		Teague et al.(a,b,c)	Higley & Wintersteen
			Kovach et al.
			Teague et al. (c)

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Uncertainty about prices and yields in enterprise budgets can be accommodated partially using sensitivity or break-even analysis. Sensitivity analysis brackets a baseline enterprise budget with more favorable and less favorable scenarios (e.g. Diebel et al.1995; Dobbs et al. 1988; Helmers et al. 1986; Sahs et al. 1988; Westra and Boyle 1992). It shows the stability of an outcome under a range of plausible assumptions about risky, uncontrollable parameters such as prices and yields. Break-even analysis identifies the yield, price, or cost threshold at which enterprise revenues would just equal costs (including opportunity costs) (Hilker et al. 1987; Mends et al. 1989; Painter et al. 1992; Schoney and Thorson 1986). If the probability distribution of the random variable is known, both kinds of analyses can be used to identify rough confidence levels for profitability.

"Green" budgeting is a new approach that includes explicit environmental costs and benefits in an enterprise budget. Faeth (1993) used off-site social costs of $0.66 to $8.16 per ton of eroded soil, based on regional estimates from a comprehensive national study done by Ribaudo (1986). Using contingent valuation, Higley and Wintersteen (1992) estimated subjectively environmental costs of pesticides from a questionnaire survey to calculate IPM "environmental thresholds" for pest control. Although green budgeting can be applied to many environmental and health attributes, the potential subjectivity of the value placed on environmental quality has limited its use.

Enterprise budgets are the building blocks for whole farm analysis. Seven studies extended their enterprise budgets to a whole farm analysis (e.g. Batte et al. 1993; Diebel et al. in press; Dobbs et al. 1988; Hanson et al. 1990; Irwin-Hewitt and Lohr 1993; Klepper et al. 1977; Mends et al. 1989).

One useful tool for whole farm analysis is the PLANETOR computer-based decision support system (Ikerd 1991). PLANETOR evaluates how alternative technologies and strategies affect average profitability and the environment. The new version links site specific farm data with the Nitrogen Leaching and Economic Analysis Package (NLEAP), the Revised Universal Soil Loss Equation (RUSLE), and other simulation models and databases to predict environmental and human health risks from erosion, leaching, runoff, and pesticide toxicity (Center for Farm Financial Management 1995). PLANETOR also projects financial outcomes and the balance between farm resource use and availability. The model can be used to evaluate crop systems for both profitability and environmental risks.

Linear programming (LP) is a mathematical technique for optimizing an objective within a set of constraints. In farm management analyses, LP is most commonly used to maximize farm profit given the constraints of a fixed supply of land, labor, and equipment. It also can be used to measure how environmental standards or alternative crop systems are likely to affect profit (see Table 2-1 for studies using this approach). Multi-period LP is used when time is a key factor, such as in studying how a crop rotation affects soil erosion (Baffoe et al. 1987), or the transition to organic farming (Dabbert and Madden 1986). Another use of LP is in interregional analysis, such as to evaluate the impact of nationwide adoption of organic practices (e.g. Langley et al. 1983; Olson et al. 1982). Although there are well established LP models for managing financial risk, a promising new extension of this approach shows how to maximize net financial returns while keeping environmental risk below a critical level (e.g. Teague et al., 1995a,b).

Dynamic programming (DP) also is used for profitability comparison. DP is a mathematical tool for solving multi-stage decision problems, such as whether to crop a field or put it into summer fallow (see Bole and Freeze 1986; Young and van Kooten 1989). Non-optimizing dynamic simulation was used in another study to determine the long term effect of extending crop rotations (Schoney and Thorson 1986).

Although dynamic programming is used primarily to analyze profitability, the data required for a DP model often comes from biophysical simulation models of processes such as crop growth or the fate of chemicals in the environment (see Foltz et al. 1993; Crowder et al. 1985). It is increasingly common to link biophysical process models with economic models (Antle and Capalbo 1993). Plant simulation models can be used to compare the stability of different systems by predicting crop yields for different input and weather (e.g. Bole and Freeze 1986; Johnson et al. 1991; Taylor et al. 1992). However, biophysical simulation requires substantial input data, such as daily temperature, precipitation and solar radiation as well as careful empirical validation of the results. Even when these models are validated in the area for which they were designed, they may perform poorly elsewhere. However, when properly validated, biophysical simulation models offer a rapid, low cost way to conduct controlled experiments by computer. Results from these analyses can show both the crop's performance and the environmental side effects of alternative cropping systems.

Comparing Multiple Criteria

A major challenge is to measure the many possible environmental impacts of a new cropping system. Two approaches have been taken in the studies reviewed: indexing and dominance analysis. Indexing creates a weighted index that integrates all the criteria of interest to the decision maker. Ikerd (1991) and the Center for Farm Financial Management (1995) took this path in designing PLANETOR, which allows financial outcomes to be compared with three classes of environmental risks. The "environmental impact quotient" of Kovach et al. (1992) is an index of pesticide impacts. Teague et al. (1995b) developed two indexes to incorporate the effects of environmental risk on farmers' decision making. One index measures the level of environmental risk from pesticides, the other measures risk from nitrates. Higley and Wintersteen (1992) followed an index-like approach to construct a measure of "environmental costs" of pesticides. To the market price of pesticides and the cost of application, they added farmers' willingness to pay for reduction of environmental risks, as expressed in a mail survey.

Although indexing is attractive because it combines many complex factors into a single measure, it is open to criticism because of subjectivity in assigning relative weights. Teague et al. (1995c) addressed this criticism by developing three alternative indices of environmental risk that incorporate different environmental effects of pesticide use. One index considers only chemical characteristics, and is similar to the "environmental impact quotient" of Kovach et al. (1992), the other two incorporate estimates of expected annual chemical runoff and percolation. Despite these differences, rankings of crop production alternatives under the different indexes were strongly and positively correlated. This

suggests that similar environmental policies might result from using any of the three indexes, although economic consequences as to whom bears the costs would differ.

Whereas an index combines different criteria into one number, dominance analysis uses the individual numbers associated with each criterion. For two desired criterion, say farm profit and soil quality (Van Kooten et al. 1990), dominance analysis identifies practices that increase one without decreasing the other, This results in a trade-off frontier showing the most profitable cropping practices available at each level of expected soil quality. In this example, higher short-term profits might require cropping practices that would decrease soil quality because of erosion. Therefore, the choice of "best" practice is left to the decision maker's personal preference.

Dominance analyses have proliferated recently. Hoag and Hornsby (1992) used it to construct cost-environmental hazard frontiers that identify the tradeoff between financial cost and environmental hazard for herbicides in southeastern soybeans. Bouzaher et al. (1992) used a similar approach to highlight trade-offs between the probability of crop loss and the cost of weed control under various herbicide bans. Swinton and Clark (1994) examined the trade-offs between leachable nitrate and farm gross margin, while Xu et al. (1995) extended this approach to include soil erosion and leachable nitrate. Carriker (1995) used a related method called "stochastic dominance with respect to a function" to examine trade-offs between profitability and both income and nitrate loading risk for different corn fertilization strategies. Ess et al. (1994) use energy use and net return dominance to compare corn silage production methods for alternative nitrogen sources. A treatment was considered superior if it was lower in energy input per unit of crop output while its net revenue was not statistically different from the baseline treatments.

Effectiveness of Various Methods

The main objective of studies comparing alternative crop production systems typically is to assess the impact of a new technology or policy, or else to provide decision support for farm managers. The study objective and the importance attached to nonfinancial criteria are central to choosing the best analytical method.

Most budgeting methods fail to evaluate environmental criteria. Two limited exceptions are green budgeting (Faeth 1993) and break-even budgeting based on meeting an environmental target. For environmental impact analysis, budgets have been supplemented by nonmonetary accounting for an externality such as soil loss (see Ikerd et al. 1993). However, unless supplemented by dominance analysis, financial budgeting provides no clear guidance for ranking different systems. Budgeting methods also miss whole-farm constraints, such as workable field time, which may not be limiting at the individual enterprise level.

At the other extreme, biophysical simulation models portray environmental processes in detail but offer no economic basis for evaluating crop systems. Getting a balanced evaluation requires compromising on the level of detail on both financial and environmental sides. The variety of environmental criteria forces analysts to focus on key ones which may cause them to miss interrelationships, or else to build indexes from multiple criteria.

Few studies have captured dynamic effects, yet these are central to the definition of sustainable systems. Dabbert and Madden (1986) made an effort with multi-period LP, but their study was based on limited biological data. Dynamic programming studies have modeled changing environmental conditions, but except for Van Kooten er al. (1990), those reviewed did not include any index that translates environmental quality into monetary terms. All the rest are driven by "value functions" defined strictly in financial terms, with environmental quality outside the optimization criterion.

Teague et al. (1995a) offer a promising approach to balancing profitability with environmental risk management. Their farm-level risk programming model evaluates changes in cropping patterns and farm incomes associated with reducing environmental risk from nitrates in groundwater. They use an LP model called Target MOTAD (Tauer 1983), which was designed to maximize net returns while ensuring a minimum probability that returns remain above a target level. Instead of an income target, Teague et al. (1995a) set an environmental target to maximize net returns while ensuring that nitrate leaching remained below a target level. Instead of a minimum probability of meeting the target, they substituted a minimum acceptable probability of complying with the maximum nitrate threshold. By changing the nitrate thresholds and compliance levels, they captured the trade-off between expected income and the environmental risk from nitrate loadings, as simulated by the EPIC-PST model, the Erosion Productivity Impact Calculator (EPIC) model supplemented by the pesticide subroutines from the Groundwater Loading Effects of Agricultural Management (GLEAMS) model.

A balanced economic and environmental analysis of alternative crop systems typically would follow either of two approaches. One is to place a monetary value on environmental impacts (Faeth 1993; Higley and Wintersteen 1992) and include them into a monetary objective function to be maximized. The other is to treat environmental impacts as parameters in an optimization model (Crowder et al. 1985; Johnson et al. 1991; Swinton and Clark 1994; Teague et al. 1995a,b; Xu et al. 1995), or build efficiency frontiers, as in dominance analysis (Bouzaher et al. 1992; Carriker 1995; Hoag and Hornsby 1992; Van Kooten et al. 1990).

To execute either approach effectively requires a minimum amount of data for joint microeconomic and environmental analysis of alternative crop systems. First, levels of resource use and financial costs are needed, including complete data on all aspects that differ between systems. Second, yields of marketable product should be monitored, including performance as they evolve over time under different natural conditions. Third, the analysis should include complete data on the environmental parameters that vary significantly across systems, such as nitrate leaching, soil erosion, or synthetic chemical application.

Putting a monetary value on environmental quality also requires assigning a value to reductions in environmental risks. Although attractive in theory, the high cost and potential subjectivity of this approach are why it has seldom been applied in analyzing alternative crop systems. Consequently, the most promising current analytical techniques link biophysical simulation models to an economic optimization model. These will only be as good as the data from which they are constructed, and the modeling results must be validated within the study area.

Conclusion

Efforts to evaluate both the economic and environmental attributes of alternative cropping systems are still immature. The particularity of environmental issues defies prescriptions for a generalizable approach, but system stability and evolution are two areas that deserve more careful study. This is true for all three main uses of these economic analyses: technology evaluation, policy analysis, and decision-support systems. When care is taken to assure data quality, existing economic optimization methods linked to biophysical simulation models have a demonstrated potential for evaluating the trade-offs among expected profitability, environmental impact, and both financial and environmental stability.

Chapter 3

AGRONOMIC AND ENVIRONMENTAL JUSTIFICATION FOR INCREASING SOIL QUALITY THROUGH INCREASED CROPPING DIVERSITY

Introduction

The last chapter identified an appropriate approach for comparing alternative crop production systems. The remainder of this thesis seeks to apply that approach to a specific case comparing systems designed to increase soil quality through cropping diversity with more typical systems which do not promote this diversity. The purpose of this chapter is to identify and provide agronomic justification for key management practices that can increase soil quality through increased cropping diversity. This chapter begins with the importance of cropping diversity in improving soil quality, then lays out the agronomic issues on nitrogen use and soil erosion, the agronomic theory on nutrient mass balance, and a discussion of the profitability and potential incentives of these alternative cropping systems. The chapter concludes by identifying several criteria for evaluating cropping systems.

ALTERNATIVE CROPPING SYSTEMS: A DEFINITION

Having identified an appropriate approach for comparing alternative cropping systems, it is important to understand the agronomic justification driving their development. In the 1989 publication *Alternative Agriculture*, the National Research Council defined alternative agriculture as any system of food or fiber production that systematically pursues the following goals:

- More thorough incorporation of natural processes such as nutrient cycles, nitrogen fixation, and pest-predator relationships into the agricultural production process;
- Reduction in the use of off-farm inputs with the greatest potential to harm the environment or the health of farmers and consumers;
- Greater productive use of the biological and genetic potential of plant and animal species;
- Improvement of the match between cropping patterns and the productive potential and physical limitations of agricultural lands to ensure long-term sustainability of current production levels; and

- Profitable and efficient production with emphasis on improved farm management and conservation of soil, water, energy, and biological resources.

Though there are many examples of practices emphasized in alternative agricultural systems such as Integrated Pest Management (IPM), site specific management systems, and organic agriculture, the focus here is on specific practices which encourage soil quality within a field through the use of cover crops and manure.

Cropping Diversity and Soil Quality

Soil quality can be defined as "the capability of a soil to produce safe and nutritious crops in a sustained manner over the long term, and to enhance human and animal health, without impairing the natural resource or harming the environment (Parr et al. 1992)." According to the National Research Council (1993), protecting soil quality should be a fundamental goal of national environmental policy. Soil texture, permeability, biological activity, water and nutrient storage capacity, and amount of organic matter all contribute to the health of the soil (National Research Council 1993). Soil and crop management strategies that focus on soil organic matter and biological activity appear to be the best ways to improve soil quality (Karlen et al. 1992). Specific strategies such as using cover crops, rotating different crops, and applying manure as fertilizer have been shown to increase both organic matter and biological activity (Doran et al. 1987). Michigan State University's Long Term Ecological Research (LTER) project holds as its central theme that soil microbial activity is driven primarily by substrate quality and that crop and cover crop diversity determine substrate quality and diversity. The resultant benefits in soil quality boosts the soil's productivity with respect to crop yields, acts as an environmental filter affecting both air and water quality, and has important effects on the nutritional quality of the foods produced (Parr et al. 1992).

Understanding Nutrient Management

Quality soils should provide an adequate supply of key nutrients such as nitrogen, phosphorous, and potassium at the time that plants can best use them. This flow of nutrients is an important determinant of crop productivity. Conventional agriculture typically relies on external application of these important nutrients as fertilizer to maximize crop output. However, when inputs into the system exceed outputs, the potential exists for water pollution from losses of nitrogen and phosphorus.

Nutrient budgets (National Research Council 1993) provide a method to account for the flow of nutrients through a cropping system, often referred to as the nutrient cycle (see Figure 3-1) These budgets can be used to review the sources and sinks of nutrients to identify opportunities for improving nutrient use efficiency. Sources provide the inputs of nutrients into the cropping system while sinks account for the outputs of nutrients from the system. Inputs of nutrients are derived from fertilizer applications, manure, legume sources and crop residues while outputs are estimated from that removed from harvested crops and crop residues. Crop residues considered as output one year are treated as inputs the following year. The difference between the nutrients entering and exiting the system is the change in nutrient storage within the system, the residual or excess nutrient

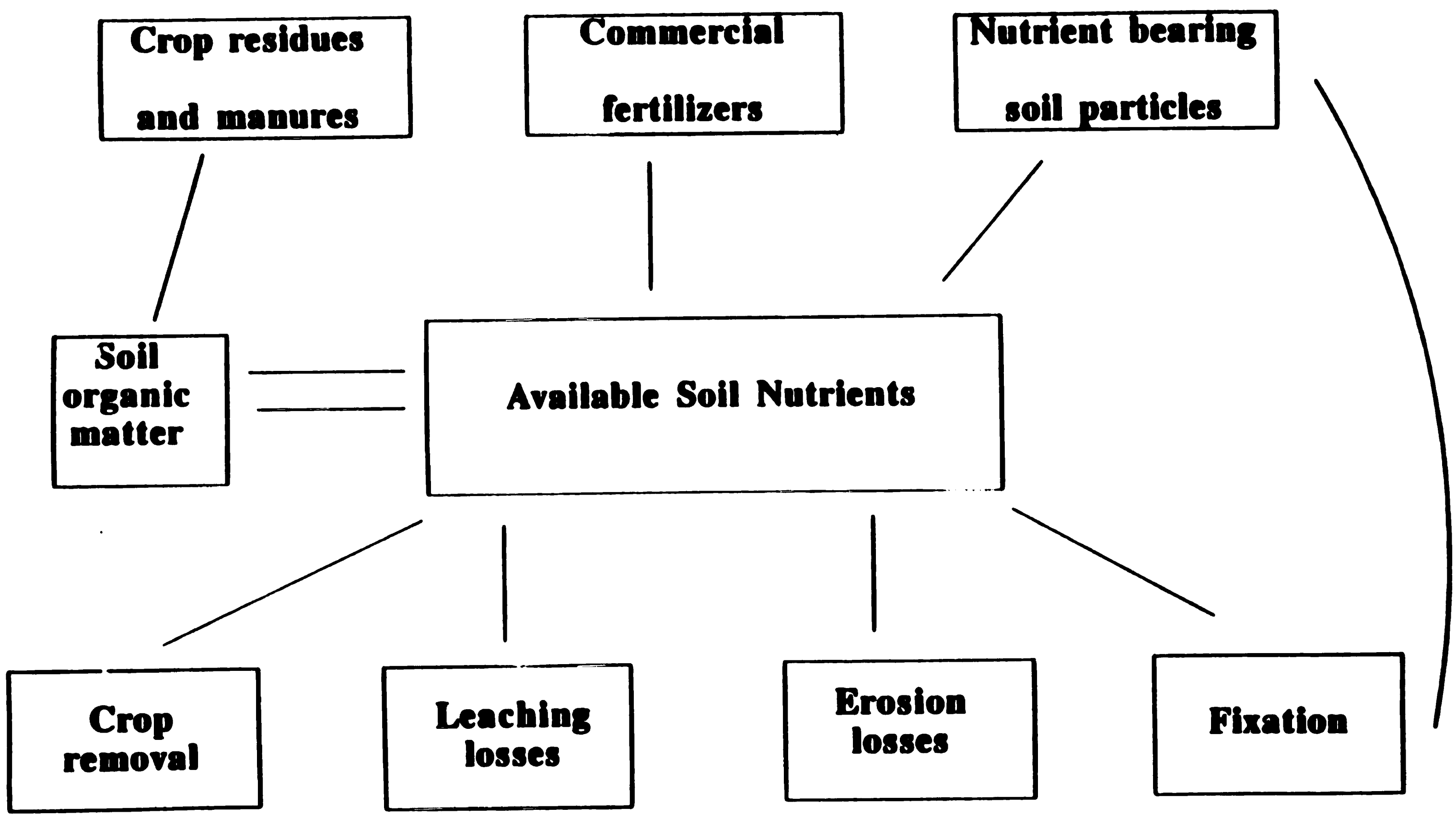

Figure 3-1: Soil Nutrient Cycle

level. These residual balances represent carryover storage and supply within the soil as well as the potential for losses into the environment. Opportunities to improve these residual balances will improve the management of nutrients and result in less potential for environmental loss from agriculture.

Improving Nitrogen Utilization

Nitrogen (N) enters the soil from rainfall and fertilizers, or is mineralized from soil organic N, crop residues, manure, and legumes. According to the National Research Council (1993), "reducing the amount of residual nitrogen in the soil-crop system by bringing the nitrogen entering the system from all sources into closer balance with the nitrogen leaving the system in harvested crops should be the objective of nitrogen management to reduce losses of nitrogen to the environment." However, current nitrogen inputs typically exceed the nitrogen harvested and removed with crops (NRC 1993). Much of this residual nitrogen is in the form of nitrates which are highly soluble and readily lost to groundwater (Hallberg 1987; Meisinger and Randall 1991; Sanchez and Blackmer 1988). It has been broadly documented that nitrates are the most commonly occurring chemical contaminant in the world's aquifers and levels are increasing (Spalding and Exner, 1993). One-half of the U.S. population receive drinking water from groundwater sources and 97% of rural households use groundwater for all freshwater purposes (Fletcher and Phipps, 1991). The ingestion of nitrates from drinking water has been shown directly or indirectly to increase risk of stomach cancer, nervous system birth defects, non-Hodgkins lymphoma, and "blue baby syndrome" (Spalding and Exner 1993).

The main difficulty with nitrate leaching into groundwater is the high cost of measuring and attributing it to any given source. Therefore, policies often have to be designed to affect indirectly the factors that cause nitrate leaching which in the case of agriculture means nitrogen applications to fields.

Important to the definition of soil quality is its ability to store and release water to plants. Erosion, acidification, compaction, and loss of biological activity reduce the nutrient and water storage capacities of the soil which increases the movement of agricultural chemicals, thereby increasing the risk of nitrate leaching to groundwater. Kellogg et al. (1992) juxtaposed high risk areas and population centers to reveal areas where the potential for ground water contamination by chemical use in agriculture were highest. The northern edge of the central Midwest (Indiana, Illinois, and Michigan) were among the most striking matches. Kellogg et al.(1992) concluded that these areas presented the highest public concern over ground water quality. Indeed, in a survey of 328 rural wells in Michigan, 15% had water nitrate levels greater than public health drinking water standard of 10 ppm and 6% more than 21 ppm (Vitosh 1990).

Methods cited by the NRC (1993) to reduce residual nitrogen include synchronizing the application of nitrogen with crop needs and increasing seasonal nitrogen uptake in the cropping system. Nitrogen is needed most during the periods of active crop growth, and can be lost when applied before planting. Changes in timing and application rates have been shown to reduce nitrogen losses and the amount of nitrogen fertilizer needed (Huang et al. 1994; Johnson et al. 1991).

Nitrate leaching typically occurs during the fallow period over the winter when excess residual nitrate accumulates from residual fertilizer, N mineralization, and nitrification of crop residues and organic matter. Policies and approaches to reduce nitrate leaching have typically dealt with limiting nitrogen applications due to the inherent difficulty of monitoring non-point source pollutants (Teague et al. 1995a; Horner 1975; Huang and Lantin 1993; Johnson et al.1991; Lambert 1990; McSweeny and Shortle 1989; Shortle and Dunn 1986; Swinton and Clark 1994; Taylor et al.1992; Thomas and Boivert 1994). Many studies have shown the superiority of effluent taxes on efficiency grounds (see Johnson et al. 1991; Huang and LeBlanc 1994; Kim and Hostetler 1991). However these policies are not usually considered because of the inherent difficulty and cost of monitoring emissions from non-point sources. Some studies have analyzed the farm level costs of implementing an effluent tax (Johnson et al., 1991; Taylor et al., 1992), but most authors also add that it is of little practical value due to monitoring costs (Griffin and Bromley, 1982; Swinton and Clark, 1994, Shortle and Dunn, 1986). The non-point nature of agricultural pollution implies that high information costs prevent direct taxation and regulation of the pollutant.

Although most of the literature has focused on reducing inputs, Addiscott and Darby (1991) contend that reducing nitrogen inputs will not necessarily result in reduced nitrate levels in groundwater due to extended periods when soil nitrate levels are high without actively growing plants. Instead they propose the use of cover crops to better manage and control the amount of nitrogen in the soil.

Managing Phophorus in the Cropping System

Like nitrogen, phosphorus enters the soil through crop residues and manures, in synthetic fertilizers and from phosphorus-bearing soil materials. The phosphorus that is not removed with the harvested crop is immobilized into the soil, incorporated into soil organic matter, or lost to surface water. Fertilizers provide the largest source of phosphorus input to croplands in the United States with corn acreage being the lead recipient (NRC 1993). The phosphorus level in the soil is the critical factor determining the actual loss of phosphorus to surface water. Most of the phosphorus lost to surface water is due to row crops (Groszyk 1978). This phosphorus binds to eroded soil particles and is carried to surface waters. Manure is also a significant source of phosphorus loads into water. Moore et al (1978) estimate that about five percent of the total phosphorus excreted by livestock annually ends up in surface waters. When manure is spread on frozen ground, losses from runoff may be severe.

Phosphorus occurs primarily in two forms, soluble phosphorus and particulate phosphorus. Losses of each are closely interrelated (NRC 1993). Since phosphorus is bound to soil particles by adsorption, most added phosphorus remains near the surface so that leaching to groundwater is typically not a problem (Gilliam et al. 1985). Both soluble and particulate phosphorus are readily lost through surface flow. Manure appears to provide more soluble phosphorus than do chemical fertilizers, so soluble phosphorus loss is generally higher from fields treated with manure (Reddy et al. 1978). The types of phosphorus are important in that soluble phosphorus is more readily available to organisms, creating more immediate short term consequences, while absorbed phosphorus can create long-term consequences once carried to surface waters.

Excess phosphorus delivered to surface waters leads to accelerated eutrophication, the process by which a body of water becomes rich in dissolved nutrients and seasonally deficient in dissolved oxygen. Algal blooms can result from accelerated eutrophication resulting in fish kills and other water quality problems. Relatively low concentrations of phosphorus in surface waters are sufficient to create eutrophication problems (Sawyer 1947; Baker et al. 1978; NRC 1993).

Encouraging Cropping Diversity

Using cropping systems as a management tool to reduce soil nitrogen and phosphorus levels, erosion, and runoff has been an increasing focus of research (NRC 1993). Crop diversity either within a field (cover crops) or over time (crop rotations) appears to be a major contributor in achieving high microbial activity necessary to achieve soil quality (Harwood, personal communication). Cover crops have been shown to take up excess water and soil N during winter fallow seasons and contribute to the soil organic matter and supply of nitrogen when incorporated back into the soil in early spring (Jackson et al. 1993; McCracken et al. 1989). Use of cover crops in this way has significantly reduced nitrate leaching (Jackson et al. 1993; Meisinger et al. 1991). Cover crops also protect the soil from potential erosion (Diebel et al. 1991; Karlen et al. 1992; Koo and Diebel 1994; Zhu et al. 1989), which will reduce the loss of phosphorus to surface waters. Lal et al. (1991) credit cover crops as beneficial in reducing erosion and runoff, improving soil quality, suppressing pest populations, and preventing water pollution. Sharpley and Smith (1991) reported reduced phosphorus losses from using cover crops of up to 94 percent over conventionally tilled corn with no cover crop. However, the potential to trap pollutants such as nitrogen and phosphorus, though promising, is not yet well understood. Cover crops designed to reduce the need for chemical nitrogen fertilizer and to prevent runoff and soil erosion can actually increase potential groundwater pollution from nitrates in some cases (Diebel et al. 1991; Foltz et al. 1993; Koo and Diebel 1994; Xu et al. 1995).

Crop diversity can also be achieved over time through the use of multi-crop rotations. Depending on the type of crops employed, multi-crop rotation has been shown to decrease the risk of soil loss to erosion or the risk of nitrate leaching to groundwater (Chuang et al. 1991; Elliott et al. 1987; Smolik et al. 1995). Emerging scientific evidence indicates that crop diversity enhanced by rotations and cover crops can reduce non-point source water pollution (Harwood 1993).

The use of manure as a fertilizer also contributes to a soil's substrate diversity. Regular use of manure at appropriate levels improves the physical and chemical properties of nearly all soils. Manure is especially beneficial in soils that are low in organic matter, shallow or coarse textured. By providing essential nutrients for crop growth, manure improves soil structure and tilth, water and nutrient storage capacity, and resistance to compaction and crusting, reducing the potential for soil and water degradation (Madison et al. 1986). The benefits attributed to the application of manure to soil is highly dependent on the use of "appropriate" levels. Gilbertson et al. (1979) developed a guide for estimating the amount of manure that must be added to supply a fixed-level of nitrogen nutrient. Of importance is the fact that less manure is required each continuous year of application to maintain an equal supply due to the slow mineralization of the nitrogen in manure. When these nitrogen credits are not given, excess nitrogen application to the soil results. This increases the risk of nitrate leaching to groundwater. While continuous corn systems exhibited a close balance between crop needs and N applications, Legg et al. (1989) found that N applications on farms using manure exceeded crop needs by up to 133 lb N per acre. Parsons et al. (1994) found that farms acquiring off-farm manure applied more manure nutrients and had the highest estimated nitrogen losses. Therefore, how much and how often manure is applied determines whether the application if beneficial or detrimental to water quality.

Environmental and Agronomic Evaluation of Crop System Diversity

Improving soil quality, reducing environmental damage, and maintaining or increasing profitability are the primary criteria used to compared alternative and conventional cropping systems.

Many of the studies related to soil fertility, structure, and environmental impact have already been mentioned. Reganold et al. (1993) compared the physical, biological, and chemical soil properties of conventional and alternative agricultural systems in New Zealand. The farms employing alternative practices were found to have relatively better soil quality. Doran et al (1987) found that alternative cropping systems, particularly those employing the growth of red clover or hairy vetch, profoundly influenced soil fertility and structure compared to conventionally managed systems. Methods for estimating soil quality were used to compare rotations with high or low diversity of crops and manure on nine paired farmer fields in central Michigan (Franco-Vizcaino, in press). Of specific interest was whether diversity of residues returned to the soil in corn-based rotations were associated with improvements in physical, chemical, or biological properties of the soils. Correlation analyses revealed that improvements in soil quality could not be associated simply with diversity in rotations, cover crops, or manure applied, but rather with diversity and frequency of all three sources of residues. These results indicate that a higher diversity of crop residues can lead to improved soil quality after a single rotation cycle.

Three articles review the literature on the environmental impact of alternative cropping systems compared with conventional systems. These cover the effects of systems employing cover crops on soil erosion, surface water quality, and groundwater quality. Langdale et. al (1991) summarize results from Wischmeiser (1960), Mills et al. (1986), Zhu et al. (1989), Shelton and Bradley (1987), Rasnake et al. (1985), Mutchler et al. (1990), Miller et al. (1988), and Putman et al. (1985) that document reductions in soil loss and soil loss probability through the use of alternative systems with cover crops as opposed to conventionally managed systems. Sharpley and Smith (1991) concluded that the inclusion of cover crops in alternative cropping systems consistently decreased runoff, soil loss, and amounts of N and P transported relative to conventional systems based on studies by Angle et al (1984), Klausner et al. (1974), Langdale et al. (1985), Pesant et al. (1987), Yoo et al. (1988), and Zhu et al. (1989). Meisinger et al. (1991) reviewed both historical and contemporary studies comparing the effects on groundwater quality of co

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conventional systems and alternative systems employing cover crops. The results of more than 16 empirical comparative studies dating from 1942 to 1990 led Meisinger et al. (1991) to conclude that alternative cropping systems using cover crops can reduce both the mass of N leached, and the NO_3 concentration of the leachate 20% to 80% compared with conventional systems with no cover crops.

Farm-Level Profitability of Improving Soil Quality

While the criteria used in these comparative studies include agronomic and economic ones, the contribution of this thesis is an economic evaluation. Results of published profitability comparisons between alternative crop systems designed to improve soil quality and current, conventional cropping systems are mixed. Neither system consistently outperformed the other. For instance, of four alternative crop rotations using cover crops and alfalfa compared against more conventional rotations common in Northeast Kansas, two were more profitable than the conventional system and two were less profitable (Diebel et al. 1993a). Profitability results by Dobbs et al. (1988) between alternative and conventional rotations varied by regional differences in production and cropping patterns. Fox et al. (1991) attributes these findings not only to variations in production systems and crops produced, but also to weather, soil type, and assumptions about price and costs structure.

A few studies have highlighted the tradeoffs that exist between net returns and improvements in soil quality. Xu et al. (1995) showed that net returns decrease for any measurable improvement in both soil erosion rate and nitrate available for leaching.

Interestingly, net returns were most affected by reductions in erosion rates. Reductions in net returns were quite small for large reductions in nitrate leaching when holding soil loss constant. Teague et al. (1995a) developed a nitrate environmental index to evaluate tradeoffs between net returns and environmental risk. Results indicated that expected net returns were highly sensitive to both the target level of the nitrate environmental index and the tolerance of exceeding the target.

However, some studies have found opportunities to reduce environmental risk without reducing profitability. Smolik et al. (1995) found that an alternative rotation relying on alfalfa reduced nitrate leaching while increasing profitability. Koo and Diebel (1994) increased net returns while decreasing soil erosion and chemical runoff, but not without increasing nitrate leaching. McQueen et al. (1982) found that soil loss could be reduced in Arkansas' North Lake Chicot by almost 25% while increasing net returns. Good manure management holds promise for reducing expenses and increasing profits by reductions in synthetic fertilizers (Bouldin et al. 1984; Hallberg et al. 1991; Lanyon and Beegle 1989). However, the cost of handling manure may offset the benefit from reduced fertilizer expense. In summary, alternative systems employing diversity through cover crops, multi-crop rotation, and manure hold promise to ameliorate environmental hazards while maintaining profits. However, since results of various comparisons differ, more research is needed to understand what factors most influence the profitability of alternative systems and why.

CHAPTER 4

FIELD CROP ENTERPRISE BUDGETS FROM 15 SOUTHERN MICHIGAN FARMS, 1994: A SUMMARY

Introduction to the Budgets

The agronomic literature clearly supports the use of manure, rotations, and cover crops to reduce the risk of environmental contamination from agriculture while improving soil quality. However, the mixed results of profitability studies indicate a need for further research into which factors most influence a system's profitability. The remainder of this thesis evaluates these factors empirically in central-Michigan corn-based crop rotations using statistical analysis and optimization modeling.

In an effort to measure the profitability of alternative crop nutrient management practices, field-level costs and returns were monitored during 1994 on fifteen farms in six counties across southern lower Michigan. The farms were selected from a 1993 soil quality survey which paired adjacent farm fields having continuous corn ("low diversity") and rotational corn ("high diversity") cropping systems (Franco-Vizcaino 1996). Data for enterprise budgets were collected through personal interviews at the start of the 1994 growing season, followed by two to three phone calls during the growing season to obtain information about the management practices and inputs used on the specific fields of interest. The data included crop yields as well as labor, machinery, and agricultural inputs for each task during the growing season.

Research Objectives and Hypotheses

The primary objective was to determine and compare the costs and returns between fields having continuous corn and corn grown in rotation with other crops, specifically accounting for the impact of manure and interseeded crops. This analysis was performed on 1994 data gathered about the fields selected for the soil quality study the previous year. The motivating hypothesis behind the selection of fields for the soil quality comparison study was that crop and cover crop diversity, which determine substrate quality and diversity, are the primary "conditioning" factors which drive the organic conversion process. These determinant effects are only marginally influenced by most chemical and non-chemical farming practices.

If these integrated production systems could be shown to lower operating costs while maintaining or increasing yield (thereby increasing field-level net returns), the adoption of these systems would provide a win-win solution economically and environmentally. The guiding hypothesis is that as soil quality increases, operating costs will decline due to 1) a reduction in fertilizer use as N is carried over from legumes grown in rotation with corn, and 2) a decline in insecticide control of corn rootworm as crop rotation can reduce risk of damaging rootworm infestations. Yields would also increase directly with soil quality, resulting in higher field net returns.

Enterprise Budget Construction

The most widely used method for measuring profitability in system comparisons is enterprise budgeting. An enterprise budget lists all estimated income and expenses associated with a particular enterprise to provide an estimate of its profitability. Field crop budgets summarize on a per-acre basis input quantities and costs by field task, output quantities and prices, and the cost of labor and machinery usage. Not all the costs in enterprise budgets represent actual cash expenses. For example, the labor involved with these farms was typically supplied by family members who did not receive a direct cash payment for time invested. However, since time requirements vary among the different management practices, it was necessary to estimate the opportunity cost of labor. Opportunity cost represents the value of any resource in its best alternative use. Custom work rates are used here to account for the opportunity cost of labor as well as equipment. Since the custom rates account for labor and the use of machinery, the gross margins represent returns over direct expenses. These omit all fixed costs associated with land, buildings, machinery, and management. Gross margin comparisons provide a clear picture of the relative difference between field-level net returns for the alternative systems being compared.

Data From the 15 Farms

Thirty-six enterprise budgets were developed to estimate returns over variable costs per acre on the farm fields monitored in 1994 (Appendix II). Data were collected on labor and machinery by task and variable inputs used throughout the growing season. For fields cropped in rotation, budgets were developed for each crop by tracking fields with the rotational crops during the 1994 growing season. For instance, if the farm operator followed a corn/soybean/wheat rotation with soybeans on the sampled field in 1994, then corn and wheat fields similar to the sampled field were also monitored. The budgets list the soil type, field number, and field size.

The budgets are based on crop prices and input costs from mid-Michigan during the winter of 1994-95 (Appendix III), along with custom work costs. Standardized prices for the crops are those cash prices quoted at the Webberville, MI, elevator on February 2, 1995, with no adjustment for dry-down, quality, or storage. Any premium prices obtained from the sale of special quality crops were not considered in the analysis. Grain equivalents were used for silage yields for ease in comparison between corn silage and corn grain. These were derived by consultation with Dr. Roy Black, an agricultural economist at Michigan State University.[*] Prices used for chemical inputs came from dealer invoice prices as of February 28, 1995. Fertilizer prices were those applicable for the 1994 growing season according to Dr. Gerald Schwab in the Department of Agricultural Economics at Michigan State University and confirmed by a local supplier of fertilizer, Golden Acre Farms.[†,‡] Seed prices were obtained from the Webberville elevator in February 1995. Custom work rates for south central Michigan were obtained from the 1992 survey reported in Schwab and Siles (1994). Total variable costs are presented

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Roy Black 1995: personal communication.

Gerald Schwab 1995: personal communication.

Golden Acre Farms 1995: personal communication.

along with returns over variable costs. Since the custom rates account for labor and equipment use, the returns over variable costs cover the returns to land, buildings, machinery, and management.

The initial survey instrument used in communication with the farmer was designed to gather general information on the farm and its available resources, such as labor supply, machinery, and those variable field inputs which were purchased or non-purchased. A second sheet was designed to gather field information to account for general data relative to that field such as its field history, field size and location. Detailed data were collected on inputs, machinery, and labor by individual task used on each field. Appendix 1 provides an example of these records.

General information was collected at the time of the initial interview while more detailed accounts of field operations were gathered through follow-up phone calls during the season. The motivation for this was to acquire the information while it was still current in the farmer's mind to improve accuracy. Some farmers kept detailed, available records, while others relied mostly on recall for those records not required by law to be maintained.

Appendix II contains the 36 budgets constructed. The first part of each budget provides the gross field revenues per acre by combining the actual yield observed with the generalized price to obtain gross revenue. Costs are broken down by task performed and then totaled down the right margin. Input costs per acre are given for each unit. The input cost per acre and the custom work rate cost per acre combine for total costs per acre per task. Total variable cost is summed and subtracted from gross revenue to give the return over variable cost, or gross margin.

Results and Analysis of Survey Data

Table 4-1 provides summary results of the 36 fields. Five of these fields were in continuous corn production, while the rest were in variants of a corn-soybean-wheat rotation. Average yields by crop are listed with a distinction made between continuously grown corn and corn grown in rotation with other crops. Mean total variable costs and mean return over variable costs with minimum and maximum returns are also listed. These data were then differentiated by use of rotations, manure, or cover crops and, using one-way ANOVA, tested for differences among means.

Table 4-1: Summary of field crop enterprise budgets, 15 central-Michigan farms, 1994.

Crops	Number of Fields	Mean Yield (bu/ac)	Mean Total Variable Cost ($/ac)	Return over Variable Costs		
				Avg. ($/ac)	Min. ($/ac)	Max. ($/ac)
Corn - continuous	5	115	163	84	52	123
Corn - in rotation with other crops	11	133	175	112	31	230
Soybean	11	44	126	108	2	188
Wheat	9	52	91	72	-5	146
CCSW rotation	11	N/A	143	97	40	150

Mean yields differed for corn between the monocrop and rotational cropping systems. At 133 bu/ac the mean yield for corn grown in rotation with other crops exceeded that of the continuous corn system. Soybeans and wheat averaged 44 and 52 bu/ac respectively among the multi-crop rotations.

The mean total variable cost for the multi-year rotation was calculated by multiplying the variable cost for a given crop by the percentage of years it was grown relative to the total rotation. For example, in a four year CCSW rotation, the total variable costs for corn was multiplied by .5, while soybeans and wheat were each multiplied by .25. These were then added to obtain the mean total variable cost and returns for the entire rotation. The mean total variable cost for the CCSW rotation was less than for continuous corn. The returns over variable costs were also higher for CCSW than for continuous corn, although the variance was greater also.

An unexpected finding is that the mean total variable cost for corn grown in rotation with other crops exceeded that of continuous corn. It was expected that costs would be lower for corn grown in rotation due to a lower need for 1) chemical fertilizer due to nitrogen carryover from legume crops in the rotation and 2) corn rootworm control due to varying crops. That this was not the case may be attributed partly to three reasons. First, other variables [such as growing no-till corn or substituting manure for fertilizer] may have had a greater effect on reducing costs with continuous corn systems. Another possibility is that farmers failed to give nitrogen credit for previous crops and therefore did not decrease fertilizer use. Third, the rotation fields included two farms with extremely high input costs. In a small sample such as this, each observation can be influential.

Table 4-2 gives a summary of mean total variable costs by rotation of corn grown. These types include continuous corn, second or third year corn in a multi-crop rotation, corn following soybeans, and corn following wheat. Second or third year corn grown in rotation with other crops had almost the same costs as continuous corn, while corn following soybeans had less, as expected. The unusual observation was that corn following wheat had a mean total variable cost of $192, greatly higher than the $163 for continuous corn. The two farmers with higher corn costs both fall into this category. However, when the two high observations of the nine growers with corn following wheat are taken out, the costs decrease to $128 per acre. The two farms in question attempt to maximize yields through intensive input use. While these farms realized greater than average yields, their returns over variable costs fell below the mean for all farms. It is interesting to note from Table 4-2 that although the corn following wheat as a whole did have greater costs, the relatively high yield more than offset the additional costs so that gross margins were higher than with continuous corn.

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Table 4-2: Summary of mean total variable costs, yields, and gross margin of corn by rotation grown.

	Continuous Corn	2nd Year Corn in Rotation	Corn following Soybeans	Corn following Wheat
Number of Farms	5	4	2	5
Mean Total Variable Costs ($/ac)	163	162	158	192*
Average Yields (bu/ac)	115	121	158	133
Average Gross Margin ($/ac)	84	98	182	95**

* Mean total variable cost for corn following wheat when the two high observations are excluded is $128/ac.
** Mean gross margin for corn following wheat when the two high observations are excluded is $115/ac.

Yields, variable costs, and gross margins for all farmers except the organic farm were tested for significant differences using one way analysis of variance. Farm operators base management decisions on prices they expect to receive. In the case of the organic farmer, these were premium prices. Since the calculated gross margin for the organic farm does not accurately reflect these premium prices, it was not included in the analysis.

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Table 4-3: One-way ANOVA tests of mean differences in yield, total variable cost, and gross margin by crop diversity type, 14 central Michigan farms, 1994.

Group	Description	Number of Farms	Yield (bu/ac)	Total Costs that Vary ($/ac)	Gross Margin ($/ac)
1	Continuous Corn	5	115*	163*	84*
	Multi-crop Rotation	10	134*	146*	103*
2	No Manure	10	127	160**	90*
	Uses Manure	5	127	134**	109*
3	Uses Manure or Multi-crop Rotation or Neither	11	125	157*	90*
	Multi-crop Rotation and Manure	4	134	136*	115*
4	No Cover Crop	12	122*	147*	96
	Uses Cover Crop	3	146*	170*	99

*Significant difference exists at the .25 level.
**Significant difference exists at the .10 level.

Results of the analyses are listed in Table 4-3. Four separate one-way analysis of variance (ANOVA) tests were run between four different groupings of the farms. The first grouping paired farms growing corn continuously with farms growing corn with one or more crops in rotation. The second grouping paired farms using manure with those not using manure. The third grouping paired those growing more than one crop and using manure with all other farms, and the fourth group compared those rotations with cover crops and those without cover crops. Differences were found to exist at both the 25% and 10% levels. Since there is no cost to rejecting the hypothesis that means are equal when it is true since alternative practices would generate equal results, decision theory supports minimizing the acceptance of the null hypothesis when it is false (Mandersheid 1965). Therefore, significant differences of up to 25% are valid for farmer decision making within this model.

While use of manure shows no effect on yield, both cover crops and multiple crop rotations appear to affect yield significantly at the 25% level. All three forms of organic matter diversity (cover crops, multi-crop rotations, and manure) jointly reduce costs at the 25% significance level. Manure appears to have the highest effect on costs with significant differences at the 10% level. Combining both manure and multi-crop rotations also yields significant differences, though not as strong as manure alone. Differences at the 25% level also appear in gross margins in manure and multi-crop rotations both separately and jointly. The higher yields and reduced variable costs for the multi-crop rotations combine for a greater effect on gross margins than does manure alone. The use of cover crops appears to increase variable costs and yields significantly. Since these work in opposite financial directions, there is little to no effect on gross margins.

Further sub-classification of the farms with respect to corn gross margins, costs, and yields produced no significant differences but an interesting summary of means (Table 4-4). Four farms had neither manure nor cropping diversity. Six farms had crop rotation but used no manure. One continuous corn grower used manure, and four farms had both crop rotation and manure. Of these, yields were lower for all continuous corn growers whether or not they used manure. Yields were the same for all farms using multi-crop rotations, whether or not they used manure. Substituting manure for chemical inputs had

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no significant effect on yields. However, lowest variable costs were observed on those farms using manure, both among the continuous corn grower and the multi-crop growers. Those farms without manure had the higher costs, although the continuous corn growers without the manure had the highest. Highest gross margins were observed among those using multiple crops in rotation along with manure, followed by those with multiple crops, manure only, and continuous corn without manure.

Table 4-4: Summary of gross margin, total costs that vary, and yield (means) for corn by crop diversity type, 14 central Michigan farms, 1994.

Description	Number of Farms	Gross Margin ($/ac)	Total Costs that Vary ($/ac)	Corn Yield (bu/ac)
No manure/ continuous corn	4	83.15	172.00	118.13
No manure/ Multi-crop Rotation	6	95.33	152.06	133.33
Manure only	1	88.16	127.84	100.00
Multi-crop Rotation with Manure	4	114.66	135.86	133.75

Senstivity Analysis

To determine the sensitivity of the results to changes in price and price ratios between the crops, historical high and low price ratios for corn, soybeans, and wheat, derived from the past 15 years of Chicago quoted prices (Ferris, 1993), were used in the budgets, see Table 4-5. Gross margins were then derived under average, high and low t

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soybean to corn and what to corn price ratios (see Table 4-6). Low price ratios reflect a higher relative price of corn, while high price ratios reflect a lower relative price for corn.

Changing the price ratios in either direction resulted in less differences in gross margin across the groups, except for rotation and no rotation under the high price ratio (Table 4-6). When the price of corn is high relative to soybeans and wheat, no significant differences existed in any group. Low price ratios increase the relative value of corn yield so that financial advantages of crop rotations decrease, encouraging more intensive corn acreage. The higher relative prices of soybeans and wheat increase the advantage of growing these crops in rotation with corn. As corn prices fall relative to other crop prices, the value of rotation crops increases gross margins. Risk averse farmers who choose to grow rotation crops would be better off in two of the three scenarios and equally well off under high corn prices. Therefore, growing corn in rotation in this analysis would be the dominant strategy for a price risk averse or risk neutral farmer.

Sensitivity analysis also reveals that the cost saving from manure decreases if relative crop prices change in either direction. Since this cost savings is associated with the amount of fertilizer applied, its benefit is expected to be less with the two rotational crops, both of which require less fertilizer than corn. These crops would be in greater demand as their prices rise relative to corn. As the value of corn increases relative to other crops, the marginal benefit of additional acreage yield from the use of chemical fertilizer offsets the costs of those inputs. Therefore, changes in either direction result in less differences in gross margins from the use of manure. Again, cover crops do not affect gross margin with either direction of price change.

Table 4-5: Commodity prices used for various price ratios.

Corn Price	Soybeans Price	Wheat Price	SBean/Corn Ratio	Wheat/Corn Ratio	Ratio
$2.16	$5.30	$3.15	2.45	1.46	Average
$2.16	$5.94	$3.80	2.75	1.76	High
$2.16	$4.64	$2.51	2.15	1.16	Low

Table 4-6: One-way ANOVA tests of mean differences in gross margins with alternative price ratios by crop diversity type, 14 central Michigan farms, 1994.

Group ID		Number of Farms	Gross Margin with Average Price Ratio ($/ac)	Gross Margin with High Price Ratio ($/ac)	Gross Margin with Low Price Ratio ($/ac)
1	Continuous Corn	5	84.15*	156.29	79.25*
	Multi-crop Rotation	10	103.06*	173.96	71.00*
2	No Manure	10	90.46*	160.96	59.32
	Uses Manure	5	109.36*	182.29	72.60
3	Uses Manure or Multi-crop Rotation or Neither	11	90.25*	160.07*	58.40
	Multi-crop Rotation and Manure	4	114.66*	190.08*	78.46
4	No Cover Crop	12	96.26	168.72	63.71
	Uses Cover Crop	3	98.75	165.46	63.91

*Significant difference exists at the .25 level.
**Significant difference exists at the .10 level.

Summary

From the results and analysis, it appears that using multiple crops in rotation offer the greatest potential to improve farm profitability by increasing field net returns while decreasing potential environmental risk. Using multiple crops appears to increase individual crop yields and reduce costs, raising gross margins. Manure magnifies this effect under average price ratios, but acting alone, its effect on increasing gross margins is not as great as multiple crops in rotation.

The generality of results is limited by the small sample size. The 15 central Michigan farms surveyed do not allow general inferences about the effect manure, rotations, and cover crops have on field input costs, crop yields, and field gross margins. They do, however, indicate tentative support for the hypothesis that integrated production systems can lower costs and raise yields, thereby increasing field net returns. Future studies should focus on a larger sample to see if these results can be verified on a larger scale. The fields used in this study sample were paired comparisons, selected because of their similarity in soil type and topographic position. Therefore, the results minimized as many external factors as possible with farmer field research. Any large scale survey would have to identify and reduce external variables that could distort the results.

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CHAPTER 5

LINKING LP WITH BIOPHYSICAL SIMULATION MODELS

Introduction to the Models

Having constructed and compared enterprise budgets for the 36 central Michigan fields, the next step in the analysis is to develop a representative farm that reflects as much as possible the field-level practices and inputs used by these farmers in order to evaluate the trade-offs among expected profitability and environmental impact through a simulation exercise. The literature review in Chapter 2 concluded that linking economic optimization models such as LP to biophysical simulation models holds the greatest promise for evaluating ex ante technology tradeoffs between profitability and environmental impact. The primary objective is to determine the optimal mix of enterprises for the representative farm under different assumptions of tolerable levels of nitrate leaching, phosphorus runoff, and soil erosion. The results obtained will provide insight into the tradeoffs that exist among profitability and environmental impact.

A linear programming model was developed to determine the optimal mix of enterprises for the representative farm. Linear programming (LP) is a useful method to assess the impact of changes in management practice and resource combinations on farm profits. LP can assist the decision maker in allocating scarce resources among competing enterprises to provide the greatest income possible given current financial, resource, and environmental constraints. The model provides a mechanism to answer questions such as how the enterprise mix and management practices might change if restrictions were placed on tolerable levels of erosion or potential nitrate leaching. The farmer is assumed to maximize profits within individual resource and time constraints.

The modeling program used in this study to evaluate the effect of field-level changes in crop rotations and inputs is PCLP, the Purdue Crop/Livestock Linear Programming Model, version 3.2 (Dobbins et al. 1994). This whole-farm model captures field-time and equipment constraints in identifying the optimal mix of enterprises which provide the greatest return to available land, labor, machinery, and building resources. A comprehensive environmental and economic farm planning tool, PLANETOR (2.0), developed by the Center for Farm Financial Management (1995) at the University of Minnesota provides estimates of nitrate leaching and phosphorous runoff associated with each cropping activity and these estimates are used in the PCLP model. PLANETOR combines site-specific environmental models with individual farm economic planning data to evaluate the impact of reducing or changing pesticide use, nitrogen applications, phosphorus application, manure applications, tillage systems, and crop rotations.

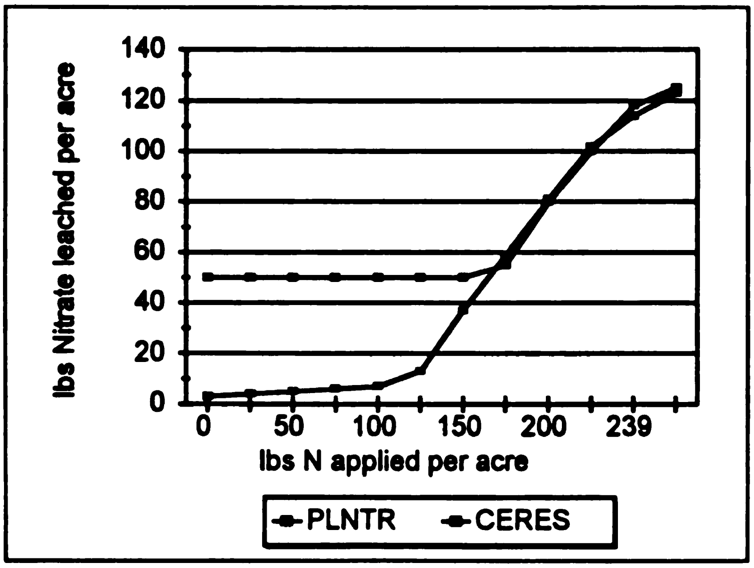

Figure 5-1: Relationship between fertillizer applications and nitrate leaching as simulated by PLANETOR and validated CERES-Maize.

PLANETOR is intended to be used to evaluate individual enterprise activities, and therefore it is used here to evaluate the environmental impact of typical field-level practices observed in the sample. While PLANETOR is able to estimate financial returns and environmental impacts of individual farm enterprises, PCLP determines the optimal resource mix that maximizes whole farm returns to resources while meeting environmental and resource constraints.

Linking the Models

PLANETOR incorporates the Revised Universal Soil Loss Equation (RUSLE), Phosphorus Runoff Index, and the Nitrogen Leaching and Economic Analysis Package (NLEAP) into its farm analysis program as well as the soils and climate information data banks required by these programs. The nearest climate site for RUSLE is Grand Rapids, Michigan, while the nearest NLEAP climate site is Lansing, Michigan. There are 185 frost free days in this region with an average monthly precipitation of 2.86 inches and maximum and minimum average monthly temperature for the year of 24 and 72 degrees Fahrenheit respectively. Soil characteristics are identified for the representative soil of Kalamazoo loam, 0-2% slope. The PLANETOR model runs through ten years of every rotation to account for carryover effects of cropping activities over time. Average annual soil loss by tons, pounds of phosphorus (P) runoff, and pounds of nitrate leached were simulated for each rotation on each field over a ten-year period. Results generated by PLANETOR represent the annual averages in the eleventh year and beyond of a rotation. NLEAP, however, is very limited in its selection of crops. It does not have a database on interseeded crops such as red clover. Cover crops must be treated as a green manure adjusted to represent the amount of nitrogen contribution from clover. Therefore the model scenarios are simplified and limited in their ability to reflect reality.

Although simulated nitrate leaching and phosphorus runoff risks differed by cropping activity, soil erosion never exceeded the tolerable limits. Therefore it is not included in the linear programming model. However, potential risk of nitrate leaching and phosphorus runoff associated with each rotation varied widely depending on management practice, specifically manure application. Appendix IV provides the numerical ranges associated with PLANETOR's "high," "medium," and "low" ratings, and the potential risks of nitrate leaching and phosphorus runoff by management practice as simulated by PLANETOR on Kalamazoo loam soil.

Twenty-nine different crop production alternatives were defined in the LP model based on the different activities, inputs, and crops grown. Each activity was assigned the level of nitrate leaching and phosphorus runoff predicted by PLANETOR. Figure 5-1 shows that at higher levels of nitrogen fertilizer application, nitrate leaching results obtained from NLEAP correlated well with validated results from CERES-Maize in central Michigan with irrigated corn (Alocilja and Ritchie; 1993). The rate of nitrate leaching predicted by CERES-Maize remains constant up to about 175 lbs. of applied N and increases at almost a one-to-one ratio after that. Lower levels differed between the two models where NLEAP continues to decrease linearly below 175 lbs N. Given the additional leaching expected with irrigated corn (about 10 lbs.), the two models still correlate well at 150 lbs. N. The differences can be partially attributed to differences in the two models. CERES-Maize assumes a buildup of residual N in the soil profile so that leaching does not continue to decrease below 175 lbs. of N application. However, CERES-Maize does not take into account long term N dynamics, but is more concerned with short term applications and their effect on nitrate leaching. NLEAP, on the other hand, looks at the long term stability of the system with given production practices. In summary, assuming per acre nitrogen application rates of at least 150 lbs., NLEAP reasonably reflects conditions in central Michigan.

The Representative Farm

Characteristics of the representative farm were drawn from the most frequently observed practices of the 36 enterprise budgets generated from the 15 farms surveyed. Of importance were the size and location of the farm, the crop and rotation alternatives, the field level operations and inputs, and the relevant input and machinery costs, commodity prices, and associated yields.

The representative farm consists of 1250 tillable acres located in south central Michigan on Kalamazoo loam soil. All of the acreage is owned and used for crop production. One and a half adult full-time equivalents of family labor are assumed to operate the farm. Seasonal part-time help is available as needed at a cost to the farm of $10 per hour. A conventional set of machinery is assumed, reflective of the equipment used by the farm operators surveyed (see Table 5-1). Working rates are based on Fuller et al. (1995). Primary crops allowed in the model include corn, soybeans, and wheat. Four rotations may be considered by the farm manager: continuous corn, corn-soybean, corn-soybean-wheat, and corn-corn-soybean-wheat. Four versions of each rotation are used, including 1) rotation without manure or cover crops, 2) with manure only, 3) with cover crop only, and 4) with both cover crop and manure. Table 5-2 lists all crop and rotation alternatives considered. Rotations with the use of cover crops employ clover interseeded with winter wheat, except in the case of corn-soybean where clover is interseeded with corn.

Table 5-1: Machinery, working rates, and operating costs in the representative farm.

Machinery Name	Tractor Required	Labor Hrs/ Machine Hrs.	Working Rate (acres/hr)	Working Cost ($/acre)
Small-Medium Tractor (≤120 hp)	N/A	1.0	N/A	N/A
Medium-Large Tractor (〉120 hp)	N/A	1.0	N/A	N/A
Chisel Plow (15')	small-medium	1.0	10.1	0.96
Moldboard Plow (4-16)	small-medium	1.0	3.7	3.30
Tandem Disk (21')	small-medium	1.0	8.2	0.82
Cultivator (6-30)	small-medium	1.0	7.7	0.58
Rotary Hoe (21')	small-medium	1.0	18.5	0.30
Sprayer (30')	small-medium	1.0	15.3	0.26
Anhydrous Applicator (30')	medium-large	1.0	12.7	1.41
Manure Spreader (225 bu)	small-medium	1.0	3.5	2.92
Field Cultivator (28')	medium-large	1.0	14.4	0.99
Fertilizer Spreader(4T/40')	small-medium	1.0	23.7	0.30
Corn Planter (6-30)	small-medium	1.5	7.0	0.88
Grain Drill (30')	small-medium	1.5	10.6	1.27
Corn Combine (6-30)large	N/A	2.0	4.2	5.81
Grain Combine (hd large)	N/A	2.0	6.7	3.42

Table 5-2 Rotations and crop alternatives available in the representative farm model.

Rotation	Crops	Manure	Clover
Rotation 1-1	Continuous Corn	No	No
Rotation 1-2	Continuous Corn	Yes	No
Rotation 1-3	Continuous Corn	No	Yes
Rotation 1-4	Continuous Corn	Yes	Yes
Rotation 2-1	Corn-Corn-Soybean-Wheat	No	No
Rotation 2-2	Corn-Corn-Soybean-Wheat	Yes	No
Rotation 2-3	Corn-Corn-Soybean-Wheat	No	Yes
Rotation 2-4	Corn-Corn-Soybean-Wheat	Yes	Yes
Rotation 3-1	Corn-Soybean-Wheat	No	No
Rotation 3-2	Corn-Soybean-Wheat	Yes	No
Rotation 3-3	Corn-Soybean-Wheat	No	Yes
Rotation 3-4	Corn-Soybean-Wheat	Yes	Yes
Rotation 4-1	Corn-Soybean	No	No
Rotation 4-2	Corn-Soybean	Yes	No
Rotation 4-3	Corn-Soybean	No	Yes
Rotation 4-4	Corn-Soybean	Yes	Yes

For the purposes of this study, all crops are assumed to be sold at harvest unprocessed and no storage is available on the farm. PCLP makes adjustments for yield and moisture levels based on the timing of planting and harvesting. This is important due to reductions in yield due to delays in planting and harvesting delays. Field days estimates for a typical Kalamazoo producer represent the number of good working days in a ten day period at an 80 percent probability (Rosenburg et al. 1982). The year is divided into 17 different time periods, with 7-10 days per period throughout the growing season. Labor is assumed to be available for 10 hours a day, 6 days a week. The periods, days in each period, and number of good working days are listed in Table 5-3. Variable crop production inputs used in the LP model are nitrogen (N), phosphate (P_2O_5), and potash (K_2O), seed, chemicals, and manure.

Table 5-3: Good field days at an 80% probability, Kalamazoo, MI.

Time Period	Good Field Days
April 20 - April 30	2.5
May 1 - May 10	6
May 11 - May 20	5.2
May 21 - May 31	6.9
June 1 - June 15	6.1
June 16 - June 30	9.6
July 1 - July 15	11.5
July 16 - July 31	11.2
August 1 - August 15	11.1
August 16 - August 31	11.6
Sept. 1 - Sept. 15	8.1
Sept. 16 - Sept. 30	9.9
Oct. 1 - Oct. 15	9
Oct. 16 - Oct 31	10.4
Nov. 1 - Nov 15	7.5
Nov. 16 - Nov 30	1.5
Dec. 1 - April 19	14

Fertilizers are separated to account for nitrogen use separately from other fertilizers. Production practices, chemical and organic inputs, and timing of crop activities are based on the statistical modes of the enterprise budgets for each crop. Using the most frequent observations avoids distortions that one or two uncharacteristic observations can cause in means. Input costs are the same as those used in the enterprise budgets.

Commodity prices reflect historic price ratios observed over the last fifteen years for corn, soybean, and wheat harvest prices (Table 5-6). Equipment costs are derived from Fuller et al.'s (1995) "Estimated Machinery Operating Costs, 1995." Dairy manure is assumed to be acquired at no cost from a neighboring farm so it has no per-unit cost. This type of arrangement was evident among the fifteen farmers from which this farm is constructed. The only cost associated with manure is the cost of spreading. The operator is assumed not to participate in government commodity programs. Restrictions are placed on pounds of nitrate leaching allowed per year followed by other environmental restrictions such as soil loss and phosphorus runoff. Corn is assumed to yield 125 bu/ac for continuous corn, and 135 bu/ac for corn grown in rotation. Soybeans are assumed to yield 43 bu/ac, and wheat at 61 bu/ac.

The initial formulation assumes average 15-year historical price ratios, and a 10 bu/ac yield advantage for corn grown in rotation with other crops. Other formulations are run using high and low price ratios (see Table 5-4). These price ratios were derived from Chicago cash prices over a fifteen-year period from 1978 to 1992 for corn, soybean, and wheat. They represent the mean, maximum, and minimum soybean-corn ratio and wheat-corn ratio over this fifteen-year period.

Table 5-4: Commodity prices used for alternative price ratios in representative farm model

Corn Price	Soybeans Price	Wheat Price	SBean/Corn Ratio	Wheat/Corn Ratio	Ratio
$2.16	$5.30	$3.15	2.45	1.46	Average
$2.16	$5.94	$3.80	2.75	1.76	High
$2.16	$4.64	$2.51	2.15	1.16	Low

Results

The results from PLANETOR provide estimates of whole-farm nitrate leaching and phosphorus runoff levels. These estimates provide the numerical values used as constraints in PCLP. PCLP determines the impact that constraints on allowable levels of these would have on the cropping mix and net return. Results are generated for an unconstrained (no restrictions on environmental factors), profit-maximizing scenario followed by restrictions on each environmental factor separately and together.

Table 5-5 shows the return to resources and Figure 5-2 the optimal crop mix for the initial unconstrained solution. This represents the profit-maximizing solution with no policy constraints, given the production alternatives, available resources, and current cost and price structure,. For the characteristic farm, the combination of enterprises that provides the largest income is 1014 acres planted to a corn-soybean-wheat rotation, 164 acres planted to a corn-soybean rotation, and 72 acres planted to a corn-corn-soybean-wheat rotation. Manure as a fertilizer source is used in all three rotations. Cover crops are noticeably absent from the model with no restrictions on environmental factors.

Table 5-5: Return to Resources when restrictions are placed on phosphorus runoff and nitrate leaching.

Restrictions	Return to Resources
Base Model	$220,016
Phosphorus Runoff	$220,007
Nitrate Leaching	$219,997
Both Phosphorus Runoff and Nitrate Leaching	$219,997

The "return to resources" of $220,016 represents the return that remains after all direct costs of production have been deducted from gross revenue. This provides the return to the investment in machinery and buildings, operator and family labor, management, and land, including overhead expenses such as depreciation, interest owed, property taxes, and insurance.

The alternatives to the base model involve whole farm restrictions on the total amounts of nitrate leaching and/or phosphorus runoff. Constraints were imposed at the upper limits of low risk as defined by PLANETOR. Restricting phosphorus runoff and/or nitrate leaching to the upper limits of "medium" levels had no effect on the optimal solution since the limits were not reached. However, constraints became binding at restricting levels to the upper limits of low risk potential (see Table 5-6 for marginal cost of environmental restricitons).

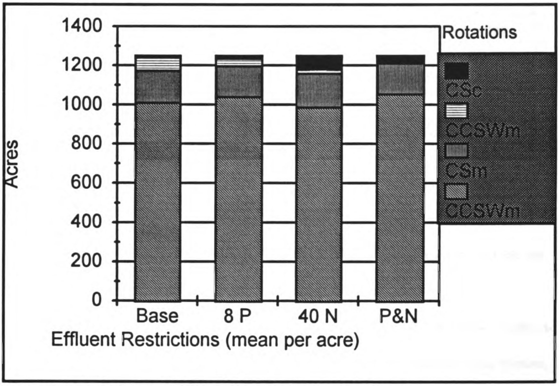

Figure 5-2: Optimal crop mix when effluent restricitons are placed on phosphorus runoff and nitrate leaching.

Table 5-6: Marginal Cost of Environmental Restricitons

	Environmental Restrictions		
Limited Resource	Nitrate Leaching (40 lbs./ac)	Phosphorus Runoff (8 lbs./ac)	Both Restricted
N Leach ($/lb)	.01	0.00	.01
P Runoff ($/lb)	0.00	.11	0.00

Figure 5-2 also shows the impact that nitrate leaching and phosphorus limits had on the crop enterprise mix. The leaching allowed was 50,000 lbs, an average per acre of 40 lbs. annually. The phosphorus runoff allowed was 10,000 lbs, an average of 8 lbs per acre annually.

Restricting phosphorus runoff alone results in 1046 acres planted to corn-soybean-wheat rotation using manure, 160 acres planted to a corn-soybean rotation using manure, 38 acres planted to a corn-corn-soybean-wheat rotation using manure, and 6 acres planted to a corn-soybean rotation with an interseeded crop. This crop mix differs from the base model by decreasing second year corn and incorporating cover crops. These substitutions occur because of the need to restrict the total amount of manure applied, due to its potential for phosphorus runoff and that cover crops provide an opportunity to acquire additional nitrogen without adding phosphorus.

Restricting nitrate leaching only results in 993 acres planted to corn-soybean-wheat rotation using manure, 173 acres planted to a corn-soybean rotation using manure, 21 acres planted to a corn-corn-soybean-wheat rotation using manure, and 63 acres planted to a corn-soybean rotation with an interseeded crop. This crop mix differs from the base model in that it results in a decrease in the C-S-W rotation with manure, a slight increase in the C-S rotation with manure, only marginal acreage allotted to C-C-S-W, and the addition of a C-S rotation with a cover crop. Cover crops are again included, though at a much higher rate. These substitutions occur because of the need to decrease nitrogen used in production. Corn is the most nitrogen demanding crop of those considered in the model, and manure also contributes to higher nitrogen inputs.

Combining both restrictions results in the lowest use of the rotation that includes two years of corn. Since restrictions on nitrate leaching constrain the model, the limit on phosphorus runoff is not reached in the optimal solution (see Appendix IV). The optimal solution results in 1063 acres planted to corn-soybean-wheat rotation using manure, 159 acres planted to a corn-soybean rotation using manure, 7 acres planted to a corn-corn-soybean-wheat rotation using manure, and 21 acres planted to a corn-soybean rotation with an interseeded crop. The optimal mix results in the smallest use of the C-C-S-W rotation, while using less cover crops than when nitrate leaching is constrained alone. The types of rotations and their relative use remain the same in all three restricted solutions.

These restrictions result in only a marginal reduction in the return to resources. While all three scenarios decrease the return to resources, this reduction was very small ($.01 per acre). However, important changes do occur in the crop mix.

Sensitivity Analysis

Results presented so far reflected the optimal enterprise mix when average price ratios exist between corn and both soybeans and wheat. However, these results are sensitive to the assumptions about price ratios. Using the jointly constrained and unconstrained models, Figure 5-3 shows the optimal mix for both high and low soybean-corn and wheat-corn price ratios (see Table 5-4).

At high price ratios where the prices of soybeans and wheat are high relative to corn, the optimal crop mix results in 861 acres planted to corn-soybean-wheat with manure, and 389 acres planted to a corn-soybean rotation using manure, and 37 acres planted to a corn-soybean rotation with an interseeded clover. Like the base model, the dominant rotation consists of corn-soybean-wheat with manure. However, more emphasis is given to the corn-soybean with manure rotation than in the base model, with two-year corn left out of the optimal solution. The higher soybean prices relative to corn cause more acreage shifted to soybeans.

Using low price ratios without environmental constraints results in substantial shifts in crop mix. Continuous corn is the predominant crop in the optimal solution due to the higher value of corn relative to soybeans and wheat. Substantial crop acreage is also devoted to corn-soybean-wheat with manure. This can be partly attributed to a shadow price of $82 per acre for the limited availability of tillage equipment . Removing this restriction would shift more acreage to continuous corn.

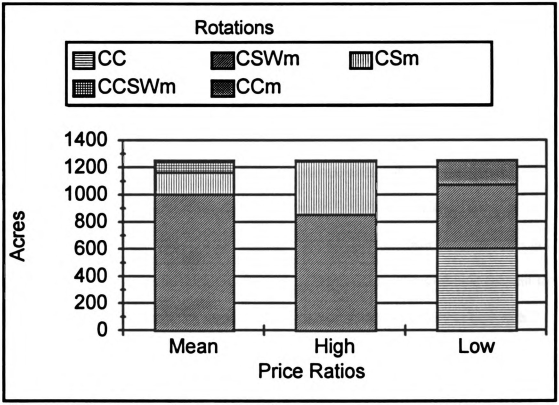

Figure 5-3: Optimal crop mix for mean, low, and high soybean-corn and wheat-corn price ratio without restrictions on phosphorus runoff and nitrate leaching.

Limitations

Simulations offer a wide range of choices and assumptions that must be made concerning the production practices and environmental resource factors. Calibration is critical and verification is a continual process. Alocilja and Ritchie (1993) verified NLEAP with irrigated corn production in central Michigan, but using model results can be misleading without ample evidence of its reliability.

This study did not capture the within-season variability of environmental risk. Annual averages over a ten-year period provide good indicators of problem fields or cropping systems, but they do not account for levels being higher than tolerable limits in a given year or month. Further research (following Teague et al. 1995a) should account for environmental variability among years or within a year. This is especially critical with respect to the timing and application of manure. Manure is also a difficult input to study. Its effect is important in reducing costs and increasing soil quality. However, its nutrient content is quite variable and difficult to represent with averages. Despite these difficulties, manure is often a profitable input to use and it is applied on many farms in central Michigan both for crop nutrient value and disposal reasons. Manure contributes to phosphorus runoff and nitrate leaching, and in some cases may contribute more than phosphate fertilizer applications (Legg et al.1989; Reddy et al. 1978). When manure is applied too heavily over several years, its build-up greatly raises the expected amount of nitrate leached. Therefore, the significant role manure plays makes it too important to be ignored, but the limitations of accurately modeling its role must be stated.

Summary

As evident in the budgeting analysis of the 15 farms, manure is heavily used in the unconstrained model with average prices due to its impact on reducing operating costs. However, its use is decreased when restrictions are placed on nitrate leaching and phosphorus runoff. The use of clover increased when leaching and runoff restrictions increased. The benefit of clover in this model is as a mechanism to reduce environmental pollutants. It is not a profitable strategy by itself under the model's assumptions when no restrictions are present. This model assumes no yield advantage to future crops from the use of clover based on the results of the enterprise budgets for the central-Michigan farms sampled.

CHAPTER 6

SUMMARY AND CONCLUSIONS

As stated in the introductory chapter, the guiding hypothesis motivating this research was that alternative production systems employing manure and cover crops in corn-based rotations with other crops will reduce environmental contamination while maintaining farm profitability. Four objectives were identified in answering this hypothesis. The first was to identify an appropriate methodology for a joint economic and environmental comparison of alternative cropping systems. The conclusions of the literature review showed that the most promising analytical techniques link biophysical simulation models with existing optimization methods to evaluate trade-offs among expected profitability and environmental impact.

A second objective was to build an understanding of the underlying agronomic relationships that motivate the use of different levels of crop diversity within a field. Using cover crops, rotating different crops, and applying manure have all been shown to increase both organic matter and biological activity (Karlen et al. 1992). Substrate diversity, in turn, improves the flow of nutrients through the system, helping to make nutrients more available when the plants can best use them, and reduces the availability of those nutrients for runoff or leaching at other times of the year. While the agronomic benefit of these cropping systems are consistently evident, economic results have been mixed. More research is necessary to understand the factors that influence the relative profitability of alternative and conventional systems.

The empirical contribution of this research tested the hypothesis that alternative production systems could reduce environmental pollutants from agriculture while maintaining farm profitability. The third objective was to test this hypothesis in actual farmer fields in central-Michigan, while the final objective was to test the hypothesis more generally by combining biophysical models with an optimization method to determine optimal crop mixes under different assumptions for a representative farm.

Results from both the empirical paired comparison study and from the representative farm study suggest opportunities to adopt alternative crop production practices. The conclusions of Chapter Four suggest that cropping patterns employing both manure and multiple crops in rotation can increase field-level gross margins. Results from Chapter Five rely predominantly on rotations of corn with other crops. These are the most profitable combinations on strictly economic criteria as well as when environmental criteria are incorporated into the model. Manure and cover crops appear in all constrained optimum solutions. Results from the field budgets and the generalized farm model agree that cover crops, such as clover, do not necessarily by themselves improve profitability. However, their use reduced environmental risk without significant reductions in whole farm return to resources.

Environmental restrictions in the LP model are placed at the farm level. Limits are placed on the total amount of allowable nitrate leaching or phosphorus runoff for the whole farm. A recent study has criticized this approach as being inefficient in meeting environmental goals (Teague et al. 1995a). Per-acre restrictions such as those imposed in this thesis achieve the target level on average but with wide variation so that the risks of environmental contamination can still be high. This can be partly attributed to the stochastic nature of environmental loadings that can not be captured by farm level restrictions. Teague et al (1995b) write that "although the expected value of loadings may not indicate the presence of an environmental problem, there still may exist a significant probability of a large loading event." Further work therefore should incorporate into an LP model such as PCLP results from a stochastic environmental model that considers field-level activity and the variations that occur within a single season.

Both PLANETOR and PCLP provide ready tools to evaluate the farm business and aid decision making. PLANETOR's strength lies in its ability to give a good snapshot of where the farm is today in terms of several key environmental indicators and how marginal changes to improve these indicators would affect the farm's financial picture. PCLP is well designed to simplify the process of representing the farm's given resources and finding profit-maximizing enterprise combinations given the farm's current or potential resources. This study has shown how these models can be used to identify opportunities to maximize income and crop enterprise mix given two sets of environmental restrictions.

Environmental hazards, such as a recent fish kill from phosphorus-laden manure runoff into a North Carolina river system, continue to increase public attention over agricultural pollution. Such negative attention will increase environmental restrictions on farm activities.. Greater conflict will occur over the cost of environmental protection and the need to maintain farm productivity and profit.

The goal of this thesis was to show that opportunities still exist for both objectives to be sufficiently met, and that by being proactive, farmers and farm organizations along with university-sponsored extension and research could develop alternative cropping practices that could improve or maintain profitability while decreasing environmental risk. The associated hypothesis was that alternative production systems employing manure and cover crops in corn-based rotations could reduce environmental pollutants while improving or maintaining farm profitability.

In 15 Central Michigan farms fields, corn-based rotations did in fact lower costs and increase field-level net returns. Manure combined with multi-crop rotations enhanced this effect. Cover crops could not be shown to increase net returns significantly. The hypothesis was further tested on a more generalized level through simulating the environmental and economic effects of rotations, cover crops, and manure used as fertilizer on a representative farm. Results indicated that while returns to resources were lowered by meeting environmental restrictions, the reduction was only marginal. In fact, nitrogen restrictions resulted in an estimated marginal cost of only one cent per pound of nitrate leachate reduced. Therefore, these results support the hypothesis that agricultural non-point source pollution can be reduced without risking farm profitability.

Since the observed sample represents a small group of farmers in a specific geographic region, these results cannot be taken as a comprehensive evaluation across an entire region. Caution is needed concerning the approach taken here. Considerable weight is placed on the accuracy of the two environmental models PLANETOR employs. These models would need better validation and calibration for the areas considered. If PLANETOR could be adjusted to incorporate probability levels for environmental risk as they have for financial risk, the model would be even more useful in evaluating effective farm plans.

Whether as policy makers, economists, or farm managers, decision makers embrace conflicts from either scarcity or abundance thinking. The scarcity thinker sees that we are pareto-efficient, operating along the frontier, so that any further improvement in one direction comes at a cost in the other direction. Life is "win-lose," and expected food production at current constraints cannot meet population growth. Abundance thinkers recognize that we are indeed operating on the frontier given current information and technology, but that the frontier itself is always expanding and each of us has the potential to push that frontier outward. Scarcity at a moment in time does not imply future growing scarcity. Life is not "win-lose," but that there is "plenty in our combined capacity to create third-alternative win-win solutions (Covey 1994)."

APPENDICES

APPENDIX A

FIELD INFORMATION COLLECTED FROM: AN EXAMPLE

Name of Farmer:
Address: Lansing, MI

Phone:
Best time: early, evening
Map Available: Yes - see Tom

Type of Farm: Organic

Field #1 Name: A (soybeans) Field #2 Name: B (corn) Field #3 Name: C(wheat)

Additional comments:
Sept. 22 - will call to see if there is anything I want to share on field day
will need estimation of yield between two parts of soybean field.1-4 pm, need rough estimation of different costs - 2 methods planting/weed control, solid drill, more weeds, yield difference; corn planter, 4 more operations (disc 2x, FC 2x)

Machinery:

Description	Size/Power Unit
Manure Spreader	250 bu.
Moldboard Plow	6-16
Roller Harrow	15'
Tandem Disk	15'
Grain Drill	13'
Hedge Mounted Seeder	3 pt
Chisel Plow	15'
Corn Planter	4-36
Solid Drill	4-16
Rotary Hoe	15'
Field Cultivator	15'
Tractors	70 hp
	90 hp
	130 hp

Labor Supply:

Name
Self
Son

Inputs:

Variable Inputs Purchased

Description	Price/Unit
Hard Red Winter Wheat "Rose" variety	$7.50/bu
Sweet Clover	$0.40/lb
Soybean seed	$10.50/bu
Corn Seed	$15-16/acre 65 bu/4 ac.

Non-Purchased Inputs

Description	Unit
Dairy Manure	tn

Field Name: 511

Date of interview: 3/23/94

Cropping History

	Crop	Yield
This year:	corn	135-140
Last year:	corn	148@$2.76/bu.
Two years ago:	corn	135

Rotation: continuous corn

Soil type: Spinks
Soil test: Yes pH: 5.9

Distance from farm: just behind barn

Time in rotation: 5-6 years

Acres: 19

Why is this rotation used? Enough hay ground (on hilly acres), so leave it in corn

		Labor Used		Inputs			Equipment	
Operations	Timing	Number	Hrs	Name	Unit	Quantity	Type/Size	Tractor
Field Preparations								
Disc	Nov, 93	1	2				tandem disk 16 ft	100 hp
plow	early April	1	6				moldboard plow 5-16	100 hpplant
	May 5	1	4	corn seed	k	21000	planter - 4 row	80 hp
				6-24-24	lb	225		
spray	May 12	1	1	root worm control	lb	8		
				Bullet	qt	2.5		50 hp
spray	June 16	1	1	Bucktrill	pt	1		50 hp
anhydrous	June 30	1	1	Anhydrous	lb	125		50 hp
				(actual	lb	96)		
harvest	Dec	1	10	gas	gal/ac	1	combine- 2 row	
dry, stored in bin								

APPENDIX B

ENTERPRISE BUDGETS FOR 36 FIELDS SAMPLED

Farmer Name:
Address: 　　　　**Soil Type:** Marlette

Enterprise Name Corn 　　　　**Field Name:** 111
Field Size: 18 acres

Revenues		Crop	Yield	Unit	Price				Gross revenue/ac
	Income 1:	corn grain	125	bu	$2.16				$270.00
Costs	Activity	Equip Used	Labor hrs/ac	Variable input Quant	Variable input unit	Input cost $/ac	Custom work rate cost $/ac		Total $/ac
	plow	chisel plow	0.33	0	0	$0.00	$10.70		$10.70
	spread urea	spreader	0.33	250	lb	$50.00	$2.20		$52.20
	disc	tandem disc	0.22	0	0	$0.00	$8.35		$8.35
	plant	conv planter	0.22	23000	kernel	$24.38	$13.20		$37.58
	w/ 6-27-27		0	225	lb	$21.93	$0.00		$21.93
	spray-Atrazine	sprayer	0.11	1.5	lb	$4.69	$4.35		$9.04
	spray-Lasso		0	1	qt	$7.15	$0.00		$7.15
	harvest	combine	2	0	0	$0.00	$18.75		$18.75
Total variable costs									$165.71
Returns over variable costs:									$104.29

Enterprise Name: corn

Field Name: 211
Field Size: 80 acres

Revenues		Crop	Yield	Unit	Price				Gross revenue/ac
	Income 1:	corn grain	92	bu	$2.16				$198.72
Costs								Custom work	
	Activity	Equip Used	Labor	Variable input		Input cost		rate cost	Total
			hrs/ac	Quant	unit	$/ac		$/ac	$/ac
	plant	no till planter		24000	kernel	$25.44		$17.20	$42.64
	spray-Atrazine	sprayer		2	lb	$6.26		$4.35	$10.61
	spray-2,4-D			0.5	pt	$1.55		$0.00	$1.55
	spray-Bicep			2.7	qt	$24.49		$0.00	$24.49
	fertilize-anhydrous			175	lb	$47.25		$4.45	$51.70
	chop	chopper						$36.80	$36.80
Total variable costs									$167.78
Returns over variable costs:									$30.94

Enterprise Name soybeans

Field Name: 222
Field Size: 35 acres

Revenues		Crop	Yield	Unit	Price				Gross revenue/a
	Income 2:	soybeans	46	bu	$5.30				$243.80
Costs								Custom work	
	Activity	Equip Used	Labor hrs/ac	Variable input Quant	unit		Input cost $/ac	rate cost $/ac	Total $/ac
	plant	no till drill		72		lb	$18.72	$17.20	$35.92
	spray-2-4D	sprayer		1		pt	$3.09	$4.35	$7.44
	spray-Classic			0.25		oz	$4.79	$4.35	$9.14
	spray-Pinnacle			0.25		oz	$9.02	$0.00	$9.02
	spray-Assure			8		oz	$7.86	$0.00	$7.86
	harvest	combine		0		0	$0.00	$20.80	$20.80
Total variable costs									$90.18
Returns over variable costs:									$153.62

Soil Type: Mixed

Enterprise Name spelt

Field Name: 314
Field Size: 8 acres

		Crop	Yield	Unit	Price				Gross revenue/ac
Revenues	Income 1:	spelt	35	bu					$0.00
	Activity	Equip Used	Labor hrs/ac	Variable input Quant	unit		Input cost $/ac	Custom work rate cost $/ac	Total $/ac
Costs	disc	tandem disc	0.09	0	0		$0.00	$8.35	$8.35
	seed	grain drill		3	bu		$30.00	$8.60	$38.60
	pest control	power harrow		0	0		$0.00	$3.45	$3.45
	beef manure	spreader		1	tn		$0.00	$11.15	$11.15
	bale/stack hay			0	0		$0.00	$0.00	$0.00
Total variable costs									$61.55

Enterprise Name spelt

Field Name: 324
Field Size: 31 acres

		Crop	Yield	Unit	Price				Gross revenue/ac
Revenues	Income 2:	spelt	30	bu					$0.00
	Activity	Equip Used	Labor hrs/ac	Variable input Quant	unit		Input cost $/ac	Custom work rate cost $/ac	Total $/ac
Costs	disc	tandem disc	0.09		0	0	$0.00	$8.35	$8.35
	seed	grain drill			3	bu	$30.00	$8.60	$38.60
	pest control	power harrow			0	0	$0.00	$3.45	$3.45
	beef manure	spreader			1	tn	$0.00	$11.15	$11.15
	bale/stack hay				0	0	$0.00	$0.00	$0.00
Total variable costs									$61.55

Soil Type: capac

Enterprise Name corn

Field Name: 411
Field Size: 80 acres

Revenues		Crop	Yield	Unit	Price			Gross revenue/a
	Income 1:	corn grain	100	bu	$2.16			$216.00
Costs							Custom work	
	Activity	Equip Used	Labor	Variable input		Input cost	rate cost	Total
			hrs/ac	Quant	unit	$/ac	$/ac	$/ac
	disc	tandem disc	0.1	0	0	$0.00	$8.35	$8.35
	spread manure	spreader		13	tn	$0.00	$11.15	$11.15
	disc	tandem disc	0.1	0	0	$0.00	$8.35	$8.35
	plant	no till planter	0.19	26000	kernels	$27.56	$17.20	$44.76
	with 6-24-24			80	lb	$6.36	$0.00	$6.36
	spray-Roundup	sprayer		2	qt	$25.77	$4.35	$30.12
	shelled corn	picker	0.75	0	0	$0.00	$18.75	$18.75
Total variable costs								$127.84
Returns over variable costs:								$88.16

Soil Type: capac

Enterprise Name Corn

Field Name: 511
Field Size: 10 acres

Revenues		Crop	Yield	Unit	Price				Gross revenue/ac
	Income 1:	corn grain	130	bu	$2.16				$280.80
Costs								Custom work	
	Activity	Equip Used	Labor hrs/ac	Variable input Quant	unit		Input cost $/ac	rate cost $/ac	Total $/ac
	fall plow	moldboard plow	0.08	0	0		$0.00	$13.00	$13.00
	field cultivate	field cultivator	0.14	0	0		$0.00	$6.85	$6.85
	field cultivate	field cultivator	0.14	0	0		$0.00	$6.85	$6.85
	plant	planter		25000	kernel		$26.50	$11.00	$37.50
	spread 8-32-16	custom hired		137	lb		$12.10	$2.20	$14.30
	spread potash	custom hired		150	lb		$20.10	$4.35	$24.45
	spread urea	custom hired		100	lb		$20.00	$0.00	$20.00
	apply anhydrous	custom hired		130	lb		$35.10	$4.45	$39.55
	spray-Partner	custom hired		3	lb		$13.47	$4.35	$17.82
	spray Atrazine	custom hired		0.25	qt		$0.78	$0.00	$0.78
	harvest	combine	0.2	0	0		$0.00	$21.00	$21.00
Total variable costs									$202.10
Returns over variable costs:									$78.70

Enterprise Name soybeans

Field Name: 522
Field Size: 40 acres

Revenues		Crop	Yield	Unit	Price				Gross revenue
	Income 2:	soybeans	50	bu	$5.30				$265.00
Costs								Custom work	
	Activity	Equip Used	Labor hrs/ac	Variable input Quant	unit		Input cost $/ac	rate cost $/ac	Total $/ac
	fall plow	moldboard plow	0.08	0	0		$0.00	$13.00	$13.00
	field cultivate	field cultivator	0.15	0	0		$0.00	$6.85	$6.85
	field cultivate	field cultivator	0.15	0	0		$0.00	$6.85	$6.85
	spray Command	custom hired		0.75	pt		$8.18	$4.35	$12.53
	plant	planter		50	lb		$13.00	$13.20	$26.20
	spread 10-10-30	custom hired		250	lb		$17.90	$2.20	$20.10
	spray-Partner	custom hired		3	lb		$13.47	$4.35	$17.82
	spray Sencor DF	custom hired		0.33	lb		$8.91	$0.00	$8.91
	harvest	combine	0.2	0	0		$0.00	$21.45	$21.45
Total variable costs									$133.71
Returns over variable costs:									$131.29

Enterprise Name wheat

Field Name: 533
Field Size:

Revenues		Crop	Yield	Unit	Price			Gross revenue/ac
	Income 3:	wheat	60	bu	$3.15			$189.00

Costs	Activity	Equip Used	Labor hrs/ac	Variable input Quant	Variable input unit	Input cost $/ac	Custom work rate cost $/ac	Total $/ac
	disc	tandem disc	0.17	0	0	$0.00	$8.35	$8.35
	plant	grain drill	0.15	2.5	bu	$18.75	$8.60	$27.35
	broadcast 10-26-26	applicator		175	lb	$16.42	$4.45	$20.87
	spread urea			135	lb	$27.00	$2.20	$29.20
	with MI Mammoth	custom hire		8	lb	$3.20	$0.00	$3.20
	harvest	combine	1.75	0	0	$0.00	$20.80	$20.80
	bale straw		0	0	0	$0.00	$0.00	$0.00
Total variable costs								$109.77
Returns over variable costs:								$79.23

Soil Type: marlette

Enterprise Name corn

Field Name: 611
Field Size: 10 acres

Revenues		Crop	Yield	Unit	Price			Gross revenue/
	Income 1:	corn grain	125	bu	$2.16			$270.00
Costs							Custom work	
	Activity	Equip Used	Labor hrs/ac	Variable input Quant	unit	Input cost $/ac	rate cost $/ac	Total $/ac
	spread dairy manure	spreader	1	5	tn	$0.00	$11.15	$11.15
	plow	moldboard plow	0.3	0	0	$0.00	$13.00	$13.00
	disc	tandem disc	0.15	0	0	$0.00	$8.35	$8.35
	pest control	roller harrow	0.13	0	0	$0.00	$3.45	$3.45
	plant	corn planter	0.2	28000	kernel	$29.68	$11.00	$40.68
	pest control	roller harrow	0.13	0	0	$0.00	$3.45	$3.45
	pest control	roller harrow	0.13	0	0	$0.00	$3.45	$3.45
	cultivate	cultivator	0.2	0	0	$0.00	$5.10	$5.10
	harvest	combine	0.5	0	0	$0.00	$21.00	$21.00
Total variable costs								$109.63
Returns over variable costs:								$160.37

Enterprise Name soybeans

Field Name: 622
Field Size: 23 acres

Revenues		Crop	Yield	Unit	Price				Gross revenue/
	Income 2:	soybeans	26	bu	$5.30				$137.80
Costs								Custom work	
	Activity	Equip Used	Labor hrs/ac	Variable input Quant	unit	Input cost $/ac		rate cost $/ac	Total $/ac
	disc	tandem disc	0.11	0	0	$0.00		$8.35	$8.35
	plow	chisel plow	0.14	0	0	$0.00		$10.70	$10.70
	disc	tandem disc	0.15	0	0	$0.00		$8.35	$8.35
	disc	tandem disc	0.15	0	0	$0.00		$8.35	$8.35
	plant	corn planter	0.14	75	lb	$19.50		$11.00	$30.50
	plant	solid drill	0.08	100	lb	$26.00		$8.60	$34.60
	pest control	rotary how	0.05	0	0	$0.00		$3.45	$3.45
	cultivate	cultivator	0.05	0	0	$0.00		$5.10	$5.10
	cultivate	cultivator	0.05	0	0	$0.00		$5.10	$5.10
	harvest	combine	0.35	0	0	$0.00		$21.45	$21.45
Total variable costs									$135.95
Returns over variable costs:									$1.85

Enterprise Name wheat

Field Name: 633
Field Size: 40 acres

Revenues		Crop	Yield	Unit	Price			Gross revenue/
	Income 3:	wheat	20	bu	$3.15			$63.00
Costs							Custom work	
	Activity	Equip Used	Labor hrs/ac	Variable input Quant	unit	Input cost $/ac	rate cost $/ac	Total $/ac
	plow	moldboard plow	0.33	0	0	$0.00	$13.00	$13.00
	pest control	roller harrow	0.2	0	0	$0.00	$3.45	$3.45
	disced endrows	tandem disc	0.05	0	0	$0.00	$8.35	$8.35
	plant-wheat	grain drill	0.25	2	bu	$15.00	$8.60	$23.60
	frost seed clover	mounted seeder	0.08	15	lb	$6.00	$11.00	$17.00
	harvest	combine	0.4	0	0	$0.00	$19.30	$19.30
Total variable costs								$68.25
Returns over variable costs:								($5.25)

Soil Type: capac

Enterprise Name corn

Field Name: 711
Field Size: 16 acres

Revenues		Crop	Yield	Unit	Price				Gross revenue/ac
	Income 1:	corn grain	100	bu	$2.16				$216.00
Costs								Custom work	
	Activity	Equip Used	Labor hrs/ac	Variable input Quant	unit		Input cost $/ac	rate cost $/ac	Total $/ac
	plow	chisel plow		0	0		$0.00	$10.70	$10.70
	plant	planter		27000	kernel		$28.62	$13.20	$41.82
	with urea			90	unit		$18.00	$0.00	$18.00
	with 9-23-30			300	lb		$27.29	$0.00	$27.29
	spray-Bullet	sprayer		3.375	qt		$18.43	$4.35	$22.78
	cultivate	cultivator		0	0		$0.00	$5.10	$5.10
	harvest	combine		0	0		$0.00	$21.00	$21.00
Total variable costs									$146.69
Returns over variable costs:									$69.31

Enterprise Name soybeans

Field Name: 722
Field Size: 38 acres

Revenues		Crop	Yield	Unit	Price				Gross revenue/ac
	Income 2:	soybeans	32.5	bu	$5.30				$172.25
Costs								Custom work	
	Activity	Equip Used	Labor	Variable input			Input cost	rate cost	Total
			hrs/ac	Quant	unit		$/ac	$/ac	$/ac
	disc	tandem disc		0		0	$0.00	$8.35	$8.35
	plant	grain drill		80		lb	$20.80	$8.60	$29.40
	with 9-23-30			300		lb	$27.29	$0.00	$27.29
	spray-Arena	sprayer		12		oz	$2.40	$4.35	$6.75
	spray-Lorox Plus			1.33		qt	$48.97	$0.00	$48.97
	harvest	combine		0		0	$0.00	$21.00	$21.00
Total variable costs									$141.76
Returns over variable costs:									$30.49

Enterprise Name wheat

Field Name: 733
Field Size: 30 acres

Revenues		Crop	Yield	Unit	Price				Gross revenue/ac
	Income 3:	wheat	35.5	bu	$3.15				$111.83
Costs								Custom work	
	Activity	Equip Used	Labor	Variable input		Input cost		rate cost	Total
			hrs/ac	Quant	unit	$/ac		$/ac	$/ac
	disc	tandem disc		0	0	$0.00		$8.35	$8.35
	spread 9-23-30	spreader		325	lb	$29.58		$2.20	$2.20
	plant	grain drill		2	bu	$15.00		$8.60	$23.60
	topdress N			50	lb	$11.00		$4.45	$15.45
	harvest	combine		0	0	$0.00		$19.30	$19.30
Total variable costs									$68.90
Returns over variable costs:									$42.93

Soil Type: spinks

Enterprise Name corn

Field Name: 811
Field Size: 26 acres

Revenues		Crop	Yield	Unit	Price	Gross revenue/ac
	Income 1:	corn grain	170	bu	$2.16	$367.20

Costs	Activity	Equip Used	Labor hrs/ac	Variable input Quant	unit	Input cost $/ac	Custom work rate cost $/ac	Total $/ac
	plow	aerator	0.08	0	0	$0.00	$3.45	$3.45
	spread dairy manure	manure spreader		8	tn	$0.00	$11.15	$11.15
	disc	tandem disc	0.1	0	0	$0.00	$8.35	$8.35
	plant	planter	0.11	20600	kernel	$21.84	$13.20	$35.04
	with 28-0-0		0	14	gall	$12.50	$0.00	$12.50
	with 8-28-5		0	2	gall	$4.00	$0.00	$4.00
	with biological		0	8	gall	$12.96	$0.00	$12.96
	spray Bullet	sprayer		1	qt	$5.46	$4.35	$9.81
	rescue-Buctril	sprayer		21	oz	$9.73	$4.35	$14.08
	cultivate	cultivator	0.11	0	0	$0.00	$5.10	$5.10
	harvest	combine	0.14	0	0	$0.00	$21.00	$21.00
Total variable costs								$137.43
Returns over variable costs:								$229.77

Enterprise Name soybeans

Field Name: 822
Field Size: 39 acres

Revenues		Crop	Yield	Unit	Price				Gross revenue/ac
	Income 2:	soybeans	35	bu	$5.30				$185.50
Costs	Activity	Equip Used	Labor hrs/ac	Variable input Quant	unit	Input cost $/ac	Custom work rate cost $/ac		Total $/ac
	plow	aerator	0.08	0	0	$0.00	$3.45		$3.45
	disc	tandem disc	0.1	0	0	$0.00	$8.35		$8.35
	plant	planter	0.11	110	lb	$28.60	$13.20		$41.80
	with biological		0	8	gall	$12.09	$0.00		$12.09
	spray Bullet	sprayer		1	qt	$2.85	$4.35		$7.20
	rescue spray Buctril	sprayer		22	oz	$12.62	$4.35		$16.97
	cultivate	cultivator	0.24	0	0	$0.00	$5.10		$5.10
	harvest	combine	0.17	0	0	$0.00	$20.80		$20.80
Total variable costs									$115.76
Returns over variable costs:									$69.74

Soil Type: spinks

Enterprise Name corn

Field Name: 911
Field Size: 19 acres

Revenues		Crop	Yield	Unit	Price				Gross revenue/ac
	Income 1:	corn grain	137.5	bu	$2.16				$297.00

Costs	Activity	Equip Used	Labor hrs/ac	Variable input Quant	unit	Input cost $/ac	Custom work rate cost $/ac	Total $/ac
	disc	tandem disc	0.11	0	0	$0.00	$8.35	$8.35
	plow	moldboard plow	0.32	0	0	$0.00	$12.15	$12.15
	plant	planter	0.21	21000	kernel	22.26	$13.20	$35.46
	with '6-24-24		0	225	lb	$17.88	$0.00	$17.88
	spray Lorsban	sprayer	0.05	8	lb	$15.60	$4.35	$19.95
	spray-Bullet			2.5	qt	$13.65	$0.00	$13.65
	spray-Buctril	sprayer	0.05	1	pt	$3.71	$4.35	$8.06
	apply anhydrous	applicator	0.05	125	lb	$33.75	$4.10	$37.85
	harvest	combine	0.53	0	0	$0.00	$21.00	$21.00
Total variable costs								$174.35
Returns over variable costs:								$122.65

Soil Type: capac

Enterprise Name Corn

Field Name: 1011
Field Size: 80 acres

Revenues		Crop	Yield	Unit	Price			Gross revenue/ac
	Income 1:	corn grain	170	bu	$2.16			$367.20

Costs	Activity	Equip Used	Labor hrs/ac	Variable input Quant	Variable input unit	Input cost $/ac	Custom work rate cost $/ac	Total $/ac
	spread potash	floater truck	0.02	233	lb	$31.22	$2.20	$33.42
	plow-anhydrous	chisel plow	0.08	145	lb	$39.15	$12.90	$52.05
	plant	planter	0.1	26200	kernel	$27.77	$13.20	$40.97
	with starter 9-44-9		0	100	lb	$10.27	$0.00	$10.27
	spray-Atrazine	sprayer	0.07	1	lb	$3.13	$4.35	$7.48
	spray-Bladex		0	1	lb	$7.19	$0.00	$7.19
	spray-Dual		0	1	qt	$16.75	$0.00	$16.75
	soil finish	soil finisher	0.08	0	0	$0.00	$3.45	$3.45
	harvest	combine	0.4	0	0	$0.00	$21.00	$21.00
Total variable costs			0.75					$192.58
Returns over variable costs:								$174.62

Enterprise Name soybeans

Field Name: 1022
Field Size: 54 acres

Revenues		Crop	Yield	Unit	Price				Gross revenue/ac
	Income 2:	soybeans	45	bu	$5.30				$238.50
Costs								Custom work	
	Activity	Equip Used	Labor	Variable input			Input cost	rate cost	Total
			hrs/ac	Quant	unit		$/ac	$/ac	$/ac
	plow	chisel plow	0.08	0		0	$0.00	$10.70	$10.70
	spread potash	floater truck	0.02	200		lb	$26.80	$12.90	$39.70
	spread lime	spreader	0.02	1		tn	$2.77	$2.20	$4.97
	plant	conv. drill	0.1	83		lb	$21.58	$8.60	$30.18
	with 8-32-16		0	150		lb	$12.10	$0.00	$12.10
	spray Broadstrike	sprayer	0.04	2.5		lb	$22.77	$4.35	$27.12
	soil finish	soil finisher	0.07	0		0	$0.00	$3.45	$3.45
	harvest	combine	0.25	0		0	$0.00	$20.80	$20.80
Total variable costs			0.58						$149.02
Returns over variable costs:									$89.48

Enterprise Name wheat

Field Name: 1033
Field Size: 40 acres

Revenues		Criop	Yield	Unit	Price				Gross revenue/ac
	Income 3:	wheat	60	bu	$3.15				$189.00
Costs	Activity	Equip Used	Labor hrs/ac	Variable input Quant	unit	Input cost $/ac	Custom work rate cost $/ac		Total $/ac
	disc	tandem disc	0.16	0	0	$0.00	$8.35		$8.35
	plant	grain drill	0.16	2	bu	$15.00	$8.60		$23.60
	lime	spreader	0.02	1	tn	$2.77	$2.20		$4.97
	apply urea	floater truck	0.03	200	lb	$40.00	$2.20		$42.20
	harvest	combine		0	0	$0.00	$19.30		$19.30
Total variable costs			0.37						$98.42
Returns over Variable Costs:									$90.58

Soil Type: capac

Enterprise Name Corn

Field Name: 1111
Field Size:

Revenues		Crop	Yield	Unit	Price	Gross revenue/ac
	Income 1:	corn grain	100	bu	$2.16	$216.00

Costs	Activity	Equip Used	Labor hrs/ac	Variable input Quant	Variable input unit	Input cost $/ac	Custom work rate cost $/ac	Total
	spray-Roundup	sprayer		2	qt	$25.77	$4.35	$30.12
	plant	no till planter		26000	kernel	$27.56	$17.20	$44.76
	with 5-14-39 starter			200	lb	$8.83	$0.00	$8.83
	with anhydrous			100	lb	$27.00	$0.00	$27.00
	broadcast spray-Accent	sprayer		0.67	oz	$18.81	$4.35	$23.16
	broadcast spray-Furadan	sprayer		0.05	gal	$3.47	$4.35	$7.82
	harvest	combine		0	0	$0.00	$21.00	$21.00
Total variable costs								$162.69
Returns over variable costs:								$53.31

Soil Type: capac

Enterprise Name Corn

Field Name: 1211
Field Size: 78 acres

Revenues	Income 1:	Crop	Yield	Unit	Price				Gross revenue/ac
		corn grain	154	bu	$2.16				$332.64
Costs								Custom work	
	Activity	Equip Used	Labor	Variable input			Input cost	rate cost	Total
			hrs/ac	Quant	unit		$/ac	$/ac	$/ac
	spread potash	spreader		200	lb		$26.80	$2.20	$29.00
	plow	chisel plow		0	0		$0.00	$10.70	$10.70
	plant	planter		27300	kernel		$28.94	$13.20	$42.14
	with urea			300	lb		$60.00	$0.00	$60.00
	with 8-40-8			125	lb		$11.60	$0.00	$11.60
	spray-Bicep	sprayer		2	qt		$18.14	$4.35	$22.49
	spot spray-Buctril	sprayer		0.75	pt		$2.78	$4.35	$7.13
	spray-Pursuit Plus	sprayer		2	pt		$9.15	$4.35	$13.50
	spray-Sencor			4	pt		$27.00	$0.00	$27.00
	cultivate	cultivator		0	0		$0.00	$5.10	$5.10
	harvest	combine		0	0		$0.00	$21.00	$21.00
Total variable costs									$249.65
Returns over variable costs:									$82.99

Enterprise Name soybeans

Field Name: 1222
Field Size: 81 acres

Revenues		Crop	Yield	Unit	Price				Gross revenue/ac
	Income 2:	soybeans	51	bu	$5.30				$270.30
Costs								Custom work	
	Activity	Equip Used	Labor	Variable input			Input cost	rate cost	Total
			hrs/ac	Quant	unit		$/ac	$/ac	$/ac
	plow	chisel plow		0	0		$0.00	$10.70	$10.70
	plow	chisel plow		0	0		$0.00	$10.70	$10.70
	plant	planter		55	lb		$14.30	$13.20	$27.50
	with 8-40-8			130	lb		$12.06	$0.00	$12.06
	spray Pursuit Plus	sprayer		2	pt		$9.15	$4.35	$13.50
	spray-Sencor			4	pt		$27.00	$0.00	$27.00
	cultivate	cultivator		0	0		$0.00	$5.10	$5.10
	harvest	combine		0	0		$0.00	$21.00	$21.00
Total variable costs									$127.56
Returns over variable costs:									$142.74

Enterprise Name soybeans

Field Name: 1232
Field Size: 161 acres

Revenues		Crop	Yield	Unit	Price			Gross revenue/ac
	Income 3:	soybeans	51	bu	$5.30			$270.30
Costs	Activity	Equip Used	Labor hrs/ac	Variable input Quant	unit	Input cost $/ac	Custom work rate cost $/ac	Total $/ac
	plow	chisel plow		0	0	$0.00	$10.70	$10.70
	plow	chisel plow		0	0	$0.00	$10.70	$10.70
	plant	planter		55	lb	$14.30	$13.20	$27.50
	with 8-40-8			125	lb	$11.60	$0.00	$11.60
	spray-Cobra	sprayer		0.75	pt	$11.55	$4.35	$15.90
	cultivate	cultivator		0	0	$0.00	$5.10	$5.10
	harvest	combine		0	0	$0.00	$21.00	$21.00
Total variable costs								$102.50
Returns over variable costs:								$167.80

Enterprise Name wheat

Field Name: 1243
Field Size: 178 acres

Revenues		Crop	yield	Unit	Price	Gross revenue/ac
	Income 4:	wheat	67.9	bu	$3.15	$213.89

Costs	Activity	Equip Used	Labor hrs/ac	Variable input Quant	unit	Input cost $/ac	Custom work rate cost $/ac	Total $/ac
	disc	tandem disc		0	0	$0.00	$8.35	$8.35
	plant	drill		138	lb	$17.25	$8.60	$25.85
	with starter 6-24-24			300	lb	$23.83	$0.00	$23.83
	top dress- actual N	app. spray		60	lb	$13.20	$4.45	$17.65
	with urea			125	lb	$25.00	$0.00	$25.00
	plant-clover			10	lb	$1.66	$11.00	$12.66
	spray-MCPA	sprayer		0.5	pt	$0.53	$4.35	$4.88
	harvest	combine		0	0	$0.00	$19.30	$19.30
	chopped straw	chopper		0	0	$0.00	$0.00	$0.00
Total variable costs								$129.17
Returns over variable costs:								$84.72

Soil Type: Ithaca

Enterprise Name com

Field Nam 1311
Field Size: 60.5 acres

Revenues		Crop	Yield	Unit	Price				Gross revenue/ac
	Income 1:	com grain	145	bu	$2.16				$313.20

Costs	Activity	Equip Used	Labor hrs/ac	Variable input Quant	Variable input unit	Input cost $/ac	Custom work rate cost $/ac	Total $/ac
	field cultivate	field cultivator	0.15	0	0	$0.00	$6.85	$6.85
	field cultivate	field cultivator	0.19	0	0	$0.00	$6.85	$6.85
	applied anhydrous ammo	applicator		170	lb	$45.90	$2.20	$48.10
	spread potash	spreader		125	lb	$16.75	$2.20	$18.95
	plant	planter	0.45	28000	kemel	$29.68	$13.20	$42.88
	with 10-40-8			150	lb	$14.58	$0.00	$14.58
	spray-Atrazine	sprayer	0.15	2.5	lb	$7.82	$4.35	$12.17
	spray-Banvel			0.5	pt	$2.57	$0.00	$2.57
	cultivate	cultivator	0.3	0	0	$0.00	$5.10	$5.10
	harvest	combine	0.99	0	0	$0.00	$21.00	$21.00
Total variable costs								$179.06
Returns over variable costs:								$134.14

Enterprise Name soybeans

Field Nam 1322
Field Size: 52.8 acres

Revenues		Crop	Yield	Unit	Price			Gross revenue/ac
	Income 2:	soybeans	49	bu	$5.30			$259.70

Costs	Activity	Equip Used	Labor hrs/ac	Variable input Quant	unit	Input cost $/ac	Custom work rate cost $/ac	Total $/ac
	plow	chisel plow	0.3	0	0	$0.00	$10.70	$10.70
	spread dairy manure	spreader	0.51	random		$0.00	$11.15	$11.15
	disc	tandem disc	0.15	0	0	$0.00	$8.35	$8.35
	field cultivate	field cultivator	0.15	0	0	$0.00	$6.85	$6.85
	field cultivate	field cultivator	0.15	0	0	$0.00	$6.85	$6.85
	plant	planter	0.25	60	lb	$15.60	$13.20	$28.80
	with 10-20-20		0	230	lb	$17.76	$0.00	$17.76
	spray-Sencor	sprayer		0.33	lb	$8.91	$4.35	$13.26
	spray-Command			1	pt	$10.91	$0.00	$10.91
	spray-Dual			0.75	pt	$6.28	$0.00	$6.28
	cultivate	cultivator	0.25	0	0	$0.00	$5.10	$5.10
	cultivate	cultivator	0.25	0	0	$0.00	$5.10	$5.10
	harvest	combine	1.14	0	0	$0.00	$20.80	$20.80
Total variable costs								$151.91
Returns over variable costs:								$107.79

Soil Type: marlette

Enterprise Name: corn

Field Name: 1411
Field Size: 45 acres

Revenues		Crop	Yield	Unit	Price				Gross revenue/ac
	Income 1:	corn grain	90	bu	$2.16				194.4
Costs								Custom work	$/ac
	Activity	Equip Used	Labor	Variable input				rate cost	Total
			hrs/ac	Quant	unit		Input cost	$/ac	
	disc	tandem disc		0	0		$0.00	$8.35	$8.35
	spread liquid hog manure	spreader	0.44	2100	gal		$0.00	$11.15	$11.15
	plow	chisel plow		0	0		$0.00	$10.70	$10.70
	lightly disc	tandem disc		0	0		$0.00	$8.35	$8.35
	plant	planter		26000	kernel		$27.56	$11.00	$38.56
	spray-Lasso	sprayer		0.75	qt		$5.36	$4.35	$9.71
	spray-Atrazine			0.75	qt		$2.35	$0.00	$2.35
	harvest	combine	0.4	0	0		$0.00	$21.00	$21.00
Total variable costs									$110.17
Returns over variable costs:									$84.23

Enterprise Name soybeans

Field Name: 1422
Field Size: 25 acres

Revenues		Crop	Yield	Unit	Price				Gross revenue/ac
	Income 2:	soybeans	55	bu	$5.30				$291.50
Costs								Custom work	
	Activity	Equip Used	Labor hrs/ac	Variable input Quant	unit		Input cost $/ac	rate cost $/ac	Total $/ac
	spread liquid hog manure	spreader	0.05	2000	gal		$0.00	$11.15	$11.15
	plow	chisel plow		0	0		$0.00	$10.70	$10.70
	lightly disc	tandem disc		0	0		$0.00	$8.35	$8.35
	plant	drill		87.5	lb		$22.75	$8.60	$31.35
	spray-Broadstrike	sprayer		0.75	qt		$17.08	$4.35	$21.43
	harvest	combine	0.4	0	0		$0.00	$20.80	$20.80
Total variable costs									$103.78
Returns over variable costs:									$187.72

Enterprise Name wheat

Field Name: 1433
Field Size: 25 acres

Revenues		Crop	Yield	Unit	Price				Gross revenue/ac
	Income 3:	wheat	45	bu	$3.15				$141.75
Costs								Custom work	
	Activity	Equip Used	Labor hrs/ac	Variable input Quant	unit	Input cost $/ac		rate cost $/ac	Total $/ac
	spread liquid hog manure	spreader	0.05	2100	gal	$0.00		$11.15	$11.15
	disc	tandem disc		0	0	$0.00		$8.35	$8.35
	plant	grain drill		2	bu	$15.00		$8.60	$23.60
	with urea			100	lb	$20.00		$0.00	$20.00
	spray-2,4-D	sprayer		0.5	pt	$0.39		$4.35	$4.74
	harvest	combine		0	0	$0.00		$19.30	$19.30
Total variable costs									$87.14
Returns over variable costs:									$54.61

Soil Type: marlette

Enterprise Name: corn

Field Name: 1511
Field Size: 63.3 acres

Revenues		Crop	Yield	Unit	Price				Gross revenue/ac
	Income 1:	corn grain	130	bu	$2.16				$280.80
Costs								Custom work	
	Activity	Equip Used	Labor	Variable input			Input cost	rate cost	Total
			hrs/ac	Quant	unit		$/ac	$/ac	$/ac
	spread lime	spreader		1.33	tn		$3.69	$2.20	$5.89
	plow-liquid hog manure	chisel plow		1176.6	gal		$0.00	$21.85	$21.85
	disc	tandem disc		0	0		$0.00	$8.35	$8.35
	plant	planter		26100	kernel		$27.67	$13.20	$40.87
	with triple 18.5 starter			130	lb		$11.93	$0.00	$11.93
	with Counter 15G			8	lb		$15.28	$0.00	$15.28
	spray Bicep II			2.4	qt		$22.22	$4.35	$26.57
	sidedress anhydrous	applicator		87	lb		$23.49	$4.10	$27.59
	harvest	combine		0	0		$0.00	$21.00	$21.00
Total variable costs									$179.33
Returns over variable costs:									$101.47

Enterprise Name soybeans

Field Name: 1522
Field Size: 24 acres

Revenues		Crop	Yield	Unit	Price				Gross revenue/ac
	Income 2:	soybeans	46	bu	$5.30				$243.80
Costs								Custom work	
	Activity	Equip Used	Labor	Variable input		Input cost		rate cost	Total
			hrs/ac	Quant	unit	$/ac		$/ac	$/ac
	spread lime	spreader		2	tn	$5.54		$2.20	$7.74
	spread liquid hog manur	spreader		1176.6	gal	$0.00		$11.15	$11.15
	disc	tandem disc		0	0	$0.00		$19.50	$19.50
	spread potash	spreader		150	lb	$20.10		$2.20	
	spread 6-27-27	spreader		200	lb	$17.54		$2.20	
	plant	no till drill		73	lb	$18.98		$13.20	$32.18
	spray-Dual	custom hired		1	qt	$33.50		$4.35	$37.85
	spray-Lorox Plus	custom hired		6.4	oz	$7.36		$0.00	$7.36
	spray-Preview	custom hired		3.2	oz	$6.56		$0.00	$6.56
	harvest	combine		0	0	$0.00		$20.80	$20.80
Total variable costs									$143.15
Returns over variable costs:									$100.65

Enterprise Name: wheat

Field Name: 1533
Field Size: 71 acres

Revenues		Crop	Yield	Unit	Price				Gross revenue/ac
	Income 3:	wheat	49	bu	$3.15				$154.35
	Activity	Equip Used	Labor hrs/ac	Variable input Quant	unit	Input cost $/ac	Custom work rate cost $/ac		Total $/ac
Costs	plant	no till drill		2.25	bu	$16.88	$13.75		$30.63
	spread urea	spreader		125	lb	$25.00	$2.20		$27.20
	spray-MCPA	sprayer		1	pt	$1.05	$4.35		$5.40
	harvest			0	0	$0.00	$19.30		$19.30
Total variable costs									$82.53
Returns over variable costs:									$71.82

Enterprise Name: wheat

Field Name: 233
Field Size: 46 acres

Revenues		Crop	Yield	Unit	Price			Gross revenue/a
	Income 3:	wheat	62	bu	$3.15			$195.30
Costs	Activity	Equip Used	Labor hrs/ac	Variable input Quant	unit	Input cost $/ac	Custom work rate cost $/ac	Total $/ac
	air seed	airplane		3	bu	$22.50	$7.50	$30.00
	harvest	combine		0	0	$0.00	$19.30	$19.30
Total variable costs								$49.30
Returns over variable costs:								$146.00

Soil Type: capac

Enterprise Name: corn

Field Name: 1611
Field Size: 22 acres

Revenues		Crop	Yield	Unit	Price			Gross revenue/ac
	Income 1:	corn grain	110	bu	$2.16			$237.60
Costs							Custom work	
	Activity	Equip Used	Labor hrs/ac	Variable input Quant	Variable input unit	Input cost	rate cost $/ac	Total
	plow	moldboard plow	0.45	0	0	$0.00	$13.00	$13.00
	disk	tandem disk	0.14	0	0	$0.00	$8.35	$8.35
	field cultivate	field cultivator	0.14	0	0	$0.00	$6.85	$6.85
	field cultivate	field cultivator	0.14	0	0	$0.00	$6.85	$6.85
	spray-actual N	app. spray	0.09	150	lb	$33.00	$4.45	$37.45
	plant	planter	0.23	30400	kernel	$32.22	$13.20	$45.42
	with '6-24-24		0	200	lb	$15.89	$0.00	$15.89
	spray-Banvel	custom hired	0	0.5	qt	$10.29	$4.35	$14.64
	harvest	chopper	0.5	0	0	$0.00	$36.80	$36.80
Total variable costs			1.69					$185.26
Returns over variable costs:								$52.34

APPENDIX C

INPUT AND COMMODITY PRICES

Chemical Inputs	Unit	Prices
Accent	oz	$28.07
Arena	qt	$6.40
Assure II	pt	$15.72
Atrazine	qt	$3.13
Banvel	qt	$20.59
Bicep	qt	$9.07
Bicep II	qt	$9.26
Bladex	qt	$7.19
Broadstrike	qt	$22.77
Buctril	qt	$14.82
Bullet	qt	$5.46
Classic	oz	$19.14
Cobra	pt	$15.41
Command	pt	$10.91
Counter 15G	lb	$1.91
Dual	pt	$8.37
Furadan	gal	$69.42
Lasso	qt	$7.15
Lorox plus	oz	$1.15
Lorsban 15G	lb	$1.95
MCPA	qt	$4.21
Partner	lb	$4.49
Pinnacle	oz	$36.08
Preview	oz	$2.05
Pursuit	pt	$84.63
Pursuit Plus	qt	$18.30
Roundup	qt	$12.89
Sencor	lb	$27.00
2,4-D	qt	$3.09

Fertilizer	Unit	Price
Potash	tn	$134.00
Urea	tn	$200.00
Anhydrous	tn	$270.00
N	lb	$0.22
P	lb	$0.17
K	lb	$0.11
Lime	lb	$0.14

Seed	Unit	Prices
Corn	kernel	0.00106
Soybean	bu	$15.60
Wheat	bu	$7.50
Clover	lb	$0.40
Spelt	50 lb	$10.00

Table 3: Commodity Prices:

2/2/95	**Webberville, MI**	
Crop	**Unit**	**Price**
Corn grain	bu	$2.16
Soybeans	bu	$5.30
Wheat	bu	$3.15

APPENDIX D

POTENTIAL RISK OF NITRATE LEACHING AND PHOSPHORUS RUNOFF BY CROPPING SYSTEM AS SIMULATED BY PLANETOR FOR A REPRESENTATIVE FARM IN CENTRAL MICHIGAN ON KALAMAZOO LOAM.

Numerical ranges for "high," "medium," and "low" ratings.

Rating	Nitrate Leaching lbs/ac/yr	Phosphorus Runoff lbs/ac/yr
Low	⟨40	⟨8
Medium	40-120	-6.00
High	⟩120	⟩14

Cropping System			Environmental Risk Levels	
Crops	Manure	Clover	Nitrate Leaching	Phosphorus Runoff
Continuous Corn	No	No	Low	Low
Continuous Corn	Yes	No	High	Medium
Continuous Corn	No	Yes	Medium	Low
Continuous Corn	Yes	Yes	High	Medium
Corn-Corn-Soybean-Wheat	No	No	Low	Low
Corn-Corn-Soybean-Wheat	Yes	No	Medium	Medium
Corn-Corn-Soybean-Wheat	No	Yes	Low	Low
Corn-Corn-Soybean-Wheat	Yes	Yes	Low	Medium
Corn-Soybean-Wheat	No	No	Low	Low
Corn-Soybean-Wheat	Yes	No	Low	Low
Corn-Soybean-Wheat	No	Yes	Low	Low
Corn-Soybean-Wheat	Yes	Yes	Low	Medium
Corn-Soybean	No	No	Low	Low
Corn-Soybean	Yes	No	Medium	Medium
Corn-Soybean	No	Yes	Low	Low
Corn-Soybean	Yes	Yes	Medium	Medium

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