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AN ANALYSIS OF THE RELATIVE ECONOMICS OF SELECTED CROP SYSTEMS ACCOUNTING FOR INTERDEPENDENT CASH FLOWS ARISING FROM DIFFERENTIAL INTERTEMPORAL SOIL PRODUCTIVITY

By

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ABSTRACT

AN ANALYSIS OF THE RELATIVE ECONOMICS OF SELECTED CROP SYSTEMS ACCOUNTING FOR INTERDEPENDENT CASH FLOWS ARISING FROM DIFFERENTIAL INTERTEMPORAL SOIL PRODUCTIVITY

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This research has five inter-related components. First, a review and critique of existing investment/disinvestment models will be presented. Second, a review and critique of previously used modeling approaches is presented. Third, a reformulation of an existing investment/disinvestment model will be presented. Finially, a simulation model will be constructed which is consistent with the underlying analytical model.

The review of existing investment models separates these models into independent and interdependent cash flow models. It is argued that the independent cash flow models are not really applicable to the problem being studied. One interdependent cash flow model is reviewed and critiqued. Based in part on this critique, an alternative formulation of this model is presented.

The review of selected modeling approaches separates these models into two categories: Math Programming and Simulation models. Generally, the Math Programming models do a better job of describing the economics of competing production proactices at a

point in time. The simulation models tend to do a better job at modeling the dynamics of the interaction between alternative rates of crop system soil loss and system cash flow.

The simulation model formulated in this research makes several contributions to existing models. First, initial steps at endogenizing input use are made. Further, this model calculates relative cash flows by comparing two systems of differential erosivity, and not requiring one system to be in a steady state. Third, the model can study the asset switching problem.

The model is then used to study the relative economics of alternative moldboard and chisel plow crop systems in two areas of Michigan. In the area characterized by relatively flat terrain, and deep fertile soil, no chisel plow system could compete with the moldboard plow system. In another area of Michigan characterised by rolling terrain and varying soil depths, some chisel plow systems are competative with moldbnoard plow systems. Further, the sooner that the chisel plow system was adopted, the closer were the profit estimates of the moldboard/chisel plow combination to that of the comparable chisel plow system, when the chisel plow was used from the beginning of the analysis.

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Larry Libby, J. Roy Black, A. Allan Schmid, and Lester V. Manderscheid composed my Guidance and Dissertation Committies. Larry and Roy provided the propulsion to lift this research off the ground. They all were instrumental in providing several mid - course corrections which directed the focus of the researcher to a coherent set of integrable research issues.

Several professionals in the Economic Research Service and in the Soil Conservation Service of the United States Department of Agriculture provided invaluable guidance in sorting through some of the more turbid technical issues of crops, soils, and production agriculture. Most notable among this group was Dan Kugler who helped cultivate my understanding of these technical issues.

My freshman english composition instructor must also be acknowledged for he had the "vision" to asset that I would attend graduate school. Unfortunately, his lessons did not stay with me as did his vision.

In passing, when one stops and thinks about what has just been completed, deciding whether or not what you did was good for you is sort of like the child who has just been administered a good

dose of cod liver oil being asked, "now wasn't that good?" Undoubtedly, one's perceptions mellow with age.

TABLE OF CONTENTS

CHAPTER SEVEN - FUTURE RESEARCH DIRECTIONS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

FOCUS OF THE RESEARCH

1.1 Introduction

Soil loss and soil productivity relationships have long been a concern to farmers, economists, scientists, and policy makers. Researchers are continuing to try to improve their understanding of the relation between soil loss today and productivity tomorrow. Agricultural economists translate this physical relation into an issue of resource management by the producer by studying the relation between producer goals, alternative management options, and the impact of differential rates of soil loss on goal attainment by the decision maker. This research will attempt to advance the thinking of analysts who pose the issue as does the agricultural economist.

1.2 Problem Statement

Asset adoption/sale decision making models have generally assumed that the level of net return in a particular year to a challenger durable good is independent of how long the currently held asset is kept. Relying on this premise, backward induction solution techniques are applied to endogenously determine how long each asset should be kept.

Studying adoption/sale decisions assuming cash flows are interdependent is a more complex problem. Interdependent cash flows arise when, because of soil loss, today's management decisions will likely affect tomorrow's cash flows. This researcher knows of no analytic framework which can study the asset switch problem using an intertemporal statics framework which is constructed in such a way as to allow for interdependent cash flows.

Moving to the empirical analysis, the reader will come to see that existing one period and multi - period models have not adequately dealt with the relation between crop systems with interdependent cash flows and asset decision making. Of critical importance is capturing the effect of a crop systems' differential rate of soil loss and net returns to the operator and/or owner.

1.3 Objectives of the Study

When this research was conceived, the questions raised were concerned with furthering the understanding of the process of switching from one machinery complement to a new machinery complement, either with or without aditional changes in the farming enterprise. It was thought that how a producer went about switching machinery complements was probably an important part of the decision to switch machinery complements.

After some initial investigation, a slightly different but related set of issues surfaced. One reason for the slight shift in focus was the observation that there didn't appear to be an appropriate analytic and empirical framework to apply to study when producers choose to switch machinery complements. From this observation was derived the overriding objective of this research. The primary objective is to develop a workable conceptual and analytic framework for studying investment decision making when asset cash flows are interdependent.

A related objective is to try to further clarify the economic roots of the transition problem. How can researchers begin to formulate the process of switching from one machinery complement to another machinery complement? Another objective is to clarify the relationships between soil loss and producer investment decisionmaking, and the impact of that relationship on the relative profitability of various courses of action. A fourth objective is to draw some inferences for erosion control policy using the information produced by this study. These inferences will be limited to the farm prodictivity dimension of selected policies.

1.4 Overview of the Thesis

Chapter two presents a review of selected approaches to the (1) asset investment disinvestment (ID) problem, and (2) empirical analysis of the relation between soil loss and net returns to farm enterprises. Subsequent model development is based, in part, on how the existing literature addresses critical aspects of the crop system selection/ soil loss/ intertemporal productivity problem.

Chapter three reformulates an existing decision rule used to answer the question of when one asset should be replaced by another, when cash flows are interdependent. First, the requirements of the new approach are specified. Next, the approach is formulated for the cases of a single transition (switch between two different crop systems). Lastly, the approach is generalized to the problem of more than one transition within a given time horizon.

Chapter four presents a discussion of the simulation model which is developed and applied in this research. What contributions the model makes to the study of (a) the relative economics of two or more mutually exclusive crop systems, and (b) the relative economics of combinations of mutually exclusive crop systems, and intertemporal productivity are presented. Lastly, a more detailed discussion of each of the models' programs which comprise the model.

Chapter five presents the alternative management scenarios which are analyzed with the model, the results of the analysis, and a discussion of the results. The empirical analysis is structured to (1) provide information to the research process on the relationship between the profitability of alternative management scenarios and the crop system/physical conditions assumed in each scenario, and (2) to illustrate how the model may be applied to the study of the relation between crop system profitability/ soil loss/ and intertemporal soil productivity.

Chapter six presents a summary of the research and a set of conclusions. Finally, chapter seven identifies some issues for future research.

CHAPTER TWO

REVIEW OF SELECTED INVESTMENT/DISINVESTMENT MODELS AND EMPIRICAL MODELS OF SOIL LOSS/CROP SYSTEM ECONOMICS

2.1 Introduction

This chapter provides the foundation for the remainder of this dissertation. Alternative approaches to the Investment/Disinvestment (ID) problem are first reviewed. Next, a review of selected empirical models used to study the relative economics of alternative agricultural practices is presented.

Both independent and interdependent cash flow models are included in the review of alternative approaches to the ID problem. Prior to reviewing an interdependent cash flow model, the concept of interdependence between asset cash flows is discussed and illustrated. Both Math Programming and Simulation methods are included in the review of the selected empirical models.

2.2 Independent versus Interdependent Asset Cash Flows

Analysis of the problem of capital allocation has included a focus on the problem of when to switch asset holdings. Generally referred to as the investment/disinvestment problem, the decision maker is attempting to determine the point in time when the opportunity cost of holding the asset for one more period exceeds the opportunity cost of switching assets during this period.

Most of the approaches to this problem have assumed that the level of cash flows in any subsequent year for the challenger (asset which may be required) are independent of the point in time when the assets are switched.

Here, interdependent cash flows are assumed to exist when the level of annual net returns to the challenger in a given year vary as a function of when the asset trade occurs.[1] That is,

$$(2.1)\ dNR(t)/dt^{*} \neq 0 \quad \forall\ t=t^{*}, \ldots, T,$$

Where,
NR(t)=Net returns to the new asset in post trade year,t;
T=Length of analysis.

Figure 2.1 is a representation of both independent and interdependent cash flows. For purposes of illustration, assume that the two assets are two machinery complements. Tillage complement A is more erosive than the alternative complement, denoted complement B. As the soil depth declines, yield also declines. Finally, only the change in yield can affect net returns to complement B, $NR_b(t)$, between when asset B is held from t=0 and when asset B is adopted in a later time period. While these assumptions are more restrictive than what one would want to assume, they simplify the analysis and allow us to focus on the relationship between alternative transition periods and the annual returns to the new asset.

As Figure 2.1 indicates, the solid line is assumed to represent the level of net returns to complement A across

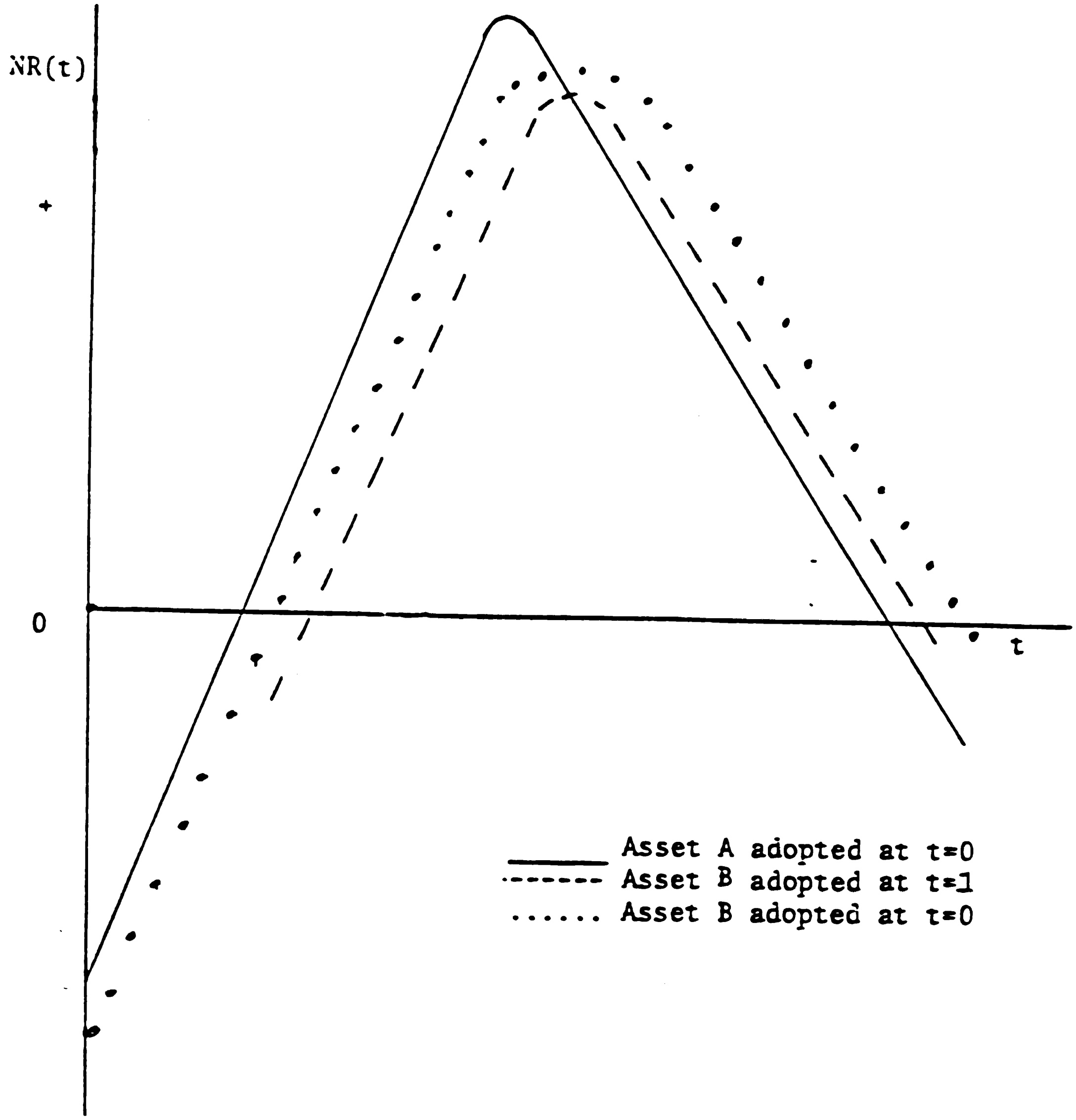

Figure 2.1

Illustration of Two Assets with Interdependent Cash Flows time. Initially, the net returns to complement B, indicated by the dotted line, are assumed to lie below those of complement A. Later, the exact opposite situation arises. If one conducts the capital budgeting analysis assuming independent cash flows, the transition period is determined using the aformentioned curves. If, on the other hand, the analysis is conducted incorporating interdependent cash flows, one needs to consider the cash flow for complement B indicated by the dashed line. The sum of the vertical distance between the dotted and dashed curves, appropriately discounted, from some potential switch year to the end of the period, represents a component of the opportunity cost of deciding not to switch from complement A to complement B at the potential switch year.[2] Reiterating, this sum of discounted differences in annual net returns, when the annual differences arise from interdependence between when asset A is traded and the annual net returns to asset B, are omitted from the analysis if the asset cash flow for the challenger is assumed to be independent.

2.3 Independent Cash Flow Models

Three independent asset cash flow models will be reviewed. These are: (1) the Myopic Rule, (2) comparison of Net Present Values (NPV), and (3) Perrin's Approach.[3]

2.3.1 Myopic Rule

Harsh, Conner, and Schwab propose an ID rule which is relatively simple and requires little information to implement.[4] They propose that the maximum annuity of the challenger be calculated and compared to the discounted value of the next period's return for the currently held asset.[5] When the maximum annuity of the challenger is at least as large as next period's discounted returns of the existing asset, it is time to switch assets. Equation (2.2) depicts this rule,

$$(2.2)\quad NR_c/(1+r)^t \leqslant \text{Max}\,[(NR_{ch}(1)/(1+r)]*AF_{1,r}),\ ([\,NR_{ch}(t)/(1+r)^t]*AF_{2,r}),\ \ldots,([\,NR_{ch}(t)/(1+r)^t]*AF_{T,r})]$$

Where,
$AF_{t,r}$=Annuity factor for asset held for T years, at interest rate r;
$NR_c(t)$=Net returns of currently held asset, in year t;
$NR_{ch}(t)$=Net returns to challenger, in year t.

There are three necessary conditions for this rule to result in a correct investment decision. First, only one replacement is being considered.[6] Second, the level of $NR_{ch}(t)\ \forall$ t=1,...,T is independent of the point in time when the transition occurs. Third, $NR_c(t)$ is a smooth concave function between [0,T].

2.3.2 Comparison of Net Present Values or Annuities[7]

Comparing the net present values (NPV's) or annuities of the challenger(s) with that of the currently held asset marks the next step in complexity. Equation (2.3) formulates the problem for the case of NPV's.

$$(2.3)\quad NPV = \int_0^{T1} NRa(t)e^{-rt}dt - Ia(0) + SVa(T_1)e^{-rT1} + e^{-rT1}\left[\int_0^{T2} NRb(t)e^{-rt}dt - I(T1) + SVb(T2)e^{-rT2}\right]$$

Where,

$I_a(0)$ = Capital cost of asset A, at t = 0;
$I_b(T_1)$ = Capital cost of asset B, when trade occurs;
$NR_a(t)$ = Net returns to asset A, in year t;
$NR_b(t)$ = Net returns to asset B, in year t;
$SV_a(T_1)$ = Salvage value for asset A, in year T_1;
$SV_b(T_2)$ = Salvage value for asset B, in year T_2.

The first step in calculating the NPV in equation (2.3) is to solve for the life of each asset, denoted T_1 and T_2. First, the second bracketed term, which denotes the NPV of some asset B held for T_2 years, is differentiated with respect to T_2. When equation (2.4) holds, the optimal time to keep asset B has been found.

$$(2.4)\quad 0 = d(NPV_b)/dT_2 = NR_b(t)e^{-rt} + (dSV_b(T_2)/dT_2)e^{-rt} - rSVb(T_2)e^{-rT_2}.$$

The last term in equation (2.4) represents the opportunity cost of keeping B one more period. The entire equation is part of the opportunity cost of keeping A one more period. Now it is possible to solve for T_1, the optimal life of the first asset. Substituting equation (2.4) into the brackets in equation (2.3) and differentiating equation (2.3) by T_1, equation (2.5) is obtained.

$$(2.5)\quad 0 = d(NPVa)/dT_1 = NRa(t)e^{-rt} + (dSVa(T_1)/dT_1)e^{-rT_1} - rSVa(T_1)e^{-rT_1} - re^{-rT1}[NPVb,T2].$$

Where,

NPVb,T2=Net present value for asset B, when asset B is kept for T2 years.

By rearranging equation (2.5), equation (2.6) is obtained in which the terms on the left side of the equation indicate the discounted marginal net returns from holding asset A one more period, and the terms on the right side of the equal sign represent the opportunity cost of keeping asset A one more period.

$$(2.6)\ NRa(t)e^{-rt} + [d(SVa(T_1))/dT_1)]e^{-rT_1} = rSVa(T_1)e^{-rT_1} + re^{-rT_1}[NPVb,T2].$$

Again, the question of what are the necessary conditions for a decision to switch assets based on equation (2.6) to be a correct decision must be raised. First, returning to equation (2.3), it was implicitly assumed that only one replacement was going to occur. At T_2, the owner disinvests in asset B, and closes up the shop.Second, it was also implicitly assumed that the returns to asset B in year t, NRb(t), are not dependent on the transition period between assets A and B. Two results of this analysis are (1) the existence of a replacement asset shortens the period of time for which a currently held asset is kept, assuming $NPVb,T_2$ | 0, and (2) how long asset A is held depends on the optimal life of B. This method of solving the problem of how long to keep each asset is referred to as the method of backward induction.

2.3.3 Perrin's Approach

Perrin[8] wanted to derive analytical solutions to the problem of when to switch assets. While only one of his approaches is summarized here, the same general framework applies to other models he derived. Here, Perrin's model assumes an infinite number of replacements and each asset is identical to the one it replaced. Using the same terms as were used in equation (2.3), his approach is represented by equation (2.7),

$$(2.7)\ NPV = \int_0^{T_1} NRa(t)e^{-rt}dt - I(0) + SVa(T_1)e^{-rT_1}$$
$$+ e^{-rT_1}\left[\int_0^{T_1} NRa(t)e^{-rt}dt - I(0) + SVa(T_1)e^{-rT_1}\right]$$
$$\vdots$$
$$+ e^{-rT_n}\left[\int_0^{T_1} NRa(t)e^{-rt}dt - I(0) + SVa(T_1)e^{-rT_1}\right]$$

Since each asset was assumed to be identical, equation (2.7) could be simplified. Equation (2.8) reflects the simplified version of equation (2.7).

$$(2.8)\ NPV = (1+e^{-rT_1} + \ldots + e^{-rT_1})\left[\int_0^{T_1} NRa(t)e^{-rt}dt - I(0) + SVa(T_1)e^{-rT_1}\right].$$

Assuming n approaches infinity, equation (2.9) is obtained. The appropriate length of time to hold each asset, denoted T_1, is determined by differentiating equation (2.9) and finding the T_1 where $dNPV/dT_1 = 0$.

$$(2.9)\ NPV = [1/(1 - e^{-rT1})]\left[\int_0^{T_1} NRa(t)e^{-rt}dt - I(0) + SVa(T_1)e^{-rT1}\right]$$

Since (1) each asset is assumed to be the same, and (2) the net returns to any one of the A assets in year t, $NR_a(t)$, is independent of when asset switching occurs, once T_1 is determined for the last asset, you have determined the lives of all the assets.

2.3.4 Summary of Independent Cash Flow Models

All of the above methods have their advantages and disadvantages. The myopic rule is easy to implement, but one must be careful when acting on the results of the rule. Comparing NPV's is an improvement over the Myopic Rule because more of the cash flow stream for the currently held asset is included. The comparison of NPV's rule raised two important questions: (1) how many trades will take place, and (2) what is the pattern of net returns to each asset? Perrin addressed these two questions in his analysis. Perrin's approach was necessary in the light of his goal to perform comparative statics analysis.

All of the above models assumed that cash flows are independent of each other. This assumption may pose serious problems in the application of ID rules to asset switching in the soil erosion area. In the next section, Walker's Method will be presented. This method relaxes the assumption about the independence between the point in time when assets are switched and the cash flow pattern of the new asset(s).

2.4 Interdependent Cash Flow Model - Walker's Method

Walker attempted to devise an analytic approach to ID analysis which could capture the component of opportunity cost which reflects the change in the discounted value of net returns to the challenger with changes in the time when adoption occurs. First, a review of his formulation of the problem will be presented. Second, his formulation will be evaluated.

Equation (2.10) to (2.12) comprise the heart of his analysis. Referring first to equation (2.10), this equation represents the NPV of using the erosive technology in the current period and switching to the conserving technology for all subsequent, T-1, periods. Next,equation (2.11) represents the NPV of using the conserving technology from the current period and in all subsequent, T-1, periods. Equation (2.12) represents the decision rule which is used to find the point in time when asset switching should occur. When DIFF(t) 0, asset switching should occur.

$$(2.10)\ EPFT = P*Ye(t,D(t)) - Ce(t,D(t)) + \sum_{t=1}^{T-1}[(P*Yc(t+i,d(t)) - Cc(t+i,D(t)))/(1+r)^{t}]$$

$$(2.11)\ CPFT = P*Yc(t,D(t-1)) - Cc(t,D(t-1)) + \sum_{t=1}^{T-1}[(P*Yc(t+i,D(t-i)) - Cc(t+i,D(t-1)))/(i+r)^{t}]$$

$$(2.12)\ DIFF(t) = EPFT - CPFT$$

Where,

Cc(t,D(*)) = Variable production cost, including equipment ownership cost for the conserving technology, in period t, with soil depth D(*);

Ce(t,D(*)) = Variable production cost, including equipment ownership cost for the erosive technology, in period t, with soil depth D(*);

P = Output price;

r = Discount rate;

Yc(t+i,D(*)) = Yield using the conserving technology, in period t+i, with soil depth D(*);

Ye(t,D(*)) = Yield using the erosive technology, in period t, with soil depth D(*).[9]

Walker presents a generalized version of equation (2.12) which allows for multiple crops and net changes in soil depth for the conserving practice is used. This is presented in equation (2.13).

$$(2.13)\ Diff(t) = P^*[Yej(t, (t-1)) - Ycj(t,D(t-1))] - [Cej(t,D(t-1)) - Ccj(t,D(t-1))]/ - \sum_{t=1}^{T-1} P^*[Ycj(t+i,D(t+i-1,t-1) - Ycj(t+i,D(t+i-1,t))] - [Cc(t+i,D(t+i-1,t)) - Cc(t+i,D(t+i-1,t-1))]/.$$

Where,

D(n,m) = Projected top soil depth at the end of year n, after using the erosive practice for m years;
h = Number of crops in the rotation;
j = Crop j.

A number of comments regarding Walker's method are in order. First, Walker's approach violates the conditions of a staged problem by varying the starting and ending dates used in selecting the set of action choices. Staged problems, of which this is one, are solved after the starting and ending conditions have been specified. Then, if the starting and/or ending conditions are varied, one can examine how the action choices vary, in turn. Walker's approach violates this set of conditions by varying the start and ending dates used in selecting the optimum set of action choices.

For example, assume T=20, and t_0=1980. Here, EPFT and CPFT will be determined using data covering the period 1980-2000. According to his discussion of how to implement his approach, if the decision is made to keep the erosive asset for atleast one more period (until atleast 1982), the next analysis will cover the period 1981-2001. To be consistent with the formulation of staged problems, the analysis should cover only 1980-2000 and explore this space for the optimal trade year. Then, the sensitivity of the trade year to alternative time horizons can be determined. What the decision maker needs is the present values in 1980 of CPFT and EPFT calculated assuming various trade years and time horizons, in either nominal or real dollars. In addition, Walker's approach implies that a farmer is concerned only with the yearly decision, and not the cumulative effect on productivity resulting from his/her decision. A well informed decision on the part of the farmer is based on the net present value of various future actions, at one point in time. Walker's approach does not provide that information.

Second, given the way Walker's approach addresses the asset trade problem, a decision to switch assets can result in a less profitable asset being adopted. This is because his analysis does not include the NPV of holding the more erosive asset until T-1. In this case, Walker's rule would suggest that a trade should occur. Since this decision is based on information which does not include the net returns to the currently held asset beyond the current period, there is no way of knowing that a decision to switch is valid. The greater the effect of increased erosion from the more erosive tillage equipment, on the net returns to the challenger, and the lower are the net returns to the erosive asset this year relative to future years, the greater is the chance that a less profitable asset will be adopted.

Third, Walker defines the various cost functions as depicting the variable cost of production including e equipment ownership costs. This cannot be the case. The analysis needs a term reflecting initial capital cost, or the cost functions must be redefined as total cost functions, reflecting both the variable cost of production, and the annualized capital cost, net of salvage value.

Fourth, it should be assumed that asset salvage value may be sensitive to when trading occurs. In turn, a discussion of the relation between asset switching and asset salvage value should be included in the analysis.

Finally, according to Walker, the correct time to switch is when DIFF(t) 0.[10] This rule implicitly assumes that once the decision rule is satisfied, the underlying cash flow streams of the assets are such that no future period exists where a higher level of NPV is attained for the combination of assets,ts when the conserving technology is adopted later.

2.5 Summary of Investment Models

Walker's approach relaxed the assumption of independence of asset cash flows. Perrin's approach made more explicit the importance of (a) specifying the number of transitions which are assumed to occur, and (b) the length of time an asset is held. Making investments based on the NPV, or annuities, of the competing investments was argued to base decision making on more information than simply using the discounted net return to the existing asset in the next period. The Myopic Rule was argued to require the least amount of information of any of the methods, but requires that the net returns to the existing asset be a smooth concave function with one maxima over the domain of the function.

2.6 Review of Selected Empirical Models of Soil Loss and Crop System Economics

Mathematical Programming and Simulation analysis appear to be the two predominant approaches used in the study of soil loss and the economics of alternative cropping systems. The Math Programming strategies emphasize the economics of the underlying production practices, and do not adequately address the dynamics of the underlying physical process. Simulation models, on the other hand,have tended to more adequately model the dynamics of the physical process and pay less attention to the economic analysis.

More substantive review of both of the above approaches appears below. First, math programming approaches will be reviewed, following by a review of selected simulation approaches. In both cases, only the models' structure and policy options are discussed. Conclusions were not summarized because of our concern with problem formulation.

2.6.1 Math Programming Approaches

Pope, Arden, Bhide, and Heady[11] report on a model they developed which also forms the basis for several subsequent math programming studies of alternative cropping systems. This particular model is a representative farm linear programming (LP) model. Eighteen representative farms were constructed using three criteria: (a) represent the full range of erosiveness, (b) include the principle soil association areas, and (c) represent the six major land resource areas in Iowa. Each farm was defined on the basis of (a) soil resources; and (b) possible tillage systems, crop rotations, and supporting practices in Iowa.

The author states that the goal of the analysis is to maximize before tax net returns to land, management, family labor, and permanent livestock facilities. Where the soil tax policy is modeled, the goal is to maximize after tax returns.

The model takes a whole farm perspective. Fifteen crop rotations, five tillage systems, three supporting practices, and two livestock activities formed the alternative activities which could be modeled.Budgets were generated using the Oklahoma State Budget Generator.

Further, the five year crop rotation was collapsed into one year by calculating the average input/output coefficient for each enterprise. The model also implicitly assumes that a producer is starting out with a new operation today. Since the LP model they develop is a one period model, changes in productivity due to erosion cannot be captured by the analysis. In addition, it must be assumed that the producer does not engage in any other enterprises outside the model, or that they are separable from the enterprises included in the model.

Banks, Bhide, Pope, and Heady[12] report on a study which explores the relation between tenure arrangements, capital constraints, and farm size on the relative economics of various cropping systems in Iowa. This analysis relies on the model presented above.

Using an objective function of maximum before tax net returns, in the absence of a soil loss tax, and an after tax maximum net returns in the presence of a soil loss tax, their analysis had four objectives. First, they wanted to analyze the economics of various cropping systems from the perspective of the (a) tenant, (b) owner - operator, and (c) landlord, under various tenancy arrangements. Second, they wanted to study the effect which alternative soil loss restrictions may have on net returns and the incentives of various groups to pursue soil conservation strategies. Third, they wanted to study the impact of capital constraints on practice adoption. Lastly, they wanted to explore for any relation between farm size and practice adoption.

There were six alternative scenarios modeled for each of five ownership/tenancy arrangements. The alternatives included no restrictions, using a moldboard plow, restricting soil loss to a pre - specified T level, and a soil loss tax set at different levels, on a dollar/ton basis.

Olsen, Kent, Heady, Chen, and Meister[13] conducted an analysis of a fertilizer restriction and a ban on selected insecticides on the production, sale, and distribution of selected crops and livestock activities at the national level.

Using a quadratic programming (QP) approach, with an objective of maximum net aggregate producer profit, the U.S. was segmented into 10 producing regions and 103 consuming regions.

Production, transportation, and demand levels for the various goods modeled in the analysis must conform to all the standard assumptions of LP, except for one. Here, the use of QP allows for some non - linearities to be incorporated into the model. In this analysis, the total revenue functions are assumed to be non - linear functions of at least the quantities of own output.

Saygideger, Vocke, and Heady[14] also conducted an analysis of the tradeoffs between production efficiency and soil loss control using a multi - goal LP model. The trade - off was between the cost of producing the food supply and maintaining a land base and limits on soil loss. According to the authors, three alternative approaches were modeled: (1) prior weighting of the objectives, (2) exploration of the search space, and (3) goal programming. Weights on the soil loss goal varied from a low of zero to a high of twenty dollars.

Endogenous crops were barley, corn, corn silage, cotton, legume, and non - legume hays, grain sorgham, sorgham silage, soybeans, sugar beets, oats, and wheat in rotation. Conservation practices were contouring, strip cropping, and terracing. Lastly, three tillage practices were included: conventional with residual removed, conventional without the residual removed, and reduced till.

2.6.2 Simulation Approaches

Williams, Dyke, and Jones have developed a simulation model useful in analyzing the relation between soil erosion and soil productivity.[15] Known as the EPIC model, the model simulates the interaction of enviornmental and technological factors on soil erosion, the impact of soil erosion on soil productivity, the impact of soil productivity on crop yield, and the economics of the above process. There are eight components of the EPIC model: hydrology, weather, erosion, nutrients, plant growth, soil temperature, tillage, and economics. All calculations are performed on a per hectar basis, using a daily time step.

Turning to the economics component, crop budgets are generated using parts of the Oklahoma State budget generator. Budgets are generated for a year or for the whole period of the simulation. Inputs are divided into fixed and variable, with machinery fixed cost being allocated to crops on an hour by hour basis.

This model is a vast improvement over the LP models in terms of how the physical system is modeled. The various subroutines in the model combine to simulate daily plant growth, erosion due to farming practices and weather, and the resulting economics of the alternative crop systems.

Pierce et. al.[16] have also developed a soil - erosion productivity model which can be used to calculate the intertemporal soil depth - yield curve for a given crop system,

on a given soil type, having a particular set of soil characteristics across horizons. This model operates on a yearly time step calculating the change in soil depth, change in soil productivity, change in crop yield, net revenues, and net present value.

In this model, the rooting zone is assumed to be the critical factor affecting plant development. The only way that weather affects yields is through the annual rate of soil loss. Combining the yield calculation from the model with exogenously specified annual costs and output prices, the annual net returns and discounted net returns are calculated. In addition, the model calculates the level of annual investment a producer can make if the producer were to shift today from the system being used to a steady - state system.

Both EPIC and this model are not optimizing models. These models simply calculate the values of the endogenous variables for a pre specified system. Like EPIC, this model has a general structure which, with appropriate data, can be used to model any given producers' circumstances. Of course, this is constrained by the limits within the model itself.

Muhtar[17] used a simulation approach in constructing a model to select machinery complements which can perform a specified set of operations at least cost, for a particular crop rotation, on a specified soil type, at a specified confidence level for completing the tasks within an alloted time period. Three alternative tillage systems can be modeled: moldboard plow, chisel plow, and no- till.

In part, the model relies on producer provided data to select an initial machinery complement, which is the smallest complement able to perform the required operations within the number of available hours provided by the user, at the specified confidence level. Then, the model iterates through alternative machinery sizes to determine if a larger complement is capable of performing the specified operations within the alloted time at a lower total cost than the next smallest complement.

Some of the management and machinery assumptions underlying the above analysis are:

1. Hours available on a given day for field work were set based on actual farming practices in the area;

2. Suitable days for field work were grouped into calendar weeks based on soil type and the probability level desired by the user;

3. Implements were assigned to power units in the following manner. Tillage and planting equipment were assigned to tillage tractors. Other operations like secondary tillage were assigned to utility tractors;

4. No limits were placed on the number of combines, tractors, or implements;

5. Row crop machinery had to match one another.[18]

2.7 Summary

This chapter began with a review of a number of analytic approaches to the problem of asset investments/disinvestment decision making. First, several models were presented which assume that the cash flow streams of competing assets are independent of each other. Next, a model was presented which relaxed the assumption of independent cash flows. The assumptions of the various models were compared, and the advantages and disadvantages of each approach was presented.

Next, several math programming and simulation models were presented which have as their focus the economic analysis of alternative crop systems and soil loss. A review of the structure of each of these models was presented, as well as the identification of the critical assumptions. From the review of the analytical and empirical models, two general observations were made. First, there is room to develop a simulation model which does a better job of applying capital theory principles and accounting for interdependent cash flows in the analysis. Second, an ID model needs to be developed which addresses the criticisms leveled at Walker's analysis.

FOOTNOTES

1. This formulation of the problem is consistent with hw the finance literature formulates the problem of selecting an investment from among a set of investment from among a set of investments whose cash flows are interdependent. For example, see: Lawrence D. Schall and Charles C. Haley, Introduction to Financial Management, 2nd Edition, (McGraw - Hill, New York, 1980), pp. 365.

2. Referring to Figure 2.1, the curve of annual cash flows for asset B, when B is adopted at the beginning of period two, does not begin at t=0 because asset A is held, and the decision maker is confronted by the cash flow stream for asset A. Further, additional cash flow schedules for asset B may exist if one is considering switching from asset A to asset B at different points in time.

3. Why Perrin's analysis is classified as it is will be discussed below.

4. Their approach to the problem is based on earlier work by Faris. Faris states that "the optimum time to replace is when the marginal net revenue from the present enterprise is equal to the highest amortized present value of anticipated net returns from the following enterprise." See: J. Edwin Faris "Analytical Techniques Used in Determining the Optimal Replacement Pattern," Journal of Farm Economics (1)1960:755-766.

5. Stephen Harsh, Larry Conner, and Gerald Schwab, Managing the Farm Business, (Prentice-Hall, Englewood Cliffs, N.J., 1981), p. 263.

6. Why this condition must be met will become clear when Perrin's method is reviewed.

7. The approach used in this section has benefited from the writings of Lindon Robison. For an example, see: Lindon Robison, "Investment/Disinvestment and Use of Durables: An Analytic Framework," pp. 41-56 in Models for Investment and Disinvestment Decisionmaking under Uncertainity, ed. by L.J. Robison and M.H. Abkin (Electric Power Research Institute, Palo Alto, CA), January 1982.

8. R.K. Perrin, "Asset Replacement Principles," American Journal of Agricultural Economics, 1 (1972):60-65.

9. David J. Walker "A Damage Control Function to Evaluate Erosion Control Economics," American Journal of Economics, 1(1982), pp. 692.

10. Ibid., p. 694.

11. C. Arden Pope III, Shashanka Bhide, Earl O. Heady, The Economics of Soil and Water Conservation Principles in Iowa: Model and Data Documentation, CARD Report 108, SWCP Series I, (Iowa State University, Ames, Iowa: Center for Agricultural and Rural Development, August, 1982).

12. Tim N. Banks, Shashanka Bhide, C. Arden Pope III, and Earl O. Heady, Effects of Tenure Arrangements, Capital Constraints, and Farm Size on the Economics of Soil and Water Conservation Practices in Iowa, CARD Report 111, SWCP Series IV, (Iowa State University, Ames, Iowa: The Center for Agricultural and Rural Development, April, 1983).

13. Kent D. Olsen, Earl O. Heady, Carl C. Chen, and Anton D. Meister, Estimated Impacts of Two Enviornmental Alternatives in Agriculture: A Quadratic Programming Analysis, CARD Report No. 72, (Iowa State University, Ames, Iowa: The Center for Agricultural and Rural Development, March, 1977)

14. Orhan Saydeger, Gary F. Vocke, and Earl O. Heady, A Multi - Goal Linear Programming Analysis of Trade - Offs between Production Efficiency and Soil Loss Control in U.S. Agriculture, CARD Report No. 76, (Iowa State University, Ames, Iowa: The Center for Agricultural and Rural Development, January, 1977).

15. J.R. Williams, P.T. Dyke, and C.A. Jones, "EPIC - A Model for Assessing the Effects of Erosion on Soil Productivity," paper presented at the Third International Conference on State of the Art in Ecological Modeling, Colorado State University, May 24-28, 1982).

16. F.J.Pierce, W.E. Larson, R.H. Dowdy, and W.A.P. Grahm, "Productivity of Soils: Assessing LOng - Term Changes due to Erosion," Journal of Soil and Water Conservation, (January-February 1983): 39-44.

17. H. Muhtar, and C.A. Rotz, "A Multicrop Machinery Selection Algorithm for Different Tillage Systems," paper presented at the American Society of Agricultural Engineers Mettings, University of Wisconsin-Madison, 27-30, 1982.

18. Ibid., p.4.

CHAPTER THREE

MANAGEMENT DECISION MAKING WITH INTERDEPENDENT CASH FLOWS - A REFORMULATION

3.1 Introduction

In the previous chapter, Walker's model had been introduced and critiqued. While Walker's attempt to deal with the interdependent cash flow problem is a step in the right direction, there were a number of reservations about the structure of his model. The model presented in this chapter is partially based on a response to these reservations.

Section Two discusses the intertemporal statics approach to dynamic processes. Section Three presents the requirements which a new approach must satasfy. In Section Four, several concepts from investment theory are applied to formulating the innterdependent cash flow problem. Section Five generalizes the model to multiple transitions. Section Six discusses some differences in decision making for the owner operator versus tenant operator. Section Seven argues that the algorithm may be applied to any change in a crop system, not just equipment switches.

3.2 Intertemporal Statics Approximation of a Dynamic Process

This chapter will focus on one approach to modeling dynamic processes. Here, an intertemporal statics approach will be developed. Another term for this approach is Hicksian Dynamics.

Approximating dynamic problems using an intertemporal statics framework reflects (1) limited data upon which to base an estimate of the rate equation(s) and objective functional of optimal control, and (2) the desire to build a model which is less presumptive of the dynamics of crop production for a given operation. Since the present analysis is concerned with developing a framework useful for individual operator decision making, it must be sufficiently general to allow the use of data describing the production process of the operator.

Conceptualizing natural resource problems as capital allocation issues related to determining what decisions lead to an optimal resource allocation has developed relatively recently, but very vigorously. Some examples of how dynamic approaches have previously been used are provided by Samuelson, Cummins, Smith, Mc Connell, and Burt.

Cummins[1] wanted to explore the analytics of the optimal extraction rate of a natural resource whose stock is exhaustable. Samuelson[2] was concerned with identifying the correct way of framing the issue of optimal timber rotation. He relied heavily on principles of Capital Theory to formulate the economic problem of combining various inputs across time, and harvesting various amounts of timber across time, in a way which maximizes the net return to the owner. As part of his analysis, he addressed the externality/common property issue.

Smith[3] is concerned with applying Control Theory to analyze the problem of optimal intertemporal capital allocation. Capital is thought of as renewable or non-renewable resources as well as enviornmental resources. He was concerned with the technology, production, and consumption of natural resources in a two-commodity dynamic economic model.

Moving to the soil erosion area, Mc Connell [4] and Burt[5] have both used optimal control approaches to resource allocation decision making. Mc Connell's article formulates the problem of soil loss in an optimal control framework. The rate equation, used to describe the path of a state variable, soil depth, across stages, has two arguments: ameliorative inputs and productive inputs. Crop production is a function of soil loss, soil depth, and an index of variable inputs. The rate equation expresses the change in soil depth as a function of a tolerance level and soil loss in that stage.

Burt also used an optimal control approach. He used two state variables: soil depth and percent organic matter in the top six inches of the soil. The objective function was defined as net returns in dollars/acre as a function of percent of land planted to wheat, an annual organic matter loss function, and an annual soil loss function. Burt has to assume that fertilizer and cultural practices were fixed for a particular rotation, which reduces the decision variable to rotation choice.

It should be noted that these are only several examples of a rather extensive literature which couches natural resource allocation questions in the context of an optimal control problem concerned with allocating a capital stock across time. Usually there is a profit function which is being maximized. Further, the capital stock at the beginning of the analysis may or may not be augmentable during the analysis. The goal is to find that set of values for the policy variable(s) across time which lead to the constrained optimum of the objective functional.

An Optimal Control problem is essentially a path selection problem. A problem, say the optimal time to switch a machinery complement, is segmented into stages. One or more rate, or state-space, equations are specified which indicate the impact some decision variable(s) have on one or more state variable(s). These state variables then enter the objective functional. The objective functional is a function of a function. Therefore, one does not solve the problem by finding the scalar which is the constrained optimum. Rather, one finds the function which describes the path across time of the constrained optimum.

Numerical Integration is an approach used to provide an approximate solution to systems of difference or differential equations. Algorithms exist which can solve systems of these equations where the objective function is non-linear, subject to non-linear inequality constraints.

A further approximation of the Numerical Integration approximation is provided by couching the problem in an intertemporal statics framework. Here, the concern is with finding the values of a decision variable, or variables, which have associated with them values for state variable(s) at each stage which optimize the objective function. External to the model, a path is selected based on the values of the objective function associated with the prespecified paths analyzed with the model. No attempt is made to pre-specify the rate equation(s) which link stages together, and which determine the value of the state variable(s) entering the objective functional, in such a way that the model determines the optimal path.

3.3 Requirements of an Alternative Approach

There are three requirements which a new approach must meet. First, the approach must not require that each asset be the same or that any difference between asset cash flows be restricted to a geometric form. Second, the method must be able to handle any number of replacements. Third, it must be able to address the criticisms leveled at Walker's approach.

3.4 Adjusting for Interdependent Cash Flows

Schall and Haley present a framework for handling this problem. First, if any of the future investments have a rate of return (ror) at most equal to the cost of capital, r, these projects can be ignored.[6] Second, for the remaining investment opportunities, three steps are followed:

1. Form all possible combinations of mutually exclusive investment options;
2. Determine the net present value (NPV), required investment, and after tax cash flows of each combination; and,
3. Adopt the combination with the greatest NPV.[7]

In this analysis, the investment options are the alternative machinery complements between which the producer may choose.[8] Two mutually exclusive investment options may also be differenciated by differences in the switch years between machinery complements. Mutually exclusive investment options, which will be referred to as management options, are composed of various sequences of the machinery complements being evaluated. One example of two mutually exclusive management options is:

Option One: Practice conventional tillage until the end of the analysis, in year T;

Option Two : Practice conventional tillage until some year $T-t^*$, where t^* is a potential switch year, and practice conservation tillage from t^* to T.

3.5 Mathematical Derivation of the Decision Rule

Using continuous discounting, the following three equations represent management options one, two, and three, respectively.

$$(3.1)\quad NPV_a = \int_0^T NR_a(t)e^{-rt}dt - I_a(0) + SV_a(T)e^{-rT}$$

$$(3.2)\quad NPV_{b0} = \int_0^T NR_{b0}(t)e^{-rt}dt - I_{b0}(0) + SV_{b0}(T)e^{-rT}$$

$$(3.3)\quad NPV_{a,bi} = \int_0^t NR_a(t)e^{-rt}dt - I_a(0) + SV_a(t)e^{-rt} + e^{-rt}\left[\int_0^{T-t} NR_{bi}(t)e^{-rt} - I_{bi}(0) + SV_{bi}(T-t)e^{-r(T-t)}\right]$$

Where,

$I_a(0)$ = Capital cost of A;

$I_{bi}(0)$ = Capital cost of B, at the beginning of year i;

$NR_a(t)$ = Gross returns minus variable cost for asset A in each period;

$NR_{bi}(t)$ = Gross returns minus variable cost for asset B in each period, when B is adopted at the beginning of period i;

$SV_a(T)$ = Salvage value of asset A at the end of period T;

$SV_{bi}(T)$ = Salvage value of asset B at the end of period T when B is adopted at the beginning of period i

Equation (3.1) will calculate the NPV corresponding to holding the erosive asset until T. Equation (3.3) is a reformulation of the equation used by Walker to calculate EPFT. It has been reformulated in order to allow the analyst to search for a trade year which will maximize NPV, given a pre-specified beginning year and ending year. Equation (3.2) calculates the NPV corresponding to using the chisel plow from the beginning of the analysis.

Referring to equation (3.3), if t is first equal one and then equal to two, the analysis boils down to addressing the question: should I switch from asset A to asset B at the end of period one or wait at least one more period? Mathematically, this appears as,

$$(3.4)\ V_2 = [NPV_{a,b2}] - [NPV_{a,b1}].$$

Substituting the terms from equation (3.3) into (3.4), and simplifying, equation (3.5) is obtained.

$$\begin{aligned}(3.5)\ V_2 = {} & [(\int_0^2 NR_a(t)e^{-rt}dt - I_a(0) + SV_a(2)e^{-2r}) \\ & - (\int_0^1 NR_a(t)e^{-rt}dt - I_a(0) + SV_a(1)e^{-r})] \\ & - [e^{-r}(\int_0^T NR_{b1}(t)e^{-rt}dt - I_{b1}(0) \\ & + SV_{b1}(T)e^{-rT}) - e^{-2r}(\int_0^T NR_{b2}(t)e^{-rt} \\ & - I_{b2}(0) + SV_{b2}(T)e^{-rT})]\end{aligned}$$

The general form of equation (3.5) is,

$$
\begin{aligned}
(3.6)\ V_h = {} & [(\int_0^h NR_a(t)e^{-rt}dt - I_a(0) + SV_a(h)e^{-rh}) \\
& - (\int_0^{h-j} NR_a(t)e^{-rt} - I_a(0) + SV_a(h-j)e^{-r(h-j)})] \\
& - [e^{-r(h)}(\int_0^{T-h} NR_{b(T-h)}(t)e^{-rt}dt \\
& - I_{b(T-h)}(0) + SV_{b(T-h)}(T-h)e^{-r(T-h)}) \\
& - e^{-r(h-j)}(\int_0^{T-h-j} NR_{bt}(t)r^{-rt}dt - I_{bt}(0) \\
& + SV_{bt}(T-h-j)e^{-r(T-h-j)}].
\end{aligned}
$$

What is the interpretation of equation (3.6)? The first bracketed term is the change in the NPV from holding asset A between h-j and h, where j is set so that h-j equals the beginning of the period when asset A could have last been traded. The second bracketed term is the change in the NPV of asset B which arises from the decision to postpone adoption of asset B from year h-j to atleast year h.

Equation (3.6) provides a stopping rule to use in searching for the correct time to switch from asset A to asset B. When $D_h = 0$, the correct transition period may have been found. Caution is used because $V_h=0$ is a necessary but not a sufficient condition for the identification of the appropriate transition period. When trading can occur at any point in time between 0 and T, there may be more than one point where $D_h=0$. In practice, it may not be possible to find a point where $D_h=0$ because asset trades can occur at discrete points in time. In addition, when trading can only occur at discrete points in time, there may more than one period within which D_h changes sign. The following section details a solution procedure which circumvents these problems.

Therefore, the new approach must (1) be flexible in both the number of replacements assumed and the pattern of net returns to all replacements, (2) be consistent with how staged problems are formulated, (3) include the net returns to the erosive asset assuming it is held until the end of the analysis, (4) be analytically correct in how the cost functions are formulated, (5) include salvage value as an explicit argument in the asset switch decision, and (6) be implemented in such a way that the probability that the local optimum corresponding to a recommended switch also is a global optimum. Alternative management options can be arrived at via alternative combinations of crop systems, the number of transitions assumed to occur between crop systems, and the points in time when a switch can occur. All of this analysis is conducted assuming the planning period is held constant. Further, the planning period is the total length of time over which the producer makes asset switching decisions. A difference exists between the time horizon and the planning period for the case of the owner operator who should consider changes in the salvage value of land when making crop system decisions.

3.6 Transition Analysis when Multiple Switches are Possible

Studying the problem of asset switching when one switch is assumed to occur is the problem raised by Walker. The analysis was structured to be consistent with the assumption that only one switch will occur. As the reader observed in chapter two, this is a very restrictive assumption. Perrin dealt with this problem by assuming that an infinite number of replacements will occur and that either (a) each subsequent asset is identical to the one it replaced, or (b) that each subsequent asset is technologically improved in a geometric fashion. Due to the definition of interdependent cash flows used in this analysis, backward induction cannot be used to solve for the life of the asset held last and working back to determine the optimal life of the asset held first.

When one allows for more than one replacement to occur, there does not appear to be any general form for a first order condition, within the structure of the current framework. Borrowing from Schall & Haley's approach, one solution to this problem is simply to specify all the alternative management options,calculate the NPV for each, and then select that option which maximizes NPV. Equation (3.7) is the general form of the equation used to form the alternative investment options.

$$
\begin{aligned}
(3.7)\quad NPV_i = & \int_0^{T_{1j}} NR_1(t)e^{-rt}dt - I_1(0) + \\
& SV_1(T_{1j})e^{-rT1j} \\
& + e^{-rT1j}[(\int_0^{T_{2j}} NR_2(t)e^{-rt}dt - I_2(0) \\
& + SV(T_{2j})e^{-rT2j}) \\
& + e^{-rT2j}[(\int_0^{T_{3j}} NR_3(t)e^{-rt}dt - I_3(0) \\
& + SV(T_{3j})e^{-rT3j}) \\
& \quad \vdots \\
& + e^{-rT((N-1)j)}[(\int_0^{T(Nj)} NR_N(t)e^{-rt}dt - \\
& - I_N(0) + SV_N(T_{Nj})e^{-rT(Nj)})]...]].
\end{aligned}
$$

Equation (3.7) is analyzed for all management options i, i=1,...,M. Interpreting equation (3.7), the first line represents the discounted net returns to pursuing crop system one for a period of T_{1j} years. Line two represents the discounted net returns to crop system two, when this system is followed for a period of T_{2j} years. The last line represents the discounted net returns to crop system N, when N is followed for T_{Nj} years. Equation (3.7) accounts for interdependent cash flows because the net returns to subsequent crop systems will, in part, reflect the use of prior crop systems on the state of the system in future periods. Changing the sequence of crop systems and/or the trading period between two crop systems will be reflected in the level of NPV for that management option. In turn, after calculating the NPV for the various options selected for analysis, the correct option can be selected based on maximum NPV.

3.7 Decision Making for the Owner versus the Tenant

While capital is assumed to be the constraining factor to which returns are maximized for both the owner and tenant, there is a difference between the capital to which returns are maximized for the owner versus for the tenant. Owners do, or should, make ID decisions with respect to their impact on returns to the investment in land and machinery. Therefore, both machinery salvage value and land salvage value must both be included. Whether or not a switch between crop systems entails switching machinery complements, the salvage values for both land and machinery should reflect any change in their value arising from a decision to not switch complements this period. Referring back to equation (3.7), an additional term must be added to reflect the value of land at the point in time when disinvestment occurs.

Within the bounds of the current analysis, an estimate of the discounted value of future land prices is provided by the Basic Capital Budgeting equation presented in equation (3.8).

(3.8) $VL = NR/r$

Where,
NR = Net returns to the asset in any year;
r = Discount rate;
VL = Present value of future returns to land.

This model is derived from equation (3.9),

(3.9) $NPV = NR(t)/(1+r)^t$.

In this model, net returns are assumed to be constant across time, no inflation or taxes exist, the asset does not depreciate, the asset is held for an infinite length of time, and the alternative investment earns a return of r.[10] The value of VL is discounted by the discount factor corresponding to the time when disinvestment is assumed to occur, and this value is added to equation (3.7).

Tenancy arrangements affect capital budgeting in several ways While the complete discussion of tenancy arrangements requires that the issue of risk spreading and decision making be discussed, there are several observations which can be made even in a deterministic model.

First, the tenant is assumed to attempt to maximize returns to the investment in equipment. Here, the tenant is assumed to provide the machinery and labor input. Second, the major difference between cash versus share rentals arises in the distribution of revenue and cost between the owner and the tenant. Third, in analyzing ID decisions, the time horizon used is determined by the tenant. Fourth, as with the owner, machinery salvage value is included in the analysis, as well as the change in machinery salvage value from postponing disinvestment. Returns to land are not part of the analysis.

3.8 Selection of the Time Horizon

All the analysis in this chapter assumed that the time horizon was finite and determined exogenously. In chapter two, the models which were analyzed had as one of their goals the endogenous determination of the economic life of the asset. Due to the fact that the annual cash flow of each future asset depends on when the transition occurs, it is not possible to use the method of backward induction to solve for the optimal life of each asset. While more sophisticated algorithms can solve for the optimal life of each asset endogenously, even when interdependent cash flows exist, the present analysis must circumvent this problem by exogenously specifying the time horizon. Sensitivity analysis can be performed to identify the rate of change in the value of the objective function to variations in the time horizon. Then, the option whose asset lives maximizes NPV, ceteris paribus, is the appproiate option to select.

3.9 Generalizability of the Model

While most of the analysis in this chapter was couched in terms of switching assets, the framework can be used to assess the impact of other changes in a crop system on the farmers' profit. For example, changes in crop rotations and/or tillage practices can also be evaluated. In this case, the alternative crop systems comprising one management option are differenciated atleast by the crop rotation used. Then, the appropriate set of crop systems, (ie: the appropriate management option), is selected by finding the management option which results in a global extremum (which one depends on the objective function) of the objective function.

3.10 Summary

Chapter three began by identifying the requirements which any new approach must satisfy. These requirements were identified based on (a) Perrin's analysis, (b) Schall and Haley's method for selecting an investment from among a set of investments whose cash flows are interdependent, (c) requirements of a new approach presented earlier,and (d) the criticisms of Walker's approach.

Based on the criticisms of Walker s approach to ID decision making when one transition is considered, the approach to this problem was reformulated. Equation (3.5) depicts the general form for the first order condition (FOC) used to search for the optimal transition period, when one transition occurs.

Going beyond the one transition problem, a model was formulated with which to analyze a multiple transition problem. Here, it was argued that a FOC probably does not exist, given the approach used in this analysis. Equation (3.7) is the general form used to determine the NPV for each management option. This equation captures the interdependent cash flow aspect of the problem.

While most of the discussion of existing ID models, as well as the derivation of the models in this chapter, were couched in terms of investment analysis, the framework can be generalized to other dimensions of management decision making. Relying on the definition of a crop system as being completely defined when the (a) crop rotation, (b) tillage method, and (c) tillage practice are specified, the model developed in this chapter can be applied to a change in any one of these three dimensions of a crop system.

CHAPTER FOUR

SIMULATION MODEL FORMULATION

4.1 Introduction

This chapter presents the empirical model used for the analysis. The next section discusses what this model contributes to the study of soil erosion. Section three presents five assumptions which affect either the calculation of net returns for each case studied, or affect the interpretation and extension of the results to other cases studies outside the model. Section four presents the components of the model.

4.2 This Models' Contribution to Studying Soil Loss and Crop System Economics

First, this model provides the broad outline of how future model building should progress in the area of producer decision making and soil loss control. Before this model can be used for producer decision making, more assumptions will have to be relaxed; but, the general approach is consistent with a focus on producer decision making.

Second, unlike existing empirical models, this model is derived from an explicit focus on interdependent cash flows from competing crop systems. Any model in this subject matter area which purports to be useful for producer decision making should address the issue of interdependent cash flows.

Third, this model determines the profitability of competing combinations of crop systems given a planning period. In turn, unlike the Pierce-Larson model, the amount which a producer can invest in a soil conserving machinery complement is determined using the NPV of two competing options, not one realistic complement and one in a hypothetical steady-state.

Fourth, numerous management options can be studied. For example, the asset switch problem can be studied using this model. In addition, two competing management options can be defined as including the same two crop systems with the only difference being when a switch between systems is assumed to occur. The conceptual basis for this empirical model includes allowing for changes in other dimensions of a crop system other than the machinery mix. This is only reasonable considering the fact that there are a range of management decisions which impact on soil loss.

Fifth, this empirical model begins to relax the assumption that input use is invariant to changes in yields as soil depth changes. Pesticide, fertilizer, potassium, phosphate, and seed demand vary as a function of output.

4.3 Structure of the Computer Model

This section will look at the model's overall structure. This is followed by a more detailed look at the various sub - programs of the model.

4.3.1 Macro Overview of the Model

As Figure 4.1 indicates, there are seven programs which together form the framework used in the analysis. Each program is called from the main program, EASL, which stands for Economic Analysis of Soil Loss. When a program is called, computation is shifted from EASL to that program, and when the computations are completed, computing shifts back to EASL.

First, INP is called which prompts the user to input user provided data. These data are then saved in a file created by the program. Next, USLE is called and the annual average rate of soil loss is calculated for each respective crop system, using the Universal Soil Loss Equation. After a number of control variables are initialized, DYNSDSP is called. This model is a modified version of the Pierce Larson et. al. model used to calculate the productivity of a specified soil, in a given year, by relying on selected soil characteristics and the annual rate of soil loss. After the productivity calculations are performed, the yield of a given crop is determined, for a given year in the time horizon. Once the yield is determined, programming moves to the input use calculation program, IU, which calculates the use, and cost, of pesticides, fertilizer, potassium, phosphate, and seed. Next, computation is transferred to the ACCT program which calculates the cash flow for each option. When all "J" components for all "K" options have been analyzed, computing shifts to the WRITE program which prints selected information. When all options have been analyzed, computing ends.

It should be noted that the model is structured to be

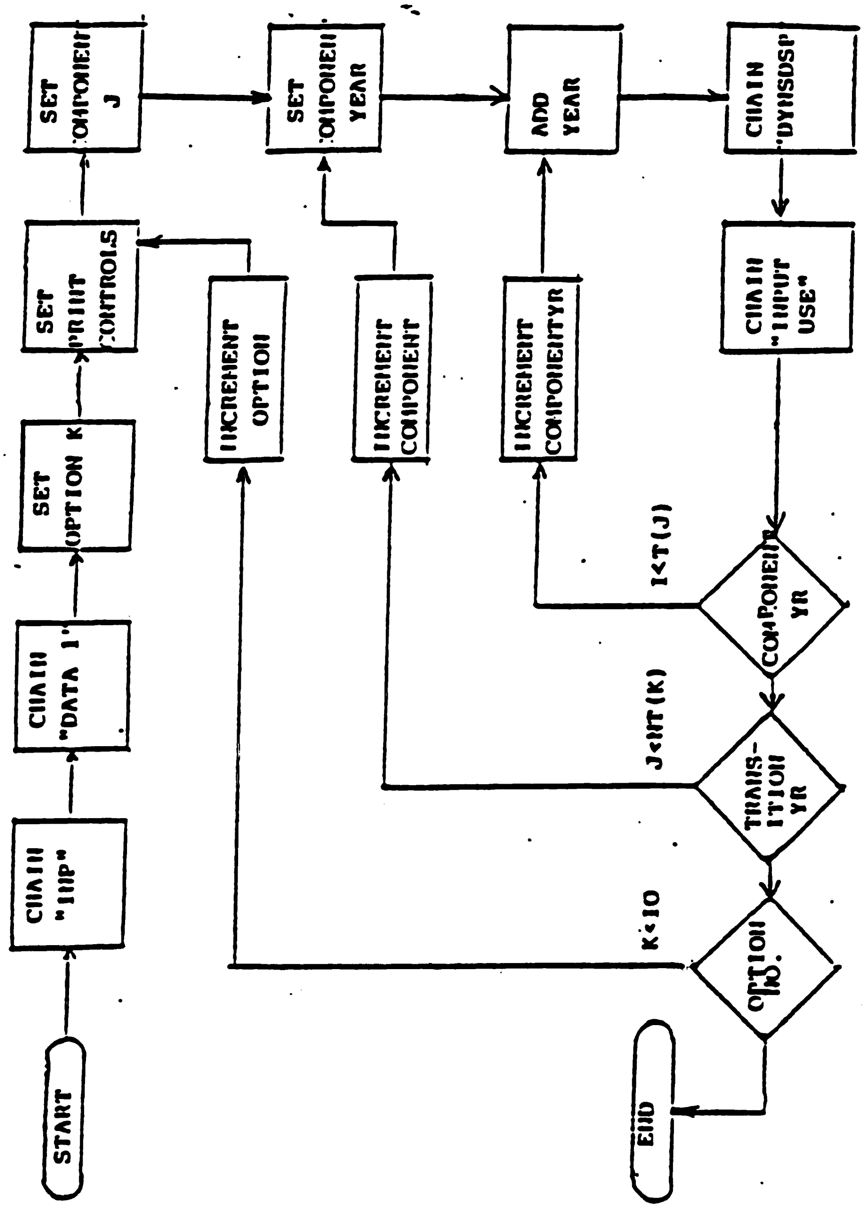

Figure 4.1 - Macro Flowchart

consistent with equation (3.7) developed in the previous chapter. In the simulation model, K represents the number of alternative management options, and NT(K) represents the number of changes in some component of the crop system which is assumed to occur within a decision maker's time horizon. For example, if Farmer Jones faces the following alternatives:

(1) Continue to use his moldboard plow and then retire;
(2) Use the moldboard plow for 5 years and then switch to a chisel plow and then retire; or,
(3) Switch to a chisel plow now and then retire.

Farmer Jones has three management options, and management option two contains two crop systems. Whereas, options one and three each contain one crop system. Each management option is composed of one or more cropping systems over a pre - specified planning period, T. For example, Farmer Jones' planning period is today until retirement. His planning period may be any length of time he sees as relevant. The user can specify both the planning period of the decision maker, T, and the length of time for which each crop system is practiced, T(J,K).

4.3.2 Structure of each Sub - Program

There are six sub - programs. These are: Input Prompt (INP), Soil Loss Calculation (SOIL), Soil Productivity (DYNSDSP), Input Use (IU), Economic Analysis (ACCT), and the Output Program (WRITE).

4.3.2.1 Input Prompt Program

Figure 4.2 is the macro flowchart for the input prompt program. Each block in the flowchart indicates the type of

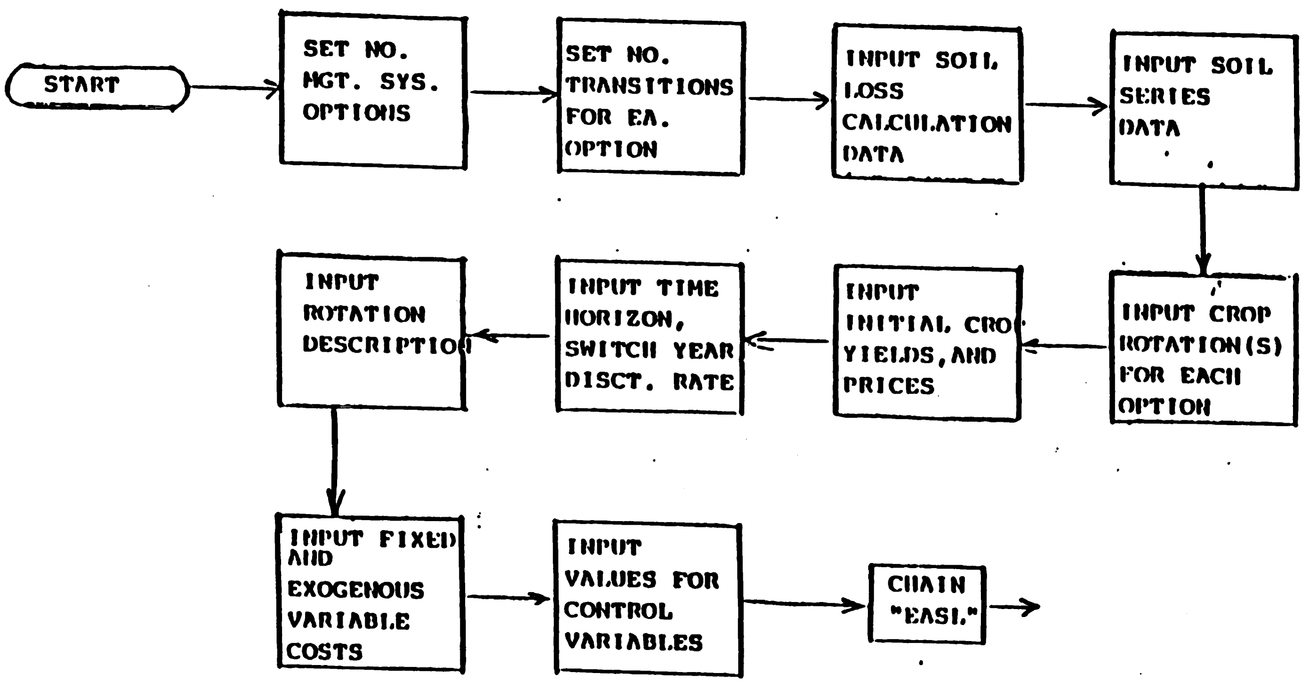

Figure 4.2 - Input Prompt Program Flowchart

information which the user must provide. The user is automatically prompted for the necessary data. When the user has responded to the prompts, the data are saved in a separate program for later use. After all the data are entered, computing returns to EASL.

4.3.2.2 Soil Loss Calculation Program

This program is depicted in Figure 4.3. First, to assure subsequent calculations are performed using the correct annual rate of soil loss, the rates of soil loss for each crop system are set equal to zero. Next, using the USLE, the average annual rate of soil loss is calculated for each crop system. These calculations are saved for later use. When a particular management option contains more than one crop system, each crop system will have a corresponding annual rate of soil loss. The form of the USLE used in the subroutine determines the average annual rate of soil loss under the specified climatic conditions, topography, and management practices. As a result, soil erosion attributable to severe storm events is not captured.

4.3.2.3 Soil Productivity Program

DYNSDSP is the acronym for Dynamic Soil Depletion and Soil Productivity. As was stated earlier, this program is a modified version of the Pierce - Larson et. al. model.

Referring to Figure 4.4, the reader will note that the model first calculates the weighting factors for each centimeter within a 100 cm rooting zone. These factors are used in the

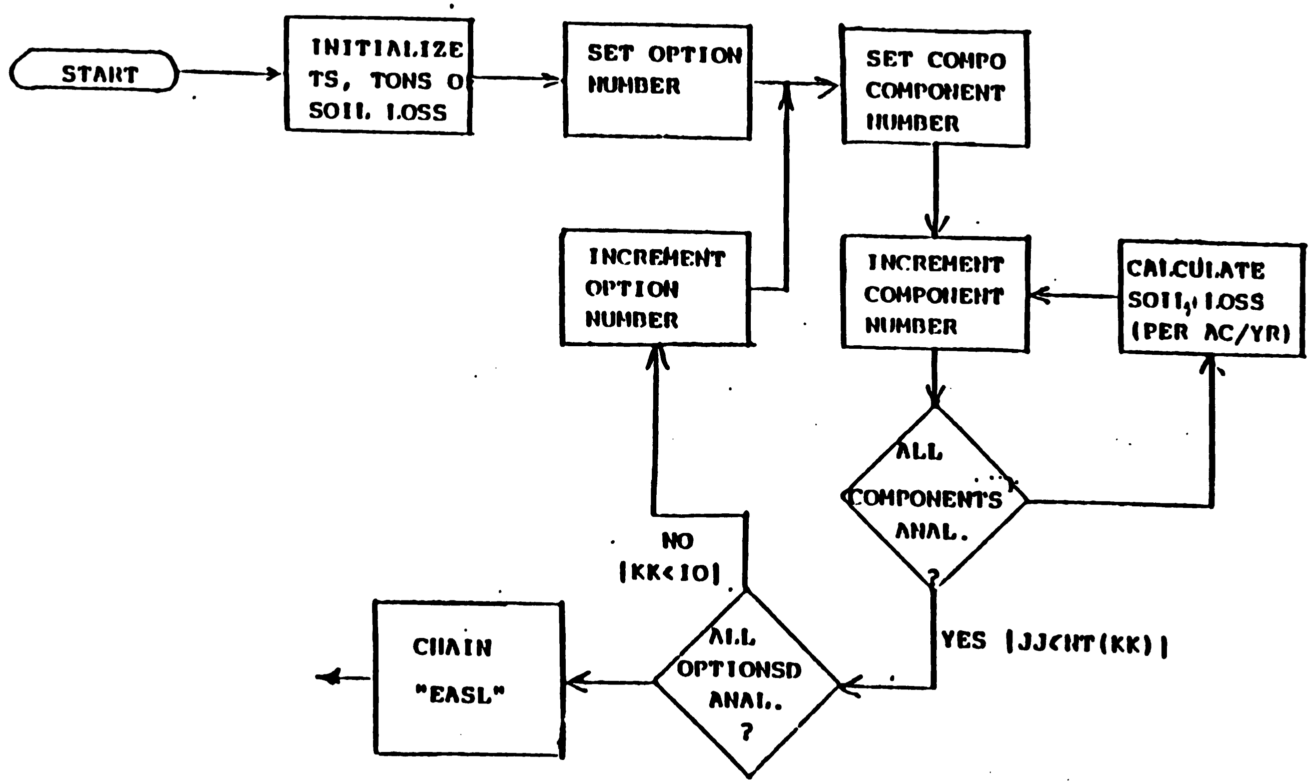

Figure 4.3 - Soil Loss Calculation Program Flowchart

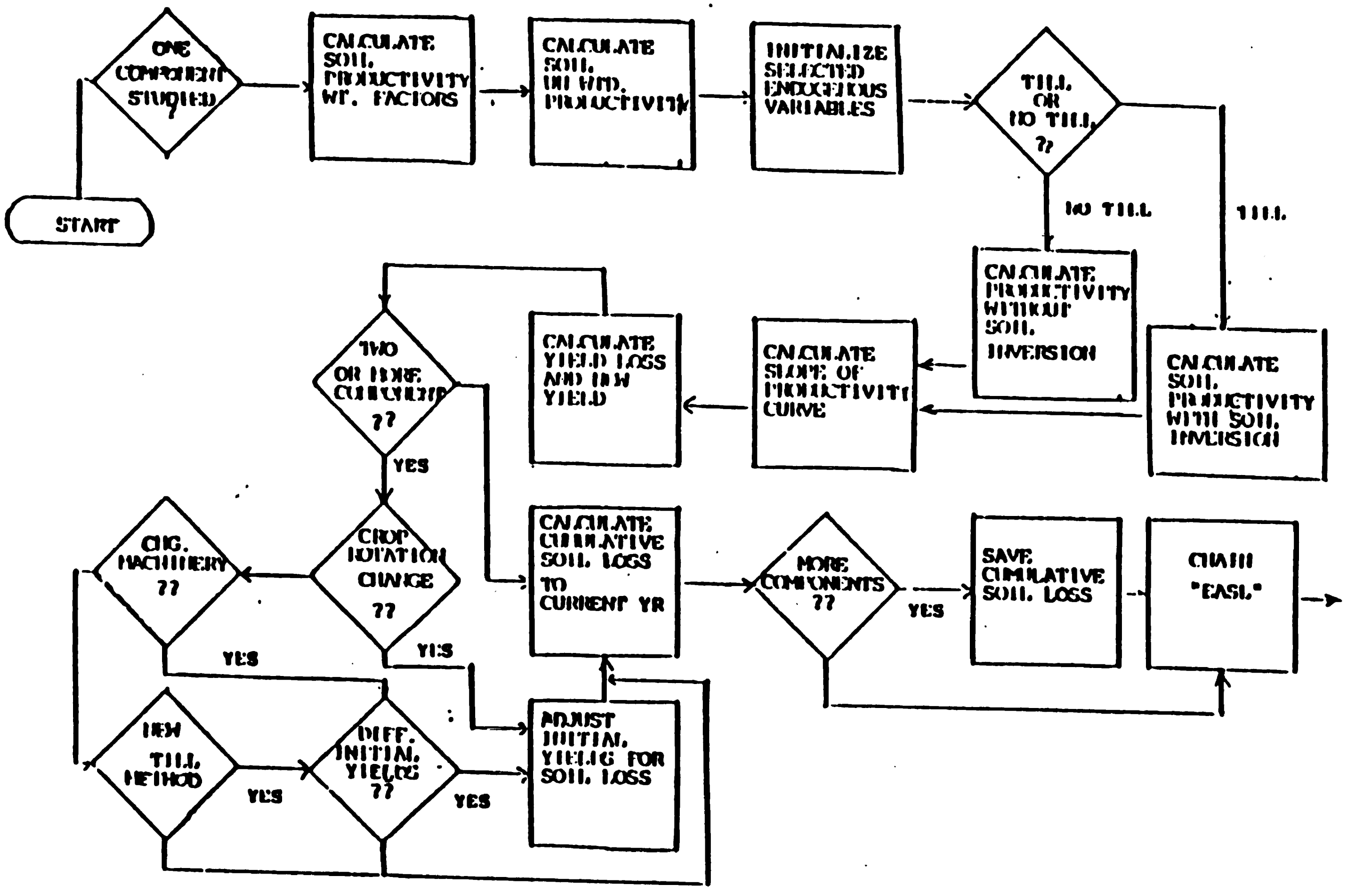

Figure 4.4 - Soil Productivity - Yield Calculation Program Flowchart

calculation of the weighted productivity for a given soil depth in the root zone. After the weighting factors are determined, the sufficiency of bulk density, sufficiency of soil reaction, and the sufficiency of available water in the horizon being studied are determined. These parameters are determined by comparing selected SOILS - 5 information to various critical values contained in DYNSDSP. The product of these terms determines the unweighted productivity by horizon.

Next, the weighted productivity is determined for the horizon(s) within which tillage and rooting are occurring. When soil inversion occurs, the model determines the horizon(s) contained within the 15cm plow depth, and adjusts the weighted productivity if more than one horizon is involved. Once the weighted productivity is known, the slope of the productivity curve is determined for the horizon being studied. This is, in part, dependent on the number of years it would take to deplete the horizon given the annual rate of soil loss and initial soil depth. In principle, the productivity curve is a piecewise linear function in yield - time space. As soil erosion occurs, the model shifts the 100cm rooting zone down into lower horizons. Therefore, the productivity of a given horizon at a point of time is partly a function of past soil loss.

DYNSDSP has memory in two ways. First, if the current year happens to also be (1) the last year for which a particular crop system is practiced, and (2) a new crop system will be adopted next year, and (3) the yields for each crop in the crop sequence differed under the two crop systems, the model adjusts the initial yields for each crop to reflect the soil loss which has occurred from t=0 to the beginning of the current period. If the initial yields are identical, the model simply starts with the yield at the end of the previous period. Another way in which the model has memory is in the determination of soil loss. In any given year, the variable which indicates soil loss actually indicates the cumulative loss which has occurred. When a transition occurs between systems, the amount of soil lost up to that point in time is saved and added to the annual soil loss which occurs under the new crop system. When all the above calculations are performed for a given year, computing returns to EASL.

4.3.2.4 Input Use Program

Figure 4.5 depicts the input use (IU) program. Within this program, the annual use, and cost, of pesticides, fertilizer, seed, potassium, and phosphate are calculated. Labor and maintenance inputs are determined in the machinery model which determines the machinery complements.

These inputs whose use is dependant on a crops' yield are modeled as a constant times yield. This constant returns to size assumption may need modification. Both the quantity and total variable cost of these inputs are determined by combining (a) yield, (b) cost per unit for each input, (c) application rate for each input, and (d) percent of each acre planted to each crop. Appendix A presents and discusses how the application rates were determined.

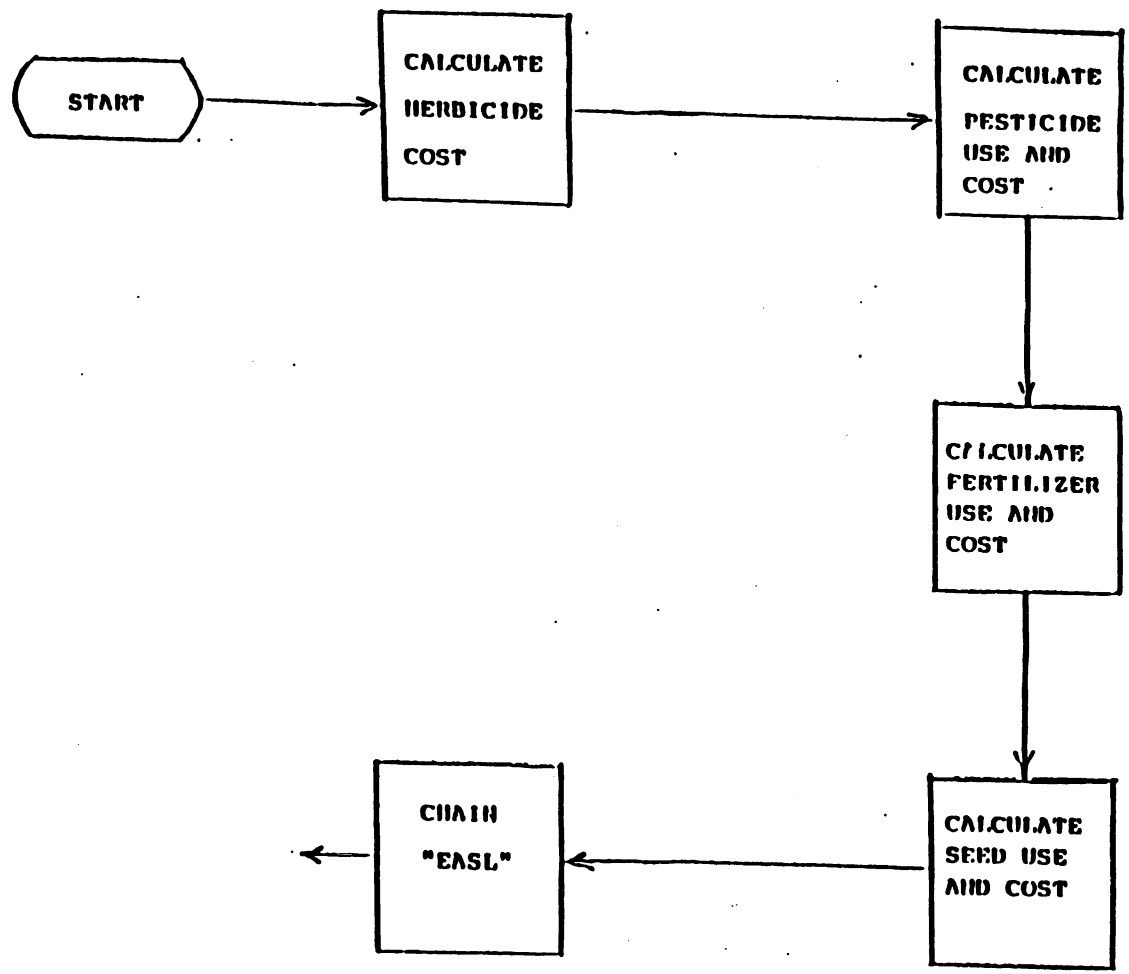

Figure 4.5 - Input Use Program Flowchart

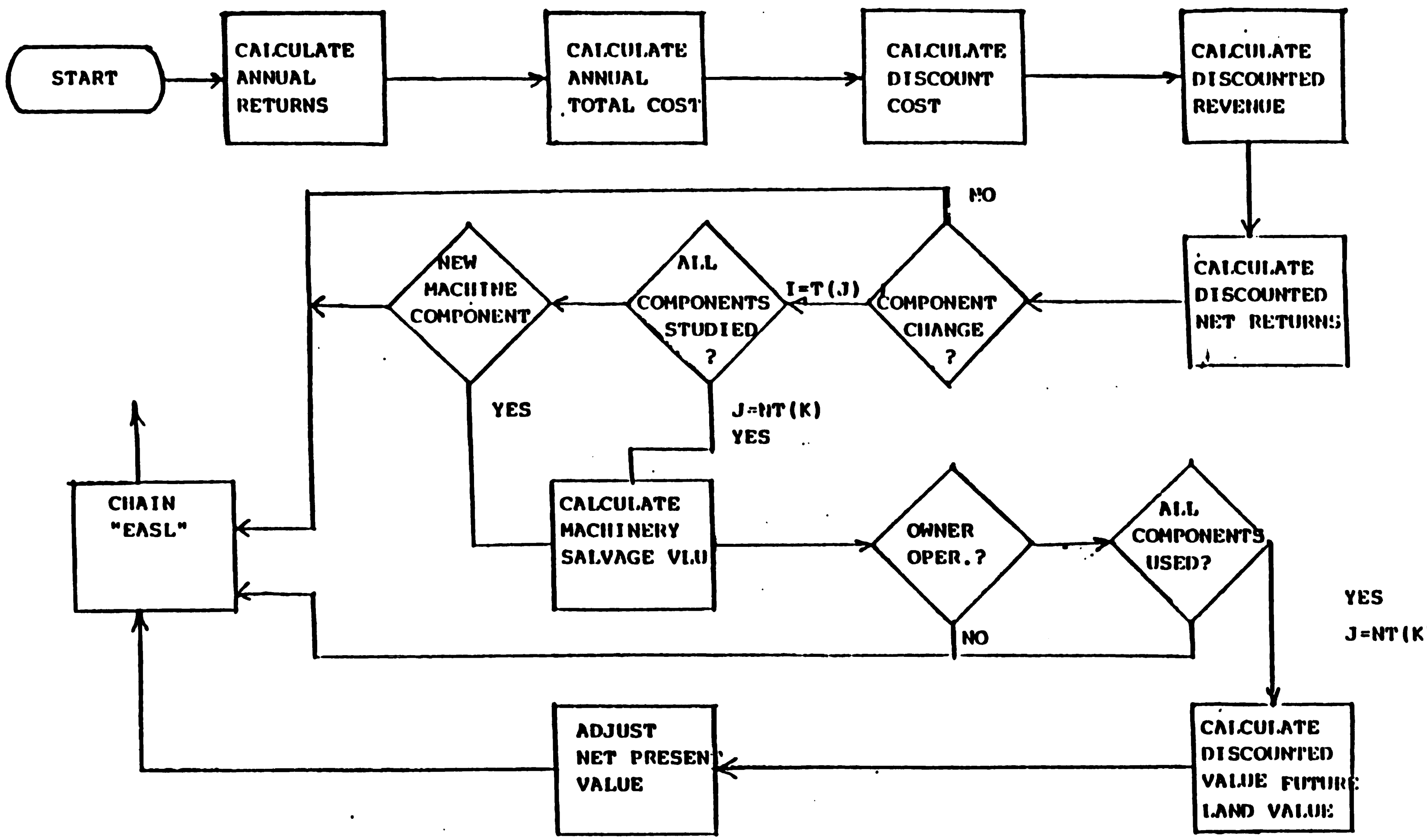

Figure 4.6 - Economic Analysis Program Flowchart

4.3.2.5 Cash Flow Program

Since the decision maker is assumed to select an option based on maximum profit, there must be some way to calculate the profit of each option and compare it to the profit of any competing option(s). Figure 4.6, which illustrates the ACCT program, performs this function.

Both annual returns and total costs are calculated by crop within the crop sequence, for each year in the time horizon. Annual total cost is the sum of annualized per acre fixed cost for the machinery complement, annualized machinery dependent variable cost for labor, fuel, and maintenance, and the annual cost for the variable inputs calculated in the IU program. These costs are all on a per acre basis.

After the net return for a given year is determined, it is discounted using the corresponding discount factor, using continuous discounting. The discounted annual returns are then summed for each crop system within each management option. When new equipment will be used next period, or when the end of the planning horizon is reached, equipment salvage value is calculated and added to NPV. Also, if the decision maker is an owner - operator, the future value of land is estimated, discounted, and added to NPV. When all calculations have been performed, computing returns to EASL .

4.3.2.6 Write Program

The WRITE program, depicted in Figure 4.7, is called after all the crop systems for a given management option have been

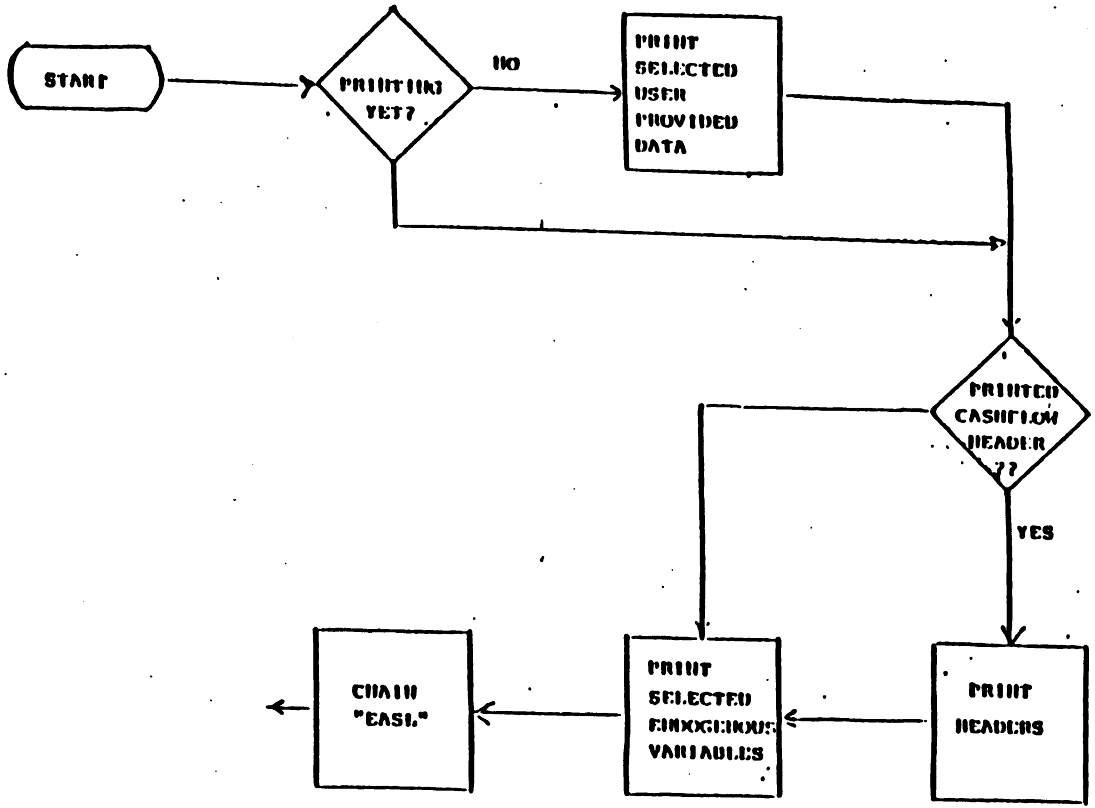

Figure 4.7 - Output Program Flowchart

evaluated. First, user provided data which are independent of any particular crop system or management option are printed. Next, crop system specific data, which are user provided, and selected endogenously calculated data are printed. At this point, the annual (1) crop yield(s), soil loss, productivity, gross revenue, total cost, and discounted net returns are printed for each year in the manager's time horizon. The last value to be printed is the NPV of the options which were analyzed.

4.4 Summary

First, the contributions which this empirical model makes to the study of the on farm economics of selected methods to control soil loss were discussed. Contributions were made to the study of inter-dependent cash flow problems, comparing systems not in a steady state, endogenizing the use of selected variable inputs, the ability to study ID problems under alternative ownership structures, and including returns to land in crop system decision making.

Second, a macro overview of the simulation model was presented. Part of the overview included a discussion of the relation between the structure of the simulation model and the analytic model developed in Chapter Three. Each of the individual programs was discussed in general terms and a flowchart was presented for each program, and program sequencing was discussed.

CHAPTER FIVE

ANALYSIS OF ALTERNATIVES

5.1 Introduction

This chapter will first present the alternative scenarios which are analyzed. Part of this discussion will focus on why these scenarios were selected. Next, the results of the analysis will be presented.

5.2 Alternative Scenarios

Two areas in Michigan were selected for analysis. One area is in the Southeast part of the lower peninsula, and is often referred to as the "Thumb Area." In this area, the land tends to be fairly flat, with deep, fertile, soils. Soil loss attributable to water run-off is not much of a problem in this area. The other area studied, St. Joseph's County in Southwest Michigan, contains much more rolling terrain, with varying soil depths, and a higher erosion potential. These two areas are assumed to represent a range of erosiveness and soil depths.

Table 5.1 lists the characteristics of the scenarios which were studied. A scenario is comprised of (a) crop rotation; (b) machinery, denoted either by conventional (moldboard) or conservation (chisel plow); (c) tillage method, either straight up/down the field, or contouring; (d) CP factor, which is a parameter in the calculation of soil loss, and is a function of the type of tillage equipment, crop rotation, when plowing occurs, and how much residue is left; (f) the number of components, where a component was previously defined as one crop system; (g) the planning period of the decision maker; (h) the length of time a particular component is held; and, (i) the discount rate of the decision maker.

Two crop rotations were analyzed for each area. They were selected to represent rotations common in each area. As was indicated in the previous chapter, the machinery complement was developed using Muhtar's machinery complement model. His model selects a moldboard plow for the conventional complement, and a chisel plow for the conservation complement.

Two tillage practices are included. Either up/down or contour plowing may be selected. The up/down plowing alternative was included to obtain some information on how a crop systems' profitability changes with a move to contour plowing. This will allow separation of profitability changes attributable to the type of plow used and the type of tilling pursued.

Chemical usage for each crop rotation - machinery mix combination are presented in Appendix A. The chemical regimes were developed with the assistance of Agronomists and Entomologists at Michigan State University.

The results can only be used to compare the profitability of one scenario. No significance is to be attributed to the absolute amount of profit for any one scenario.

5.3 Saginaw Results

Referring to Table 5.1, scenarios one through eight represent analysis conducted in the Saginaw Bay area. Table 5.2 presents net present values (NPV) for these cases. Recall that the NPV's represent the discounted net return per acre from the beginning of the analysis to infinity, and that significance can only be attributed to their relative magnitudes.

As the results in Table 5.2 indicate, in all the cases evaluated, the conventional tillage system results in a greater per acre net return than all comparable conservation systems. Muhtar's study of the relative economics of conventional and conservation systems in the Saginaw area indicate that the conservation system had higher net returns than the conventional system. Two important differences between his analysis and the present analysis are (1) his model could not capture the intertemporal soil productivity relation, and (2) in his analysis the herbicide programs were assumed to remain constant.

The latter point turns out to be particularly critical in the cases evaluated. Referring to cases one and two, the reader will note, referring to Table A.2, that the capital cost of the conventional system was $1.25 per acre cheaper than the corresponding conventional system. In addition, the fuel, labor, and timliness costs were $5.45 less for the conservation system than they were for the corresponding conventional system. Comparing the herbicide program for the two systems, the per acre cost for both corn and navy beans is greater under conservation tillage than the conventional system.

Table 5.1

Characteristics of Alternative Scenarios

Option	Crop Rot.	Machinery Comp.	Till Method	CP Factor	Disct. Rate	No. Comp	Yrs. Held
1	C/NB[1]	CVT[2]	UP/DOWN	.49	8.125	1	25[3]
2	C/NB	CON	UP/DOWN	.32	8.125	1	25
3	C/NB	CVT	CONTOUR	.49	8.125	1	25
4	C/NB	CON	CONTOUR	.32	8.125	1	25
5	C/NB	CVT	UP/DOWN	.52	8.125	1	25
6	C/NB	CON	UP/DOWN	.32	8.125	1	25
7	C/NB/SGB	CVT	CONTOUR	.54	8.125	1	25
8	C/NB/SGB	CON	CONTOUR	.44	8.125	1	25
9	C/C/SYB	CVT	CONTOUR	.37	8.125	1	25
10	C/C/SYB	CON	CONTOUR	.26	8.125	1	25
11	C/C/SYB	CVT/CON	CONTOUR	.37/.26	8.125	2	10/15
12	C/C/SYB	CVT/CON	CONTOUR	.37/.26	8.125	2	5/20
13	C/C/SYB	CVT/CON	CONTOUR	.37/.26	8.125	2	15/10
14	C/C	CVT	CONTOUR	.3	8.125	1	25
15	C/C	CON	CONTOUR	.17	8.125	1	25
16	C/C	CVT/CON	CONTOUR	.3/.17	8.125	2	10/15
17	C/C	CVT/CON	CONTOUR	.3/.17	8.125	2	15/10

Notes: 1/C=Corn, NB=Navy Beans, SGB=Sugar Beets, SYB=Soybeans.
2/ CVT=Moldboard Plow, Con=Chisel Plow. When a slash appears, this indicates that the type of plow used is switched during the 25 year planning horizon.
3/This indicates the number of years each component of a management option is held for.

This cost differential more than overcomes the conservation systems' lower cost for fuel, labor, and timliness. It still could be the case that the conservation system would result in a greater NPV than the conventional system, but for this to occur, the intertemporal yield differentials must be great enough to overcome the per acre cost disadvantage of the conservation system. Since yields do not fall fast enough under the conventional system vis-a-vis the conservation system, the end result is a higher level of profit for the conventional system. This same analysis can be applied to a comparison of the results of options three with four, five with six, and seven with eight.

These results also indicate that there is no justification for finding the year in which a producer would shift from a conventional to a conservation system. The producer can do no better than he/she does by using the conventional system from the beginning, under the cases studied.

One question which is reasonable to ask is how sensitive might the results be to a greater difference in potential erosion between systems? Comparing scenarios five with six, you can see from Table 5.1 that the CP factor, which is a function of tillage system, and crop rotation, and is used in the USLE calculation of soil loss, for these alternatives are .52 and .32, respectively. This is an increase in erosion differential between the conventional and conservation systems of about 50 percent, when compared to alternatives one and two. For the alternatives analyzed, this is probably the most erosive set of conditions. As Table 5.2 indicates, even here the NPV of the

Table 5.2

Cash Flow and Soil Loss - Saginaw Scenarios

Option	Soil Loss (Tons/Acre/Year)	NPV ($/acre/year)
1	3.06	4574.07
2	2.18	4386.80
3	1.53	4600.03
4	1.09	4352.69
5	3.24	4568.18
6	1.44	4402.18
7	3.37	7651.14
8	2.75	7584.91

conventional system, $4568.18, is greater than the conservation system, $4402.18.

Changes in the discount rate, either higher or lower should not have any effect on the relative positions of the options which were studied. This prediction follows from the observation that the yield differential across systems across time is not significant enough to result in annual net return patterns which are different enough to allow the discount rate to affect option rank. This prediction may not hold when tax based subsidies are provided to encourage adoption of chisel plow systems.

Lastly, one might ask how sensitive the results might be to the herbicide program. Here, in fact, is where one might expect that the ranks might change given different assumptions about the herbicide programs. For example, the greatest difference between NPV values occurs when one compares the NPV of options three with four, a differential of $217.34. In this case, these systems would have the same NPV if annual conservation system costs, were $17.66/acre lower.

It should be noted that the analysis assumes that transition costs are zero. If there are any costs of moving from conventional to conservation plowing, either because costs of the latter system being higher than assumed or yields are lower, the conservation system will be even less attractive.

5.4 St. Joseph's Results

Turning to the results for the St. Joseph's area, one should expect to observe the effects of differential soil depletion across systems exerting more effect of options rank. Since the soils in this area are more erosive than those in the Saginaw area, a switch from a more to a less erosive crop system should exert a greater influence of system cash flows, ceteris paribus. Therefore, the relatively higher chemical costs for the conservation system should be able to be more easily counteracted by the higher productivity of the conservation system than was the case in the Saginaw area where the soil was not very erosive.

Turning back to Table 5.1, scenarios 9 through 17 represent cases analyzed in the St.Joseph's area. Profit and soil loss results are presented in Table 5.3.

One striking result, indicated in Table 5.3, is the comparison between the NPV of the conventional system in scenario 9 ($2843.45), with that in scenario 10, ($3188.42). What this result suggests is that it is at least worth conducting an analysis of when to switch systems, since the NPV of the conservation system excedes that of the conventional system.

Looking at scenarios 11 - 13, the period of switch from the conventional to the conservation system is varied from year 5, to year 10, to year 15, respectively. The earlier that the switch occurs, the closer is the level of NPV to that for option 10, which corresponds with holding the conservation system from the beginning of year one. What these results tend to suggest is that the earlier that the trade occurs, the more profitable it will be.

One way to look at the results in Table 5.2 is to compare the profitability of alternative crop systems for a given type of tillage. For example, comparing the profitability of scenarios 9 with 14, we see that a shift from a corn-corn-soybean rotation to a continuous corn rotation reduces soil erosion by 3.36 tons/acre/year, and increases profit by $114.54/acre, which corresponds to an annual average increase of $9.31/acre/year. e closer together, ceteris paribus.

Referring back to scenarios 9 and 10 again, one issue that the relative NPV's raises pertains to the magnitude of any transition costs. Calculating the difference in the NPV of these two scenarios, and analyzing this figure, one notes that

Table 5.3

Cash Flow and Soil Loss - St. Joseph Scenarios

Option	Soil Loss (Tons/Acre/Year)	NPV ($/acre/year)
9	17.76	2843.45
10	12.48	3188.42
11	17.76/12.48	3122.32
12	17.76/12.48	3060.97
13	17.76/12.48	3024.26
14	14.40	2957.99
15	9.12	3107.80
16	14.4/9.12	3192.68
17	14.4/9.12	3171.03

break - even is attained if the NPV of scenario 10 declines by an annual average amount of $ 28.04/acre. This difference could arise in a number of ways. Considering the fact that conservation systems require a higher level of management skill, it could be the case that the potential yields generated by the model overestimate actual yields due to a learning curve effect. Also, there may be other opportunity costs associated with switching management practices.

Comparing the NPV's for scenarios 9 and 14, at $ 2843.45 and $ 2957.99, respectively, it could be argued that this is the value of using a less erosive crop rotation, keeping the tillage method and practice constant. Shifting to continuous corn from orn - corn - soybeans reduced the annual erosion by 3.36 tons/acre/year. The profit increased by

$114.54/acre, or an annual average of $9.31/acre/year.5.4

5.5 Conclusions

First, given the assumptions of this analysis, there appears to be little reason for farmers in the Thumb area to consider adopting a chisel plow system, if the decision is based solely on relative profitability. In the options studied, no chisel plow system had a higher level of profit than the corresponding moldboard plow system.

Second, given the assumptions of this analysis, the chisel plow system is more profitable than the corresponding moldboard plow system in the St. Joseph's area. It was also the case that the sooner the chisel plow system was adopted, the higher was the level of profit.

Third, while the analysis (a) was before taxes, and (b) assumed hat all costs and prices were constant in relative terms, the relative pattern of results should be invariant to relaxation of these assumptions, except for the introduction of subsidies for the use of chisel plow systems. Again, while the estimates of NPV were interpreted as profit estimates, they are not to be interpreted as returns to land in either the Saginaw or St. Joseph's areas. Taxes were not included, the discount rate used may be different than a potential investors weighted average cost of capital, and the NPV figure includes other returns to the current owner which would not be included in a prospective purchaser's bid price calculation.

CHAPTER SIX

SUMMARY AND CONCLUSIONS

6.1 Introduction

First, the literature review will be summarized. Next, the reformulation of interdependent cash flow models will be summarized. Following this will be a review of the simulation model. Finally, the empirical results will be summarized.

6.2 Literature Review

Chapter two presents a review of both selected disciplinary principles which address the issue of how to decide when to trade assets and empirical studies of the relation between soil loss and returns to the farm enterprises. It was argued that most of the analytic frameworks which address the problem of asset cash flows are independent of one another. One model was presented which was implicitly designed to include in ID decision making an additional component of opportunity.

6.3 Decision Making with Interdependent Cash Flows

An existing decision making model, developed by Walker, was reformulated in order to correct for several flaws in his model. First, the one transition problem was addressed, and then the multiple crop system switch problem was addressed. It was argued that the same framework can be used to study crop system switching from either the owner operator or tenant's perspective. Finally, it was argued that the framework used to determine when to switch tillage complements could also be used to study other changes in a crop system which will affect the pattern of intertemporal cash flows.

6.4 Simulation Model Formulation

A modified version of a simulation model developed by Pierce - Larson et. al. was further modified for use in this analysis. Using the parts of the model which calculate annual crop yield, a modified set of economic calculations was added to the model. This new model (a) calculates the use of some inputs based on yield, (b) can address the question of when to switch crop systems, and (c) selects a system or sequence of systems based on the relative economics of competing systems as opposed to comparing the economics of a soil depleting system to one assumed to be in a steady state.

It was noted that the model is written in ADVANCED BASIC, and is composed of four sub-programs. These sub-programs calculate (1) amount of selected variable inputs used, (2) annual soil loss, (3) annual crop yield, (4) annual cash flow, and selected discounted values. An input data and output program is also included.

6.5 Empirical Analysis

Chapter 5 noted that two areas were selected for study. One area, Saginaw County, contained less erosive soils, and the other area, St. Joseph County, contained more rolling, erosive, soils. Two tillage systems were modeled, a moldboard and a chisel plow system. Two crop rotations for each area, representing crop rotations could in that area, were assumed in the analysis.

In all cases studied for Saginaw County, the moldboard plow systems resulted in a higher net present value (NPV) than any comparable chisel plow system. Turning to St. Joseph County, there were some cases where the NPV for the chisel plow system exceeded the NPV for the comparable moldboard plow system. For these cases, the NPV of the combination increased the earlier a switch occured. Finally, the results suggest that correct specification of the pesticide-herbicide regime was particularly important to the relative economics of moldboard versus chisel plow systems.

6.6 Conclusions

While the empirical analysis in the previous chapter is not very exhaustive, it does convey some information about the relative profitability of competing crop systems under a range of soil erosion conditions. One result of that analysis is that even after accounting for intertemporal productivity and differences in recommended pesticide/fertilizer regimes, the change in capital costs between the conventional system and conservation system must be sufficiently different in order for the crop system using conservation tillage to be profitable in low erosion potential areas. In low erosion potential areas, the gain in discounted revenues arising from using a less erosive machinery complement is at least partially offset by the higher variable costs associated with increased pesticide/fertilizer applications. When positive transition costs are included, the less erosive machinery complement will appear even less attractive, from a profit maximizing perspective.

In low erosion areas, target subsidies may have their greatest impact on changing an investor's go-no go decision. It is also the case that a given subsidy will likely "buy" less soil loss reduction here than in a more erosive area. In more erosive areas, a subsidy may be (1) a rent to the potential investor, and/or (2) an inducement to adopt at an earlier point in time. Further, the subsidy can also be viewed as compensation for the investor's lack of information about the economic success of a conservation tillage machinery complement. Clearly, there is ample grist here for anyone's political mill.

One question for policy is whether to offer subsidies to farmers where the economic incentive to adopt conservation tillage may not exist, or to offer subsidies where soil loss reductions may be greater, but where farmers may already have an incentive to adopt conservation tillage. Current discussions on targeting focus on allocating cost share funds to areas with the greatest soil loss. These are also the situations where farmers have the greatest incentive for voluntary adoption, ceteris paribus. This leaves three alternative justifications: to induce earlier adoption, to compensate for any perceived increased riskiness of conservation versus conventional tillage, and to serve as a proxy for the value of mitigating off-site impacts. A related policy issue pertains to determining whether or not any soil savings are of sufficient value to society to compensate for any rents conferred on farmers.

Analysis in Chapter Five also suggests that conservation tillage does not always pay. While soil loss is lower, and therefore, discounted gross revenues are higher, pesticide and fertilizer expenditures also tend to be higher. The question then becomes whether or not the present value of revenues minus operating costs is greater than the sum of (1) any increased capital cost of the conservation system, (2) any transition costs, and (3) the farmer's risk premium associated with moving to a management system which may be perceived as being riskier. Since this research assumes away the latter two costs, which in reality are probably positive, the issue is whether or not the present value of revenues minus operating costs compensates for the higher capital cost of the conservation tillage system. In the cases analyzed, the answer was no in the area of low soil erosion potential. Unless there is some paticularly unique aspects of the off-farm enviornment it would be relatively more difficult to justify subsidies as a bribe to farmers, in these areas, to reduce their rates of soil loss.

Another observation from results in Chapter Five is that when the value of increased future soil productivity attributable to lower current erosion is included in the analysis, some farmers have an incentive to act in a manner consistent with reducing off-site impacts of soil loss. That is, there is a limit to which the farmer's interests are served by mining the soil. This limit will tend to increase with increases in net returns, to the less erosive crop system. In turn, this would tend to suggest that the allocation of cost share funds should perhaps also be affected by income level.

The analysis conducted in this research does not provide information for such a global question as: what is the correct government policy? What this research does represent is a further step towards a more complete formulation of the investment problem from the individual investors' view. In a world of voluntary adoption, this is the relevant unit of analysis.

Finally, there are some specific conclusions from the analytical model and analysis. These are presented below.

First, concerning the development of the analytic model, it is important to distinguish between the one trade problem and the multiple switch problem, at this level of sophistication. With the one trade problem, a piecewise linear solution algorithm can be used to solve the problem which does not require exhaustive enumeration, as does the multiple switch problem.

Second, given the simplicity of the algorithm used in this model to solve the problem of which set of crop systems to use, the analyst must pay particular attention to the set of management options which are selected for consideration. Taking into consideration that one management option can be differentiated from another by (a) number of crop systems, (b) differences in switch years, (c) types of crop rotations, and (d) types of tillage equipment, how good a selection is made depends, in part, on how good the set of management options is from within which one is choosing.

Third, in Saginaw County, the moldboard plow systems had higher NPV's than their comparable chisel plow systems. Since the capital cost of the moldboard and chisel plow systems were nearly identical, it was the relative yields and the pesticide-herbicide regimes which exerted the greatest effect on the relative profitability of competing systems. Fourth, for St. Joseph County, some crop systems using the chisel plow had a higher NPV than the comparable crop system using the moldboard plow. For these cases, the joint profit of a moldboard-chisel plow combination approached the profit level of the system using the chisel plow from $t=t_0$, the sooner the chisel plow system was adopted. Therefore, it was always better to use the chisel plow system from the beginning, rather than switching to it later.

Fifth, the model developed in this research, and the existing version of the Pierce et. al. model used by ERS, are not adequate for policy analysis where accurate profit estimates for a particular system are required. This is because (a) both the model used in this research and ERS'model omit many financial and tax parameters important to a financial analysis of competing crop systems; (b) this analysis assumed that real prices would remain constant in relative terms; and (c) ERS' model calculates the maximum amount that a farmer can invest in a chisel plow system by comparing the cash flows for a moldboard plow system and a hypothetical system assumed to be in a steady state.

CHAPTER SEVEN

FUTURE RESEARCH DIRECTIONS

7.1 Introduction

Based on the prior six chapters, what suggestions can be made regarding issues for future research? Referring back to chapter one, one goal of this analysis was to identify a set of issues which could comprise a research agenda in this subject matter area.

For purposes of discussion, future research directions are segmented into: (1) model structure and development, and (2) data base development. Further, model structure issues are limited to advancing the sophistication of simulation approaches.

7.2 Model Structure Development

Four research areas are: (1) incorporating tax/financial structure in the model, (2) expanding the range of activities a producer may pursue, (3) inbedding equipment selection in the productivity analysis, and (4) including weather in the analysis to a greater extent than is currently the case. Each of these points will be discussed below.

7.2.1 Incorporating Tax/Financial Structure

This may be the most important extension which could be made to the modeling of this problem. Issues of capital availability, after tax cash flow, after tax profit, depreciation,and other financial parameters are important to the decision making process. In turn, policy analysis is improved when based on after tax profit because of the relation between after tax profit and the ability to invest. Even if the relative profitability of any two or more alternatives remain the same after tax as before tax, shifting to an after tax analysis may be important for policy analysis when policies, such as subsidy levels, are being considered. If the relative magnitudes change after tax as compared to before tax, there is an even greater need to use an after tax analysis.

7.2.2 Expand the Range of Possible Activities

At present, the various simulation models have implicitly assumed either that (a) the producer does not engage in any other activities, or (2) the producer's cash flow from other activities is separable from the investment and returns from the cropping activities being studied. At the very least, this limits the applicability of the simulation approaches to producers who are not vertically integrated forward or backward.

One possible extension would be to explicitly allow for interdependent cash flows between operations. For example, this would allow the analyst to endogenize a livestock enterprise and study the relation between changes in the crop enterprise and the livestock enterprise. Some of the existing LP models which were reviewed in chapter two already have dealt with this issue.

Another extension of this analysis would be to allow for stochastic cash flows and to study the problem of asset investment/disinvestment in a portfolio theory context. One contribution of this type of extension would be to characterize the capital allocation process of the decision maker in a broader context.

One additional extension would be to allow for a broader range of enterprises in the farm operation. While the current analysis includes some horizontal integration, producing corn and soybeans for feed, for example, vertical forward integration into storage, transportation, and livestock activities would be some possibilities.

Extending the analysis in this way may be important for several reasons. First, the issue of capital allocation in a portfolio theory context, as was discussed above, may lead to different results concerning partial allocation. Second, to the extent that alternative crop rotations are affected by livestock operations, a shift in machinery and/or crop sequences which would be desirable from the view towards soil loss are separable cash flows, may in fact not be desirable from the expanded whole farm perspective.

Third, the present model cannot be used to analyze the relative economics of switches in crop rotations during the time horizon the decision maker. While the model has been constructed to address this possibility, the data are not available as to how the machinery complement may change. Currently, studying switches in crop rotations also requires that the machinery complement be traded. This arises because MACHSEL generates different machinery complements for the crop sequences studied, ceteris paribus. Information needs to be compiled on how the machinery complement may change, given a change in crop rotation.

7.2.3 Endogenize Equipment Selection in the Productivity Analysis

One limit to all the simulation modeling approaches is handling the machinery complement. Selecting the appropriate mix and size of machines is an input to the model which performs the productivity analysis. Then, the selection of a machinery complement occurs via the selection of the most profitable crop system, based in part on the productivity model. It is not necessarily the case that the type and/or size of the machinery mix which corresponds to the optimal crop system, as it is presently selected, is the same as would be selected based on net cash flows derived based on the productivity model. There doesn't appear to be any way to say, apriori, how the equipment sizing/selection may change.

7.2.4 Endogenize Weather

Setting aside both the EPIC model and Muhtar's model, in both the ERS model and the model developed by this author, weather is deterministic. Weather is accounted for only through the use of long run rainfall parameters in calculating soil loss. Including weather is important for the impact it can have on actual crop yields as this is affected by the soil type, machinery complement, and crop residue.

7.3 Data Base Development

Three areas where data can be improved are: (1) the relation between crop rotation/ tillage method/ and pesticide - fertilizer regime, (2) the relation between crop rotation/ tillage method/ soil type and initial yield, and (3) the cost, process, and decision making involved in the decision to adopt some soil conserving practice. Each of these points will be discussed below.

7.3.1 Crop Rotation, Tillage Method, Pesticide - Fertilizer Regime

Based on this authors' research, the pesticide - fertilizer regime assumed to be used with various crop systems can be a very important determinant of the relative economics of conventional versus conserving systems. There appears to be controversy among various researchers in this area concerning what pesticide - fertilizer regime to assume under a given set of circumstances. This should be explored not only to arrive at some consensus among researchers, but to reconcile theory with practice.

7.3.2 Crop Rotation, Tillage Method, Soil Type, Initial Crop Yield

Again, there appears to be a lack of consensus as to the relation among crop rotation, tillage method, soil type, and initial crop yield. It is particularly important to determine the extent to which conservation systems have higher or lower yields than a conventional system, <u>ceteris paribus</u>. To the extent that more pesticides and fertilizer are used with a conservation system, relative yields, become more important. As the discount rate decreases, this observation attains even more importance.

7.3.3 Cost, Transition, and Selecting a Soil Conserving Strategy

Not much is known concerning the transition process producers go through when adopting a less erosive crop system and/or structural improvement. Referring to the machinery complement, to what extent is the old equipment kept versus sold? What does the learning curve look like pertaining to achieving potential yields under the adopted system?

APPENDIX

APPENDIX

DATA

Economic analysis of alternative cropping systems which attempts to endogenize intertemporal soil productivity under a given management system requires that the analyst compile data on both the relevant economic, management, and physical parameters. One possible taxonomy of the data is the following:

1. Economic - non producer dependent;
2. Economic - producer dependent;
3. Management system; and,
4. Physical system.

The data used in this analysis, and the sources of the data are the subjects of this appendix.

Economic - Non Producer Dependent

Both the prices of selected inputs to production and outputs from production are assumed to be independent of the actions of any one producer. Table A.1 lists the input and output prices assumed in this analysis. Other inputs to the production process which are producer dependent will be discussed in the following section.

Economic - Producer Dependent

The remaining economic parameters are (1) the discount rate; (2) annualized machinery cost; and (3) timliness, fuel, and labor cost. The reader should note that if the analysis was extended to after tax from before tax, there would be additional producer dependent costs reflecting the producer's tax bracket, tax rates for all the relevant taxes, depreciation rates, and so forth.

Table A.2 lists the values of the previously mentioned parameters. As is indicated in the table, the machinery costs used in this analysis represent the annualized cost on a per acre basis. These costs are calculated by an engineering model, MACHSEL, developed in the Agricultural Engineering department at Michigan State University. As was discussed in chapter two, MACHSEL is a heuristic simulation model which searches for the approximately optimal machinery complement which minimizes the annualized cost of performing a specified set of farming practices, for a particular crop rotation, subject to a constraint on time. When a particular complement is not able to perform the operations within the time constraint, a penalty, in the form of an opportunity cost, is assessed. Adding discounted maintenance costs, discounted owner labor charges, and discounted fuel costs together, the total machine complement dependent variable cost is obtained. Dividing discounted machinery fixed cost and machine dependent variable cost, by the appropriate annuity factor and farm size, one obtains annualized fixed and machine dependent variable cost, on a per hectar basis. Since MACHSEL assumed a 200 hectar farm when generating the equipment complements, the value in the table assumes a farm size which is the acre

Table A.1

Factor-Product Prices for Inputs/Outputs whose Price/Cost are Non-Producer Dependent

Factor - Product[a]	Price ($)
Amiben	8
Atrazene	2.37
Basagran	21.05
Betamix	44.07
Blazer	37.50
Crop Oil	4.0/gal.
Dual	5.96
Eptan	2.92
Lasso	5.02
Lexone	23.90
Nortron	35.50
Pyramin	13.25
Treflan	7.0
H 273	9.74
2,4 - D	2.0
Nitrogen	.15
Phosporous	.23
Potassium	.10
Corn seed[b]	1.25
Navy bean seed	.50
Soybean seed	.28
Sugar beet seed	10.0
Corn[c]	2.78 bu.
Navy bean	22.38 cwt.
Soybeans	6.54 bu.
Sugar beets	35.47 ton

Notes:
a/All herbicide prices are adjusted to reflect the cost per pound of active ingredient. The prices were developed by David Tschirley and Gerald Schwab, Department of Agricultural Economics, Michigan State University. August 1984.
b/ Seed prices are per pound. Source:Sherril Nott, Gerald Schwab, Mike Kelsey, Jim Hilker, and Al Shapley,Estimated Crop and Livestock Budgets for 1984, Agricultural Economics Report 446, Michigan State University,February, 1984.
c/ Product prices were obtained from: Economic Research Service, USDA, Normalized Prices,Washington, D.C., October 24, 1983.

equivalent of the 200 hectar farm.

Management System Data

All of required data describe characteristics of the crop system(s) which are studied. For the purposes of this discussion, the crop system is completely described when information on the following three characteristics are provided:

1. Crop rotation;
2. Tillage method (machinery complement); and,
3. Tillage practice.

The machinery model used to calculate the machinery complement assumes that the farm's acreage is equally divided between the crops in the rotation. Since the depletion/productivity model is structured on a per acre basis, for modeling purposes, each acre is assumed to be divided between the various crops in the same fraction as is the entire farm's acreage. Table A.3 lists the various crop rotations, fraction of an acre planted to each crop, and yields. Table A.4 lists the herbicide, pesticide, and fertilizer usage by crop rotation and machinery complement. Table A.5 lists the machinery complements and tillage practices used in the analysis.

The crop rotations,machinery complements, and soil series were selected in response to the following guidelines:

1. Select crop rotations which are representative of rotations used in each study area;

2. Secect one machinery complement which uses a moldboard plow, and one which uses a chisel plow;

3. Select a soil series which is representative of the soil characteristics found in the study area;

Table A.2
Producer Dependent Factor Prices

	Equipment Dependent Costs[c] Conventional	Conservation
	----------Machinery Costs-----------	
C/NB[d]	76.57	75.23
C/NB/SGB	96.00	92.96
C/C	77.98	72.28
C/C/SB	66.89	66.98
	---------Fuel, Labor, Timliness-------	
C/NB	23.34	17.79
C/NB/SGB	27.60	23.98
C/C	20.49	17.60
C/C/SB	26.22	24.95

Notes: a/ Equipment dependent costs are obtained from a Tillage report prepared by the Department of Agricultural Economics and Agricultural Engineering, Michigan State University, Summer 1984.
b/ Rate used to evaluate public projects, published by the Water Resources Council.
c/ All cost are annualized cost on a $/acre basis.
d/ C=Corn, NB=Navy Beans, SYB=Soybeans, SGB=Sugar Beets. C/NB denotes a corn-navy bean rotation. All other rotations can be similarly interpreted.

4. Make sure that there is compatibility between the selection made in response to the above four points;

5. Be sure that the selections above can be analyzed, which requires that there exist the necessary informatio on the soil, on soil erosion, on yield, and on input use for those inputs listed in Table A.4.

Physical Systems Data

Since the relative economics of alternative management practices depend in part on the nature of the underlying physical system, it is important to be specific about what is being assumed about that system. Some of this information is contained within the computer model and is invariant to the selection of a crop system. Other pieces

Table A.3

Crop Rotations, Acerage Allocation, Initial Yields

Rotation	Percent Ac.	C[a] (bu)	NB (cwt)	SYB (bu)	SGB (ton)
Saginaw County					
Conventional					
C/NB	50/50	115	13	-	-
C/NB/SGB	33/33/33	115	13	-	21
Conservation					
C/NB	50/50	115	13	-	-
C/NB/SGB	33/33/33	115	13	-	21
St. Joseph County					
Conventional					
C/C	50/50	105/100[b]	-	-	-
C/C/SYB	33/33/33	115/105	-	38	-
Conservation					
C/C	50/50	100/100	-	-	-
C/C/SYB	33/33/33	115/100	-	38	-

Source: Data compiled by David Tschirley in conjunction with Don Christianson. Departments of Agricultural Economics and Crops and Soil Science, respectively. August 1984.
Notes: a/C=Corn, NB=Navy Beans, SYB=Soybeans, SGB=Sugar Beets
b/ A/B: A = yield of corn in first year; B = yield of corn in the second year for corn.

of information are dependent on either the crop system and/or soil being studied. Two blocks of information must be user supplied:

1. Physical system and crop system parameters used to calculate soil loss;

2. Selected characteristics of each horizon in the soil profile of the soil series being studied.

The second block of information is used in calculating the productivity index of each horizon in the soil profile, and the annual rate of soil loss. Data which are required to calculate the annual rate of soil loss correspond to the parameters of the Universal Soil Loss Equation. These parameters are:

R = Rainfall factor;
CP = Crop rotation/Farm practice composite factor;
LS = Field slope/Slope length composite factor;
TP = Tillage practice factor.

Several of the parameters need explanation. First, the Cp factor is a function of (a) crop rotation; (b) tillage method; (c) when tillage occurs using a mold board plow, (d) whether residue is removed or not, and (e) the amount of residue (lb/ac) left on the field when chisel plow is used. Table A.5 presents the assumptions underlying the CP factors used in the analysis.

Second, the LS factor is read off a graph which correlates slope length and percent slope and indicates a particular LS factor. The percent slope which is used corresponds to the mean of the range of possible slope for the predominant slope range for the particular soil being used in the area being studied.

Third, the TP factor is a weighting factor whose value depends on what type of plowing occurs (eg: whether straight up/down plowing is pursued, or contour plowing is used). Up/down plowing has a factor of 1.0.

Data which are used to calculate soil productivity which are situation specific are obtained from the SOILS - 5 record for the particular soil series being used. These data are: (1) depth of each horizon in the soil profile, (2) permeability of each horizon, (3) Ph for each horizon, and (4) available water

Table A.4

Herbicide, Fertilizer and Seed Use
by Crop, Crop Rotation, and Tillage Method

Conventional	Conservation
Herbicides	
Corn, except preceding sugar beets	
Lasso - 2.0	Lasso - 2.5
Atrezene - .5	Atrezene - .75
Bladex - 1.0	Bladex - 1.0
Corn, preceding sugar beets	
Lasso - 2.0	Lasso - 2.5
Bladex - 1.5	Bladex - 1.5
Navy Beans	
Eptan - 2.25	
Treflan - .5	Amiben - 2.0
Amiben - 2.0	Basagran - .75
Crop Oil - 1 qt./ac	
Soybeans	
Treflan - .75	Lasso - 2.5
Lexone - .38	Lexone - .38
Basagran - 1.5	
Blazer - .25	
Crop Oil - 1 pt./ac.	
Sugar Beets	
Pyramin - 3.0	
Nortron - 2.0	
Antor - 2.0	Same
H 273 - .5	
Betamix - 1.0	

Seed application rates[1]	
Corn	15 lb/ac
Navy beans	40 lb/ac
Soybeans	45 lb/ac
Sugar beets	1 lb/ac

	Phosphate[1]	Fertilizer[1]	Potassium[1]
Corn (lb/bu)	.35	1.25	.27
Navy beans (lb/cwt)	.83	3.13	.83
Soybeans (lb/bu)	.9	0	1.4
Sugar beets(lb/ton)	1.3	5	3.3

Sources:1/Data compiled by David Tschirley and Ted Jenne with assistance from Drs. Don Christianson and John Kells, Departments of Agricultural Economics and Agronomy, respectively, Michigan State University, August 1984.

Table A.5

Crop Rotation/Farm Practice, CP, Factors for Alternative Crop Rotations, Tillage Methods, and Geographic Locations

Rotation		CP Factor
	Saginaw County	
	Conventional	
C/NB		.49/.52[a]
C/NB/SGB		.54
	Conservation	
C/NB		.32
C/NB/SGB		.44
	St. Joseph County	
	Conventional	
C/C		.30
C/C/SYB		.37
	Conservation	
C/C		.17
C/C/SYB		.26

Note:a/ The first figure assumes up/down plowing and the second assumes contour plowing.

capacity. Except for depth, the number used in the analysis corresponds to the mean of the range of possible values for each parameter for each horizon.

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