PRODUCTION PLANNING AND INCOME VARIABILITY ANALYSIS

FOR ALTERNATIVE SAGINAW VALLEY NAVY BEAN

CROPPING SEQUENCES

By

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

In 1987 dry edible beans ranked fourth as an income source among Michigan's agricultural crops, surpassed only by corn, soybeans and apples. In this year, twenty-seven counties produced dry beans, with the Saginaw Valley and the Thumb area producing 90 percent of the State's total. Navy beans comprised 80 to 85 percent of total dry bean value (Michigan Agricultural Statistics, 1988).

Since the 1800s, Michigan has been the largest single producer of navy beans in the U.S. (Krebs, 1970). However, since 1964 the State has experienced a downward trend in both navy bean yields and acreage (Wright, 1978; Hebert et al., 1988). In addition, there is an increasing competition in the marketplace from the consolidation of navy bean producers in Canada, Minnesota and North Dakota. As a result, in the last years, Michigan's share of total U.S. and Canadian navy bean output has fallen from 75% in the 1970-75 period, to 63% in the 1980-85 period (Hebert el al., 1988).

1.2 THE PROBLEM

Acreage allocation decisions by farmers have been identified as <u>one</u> of the causes of the decline in Michigan's navy bean production (Christenson et al., 1978). Growing navy beans in successive years or in short rotations with other crops that return little organic matter to the soil has been shown to adversely affect soil structure (Robertson et al., 1976)[1], depletion of organic matter (Lucas and Vitosh, 1978)[1], and increase disease and pest problems (Anderson et al., 1975)[1]. Furthermore, Hebert and Jacobs in their review of sources of instability in the navy bean industry suggest that a large portion of the instability present in the quantity of navy beans produced, and therefore in prices and revenue, is directly related to variability in acreage allocation decisions of growers (Hebert et al., 1988).

In consequence, the problem as it is seen in this paper is one of resource allocation decisions by farmers. There is a need for defining a navy bean production strategy, which takes into consideration the overall crop production system.

Given the importance of the navy bean sector in Michigan and its continuous decline in production, this paper focuses on risk and farm planning issues associated with rotations in which this crop is grown. In addition, it investigates a

point raised by Hebert and Jacobs (1988) regarding assessing the correlation between instability of other crops in the grower's rotation with navy bean instability.

The general approach taken in this paper is that of a "system management perspective" where the goal is to determine system inputs given a system structure and a set of desired system outputs (Manetsch and Park, 1986)[2/].

1.3 RESOURCE ALLOCATION

Christenson et al. (1978) identify two types of resource allocation schemes among Michigan farmers. One is described as "haphazard", where acreage allocation decisions are made one year at a time on the basis of price expectations. This approach is a "problem-creator", and partially explains recent yield trends. The second is where farmers allocate resources to well defined cropping sequences which change little from year-to-year. Under this second approach, farm resources are seen as components of a crop production system where the objective is to exploit jointly beneficial interrelationships among individual crops. This second scheme provides benefits in that it lowers the incidence of weeds, insects and plant diseases; improves soil productivity through addition of organic matter and increases the soils water holding capability; balances the

seasonal requirements for resources; and stabilizes the level of farm profits over time (El-Nazer and McCarl, 1986; Zublema, 1987).

1.4 PREVIOUS INVESTIGATIONS

Research conducted at Michigan State University research farms has led to the identification of sixteen cropping sequences[3/] that result in higher yields than if the crops were grown continuously (Christenson et al., 1980, 1986). Hoskin (1981) ranked these rotations in terms of their relative risks and returns to the farmer. He employed a comparative budget analysis which simulated the two main stochastic variables: crop yields and product prices. He found that a corn-navy bean-sugar beet rotation offered the best risk-return prospects. This analysis was performed on 400 and 600 acre farms in the Saginaw Valley, and assumed that the total acreage available would be allocated in equal-sized parcels to each crop in a given rotation, and that farmers used a conventional tillage system.

Wolak (1981) developed field machinery complements for each of the sixteen rotations. His study provides a detailed analysis of machinery costs associated with each rotation. His analysis was also undertaken for 400 and 600 acre farms in the Saginaw Valley.

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Subsequent research on the same cropping sequences has focused on comparing relative yields, machinery requirements and costs for conventional versus conservation tillage practices[4/] (Rotz and Black, 1984; Black et al., 1984; Christenson et al., 1986).

This paper will be focused on seven of these cropping sequences (See Table 1.1). These sequences are chosen because they include the crops more commonly grown in Michigan's Saginaw Valley cash crop farms[5/] (navy beans (NB), sugar beets (B), corn (C), soybeans (SB) and wheat (W)). In addition, these crops are considered in some studies (Jacobs, 1988) as the typical enterprises of a navy bean farm.

1.5 STUDY OBJECTIVES

This paper relaxes the assumption of having the **total** farm divided into equal-sized parcels when allocating resources among crop sequences. Rotz and Black (1984) recognize that realistically this is not the situation. Moreover, evidence presented in Chapter 2 supports this position . This paper develops a framework for resource allocation decisions in multicrop farm operations that use "well defined cropping systems" as opposed to "haphazard" crop production systems (Christenson et al.,1978). The specific objectives are:

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Table 1.1 Selected Navy Bean Cropping Sequences.

NUMBER	DESCRIPTION 1/
1	C-NB
2	C-NB-B
3	NB-C-SB
4	C-C-NB-B
5	C-NB-W-B
6	C-C-NB-W
7	C-NB-NB-B

1/ C = Corn; NB = Navy Beans; B = Sugar Beets;
   SB = Soybeans; W = Wheat;

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1. To analyze the degree of income variability associated with the most common field crops grown in Michigan's Saginaw Valley, and the rotations in which they are grown.

2. To investigate the relationship between stability and level of farm income for different navy bean cropping sequences.

3. To determine the optimum continuously repeatable crop sequence mix and the optimum time for field operations for a 400 acre Saginaw Valley farm growing navy beans in rotation with sugar beets, corn, wheat and soybeans.

1.6 METHODOLOGY

This study develops a linear programming model which determines resource allocation decisions throughout the cropping year. The competing criteria of profit maximization and risk minimization for defining optimum cropping plans are explored. In both cases the model determines the optimum crop production strategy under two different assumptions. First, considering participation in government price support programs for corn and wheat; and, afterwards under a free market scenario.

The specific set of interacting production constraints under

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consideration includes land size, available machinery, weather conditions, labor supply, soil type, power requirements, sugar beet contract, maximum acreage in wheat and corn (when participation in government programs is assumed), rotation restrictions, and land use precedence. The income objective is defined in terms of the difference between gross income derived from each enterprise under each cropping sequence, and the corresponding variable cash costs, machinery costs, and timeliness costs. Likewise, the risk objective is defined in terms of the level of income variability associated with each production plan.

The concept of risk employed in this paper focuses on the randomness or variability of outcomes (Robison and Barry, 1987). This concept of risk finds theoretical justification in the Expected Utility Maximization behavioral decision model. In particular, an expected value - variance (EV) approach is followed, where the unique measure of risk is the variance of outcomes. This approach results from assuming that the decision-maker's underlying utility function is quadratic or that profits are normally distributed.

Four alternative historical risk measures are applied. They are based on the work of Carter and Dean (1960), Persaud (1980), and Dalziell (1985). The first three approaches seek

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to estimate the degree of variability of the random component of the time series of prices, yields and net returns to land of the different crops and cropping systems under study. The latter measures the variance of annual percentage changes of the same crops and cropping sequences.

1.7 OUTLINE OF RESEARCH PAPER

Chapter 2 describes recent trends in resource use in Michigan's Saginaw Valley cash crop farms. Chapter 3 presents a literature review of income variability analysis, and classifies the crops and crop sequences under study from this perspective. Chapter 4 presents the farm planning model used to determine risk-return efficient farm plans for a hypothetical farm. Input-output relationships, expected yields, prices, and field work time constraints are developed for alternative production enterprises. Chapter 5 presents empirical findings for the different scenarios analyzed, sensitivity analyses of model parameters, and model validation. Finally, Chapter 6 summarizes the study and includes suggestions for further research.

END NOTES

1/ Referenced in Hoskin (1981).

2/ This is a different perspective to the one followed by Hoskin (1981) and Wolak (1981). Their approach is one of a "system design perspective", where the goal is to determine a system structure that will achieve the output desired given available system inputs and the desired system outputs (Manetsch and Park, 1986).

3/ A cropping sequence, in this paper, refers to the sequence in which crops are grown. For example, a 200 acre corn - navy bean (C-NB) land allocation would find: 100 acres of corn following navy beans and 100 acres of navy beans, following corn.

4/ Conventional tillage refers to any method of seeded preparation which results in a smooth surface that is free of residue and trash. Conservation tillage is a general term referring to a range of systems which do not cause total soil inversion. There are fewer tillage operations than in conventional tillage and crop residue is left on the soil. The specific conservation tillage method considered in this paper is chisel plowing. Substantial amount of residue are left on the soil surface (Christenson et al.,

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1986).

5/ In 1987 these five crops occupied 70% of the total acreage allocated to field crops in the Saginaw Valley (Michigan Agricultural Statistics 1988), and 91% of the total acreage reported by Telfarm cash crop farms (Hepp, 1988).

CHAPTER 2

TRENDS IN RESOURCE USE

This chapter summarizes recent trends in land and labor use in Saginaw Valley cash crop farms. This information is used later on in the formulation and analysis of results of the farm planning model developed in Chapters 4 and 5.

The information is derived from production records mantained by Michigan State University Cooperative Extension Service from farmers enrolled in the Telfarm record program. These data are compiled and published by MSU's Department of Agricultural Economics (Hepp, 1984 - 1988).

Table 2.1 summarizes enterprise mix decisions made by participating farmers during the period of 1983 to 1987. As is shown, the group of farms with less than 400 tillable acres (group 1) in all but one year has devoted the highest proportion of land to dry bean production. The same behavior is observed in farms with 400 to 800 tillable acres (group 2). On the other hand, cash crop farms with over 800 tillable acres (group 3) have devoted the highest proportion of land to either soybeans or corn.

In all years, the five crops under consideration almost always occupy more than 90% of the total tillable acreage.

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Table 2.1 Trends in Enterprise Mix Decisions Saginaw Valley
          Cash Crop Farms.

YEAR	GROUP 1/	AVERAGE FARM (acres)	CORN	NAVY BEANS	SOYBEANS	SUGAR BEETS	WHEAT	TOTAL
1983	1	279	11%	28%	22%	17%	12%	90%
	2	577	20%	21%	14%	20%	15%	90%
	3	1,207	24%	10%	34%	12%	9%	89%
1984	1	253	18%	29%	19%	22%	12%	100%
	2	471	27%	23%	12%	19%	13%	94%
	3	1,233	23%	16%	26%	15%	10%	90%
1985	1	273	29%	28%	13%	20%	10%	100%
	2	469	27%	32%	9%	19%	8%	95%
	3	1,223	26%	21%	20%	15%	8%	90%
1986	1	278	17%	36%	13%	24%	6%	96%
	2	510	24%	37%	7%	18%	7%	93%
	3	1,162	28%	24%	22%	18%	6%	98%
1987	1	309	12%	29%	24%	19%	7%	91%
	2	543	21%	34%	10%	16%	6%	87%
	3	1,352	25%	23%	19%	18%	9%	94%

1/ 1 = farms with less than 400 tillable acres
   2 = farms with 400 to 800 tillable acres
   3 = farms with over 800 tillable acres
SOURCE :Hepp (1985, 1986, 1987), Hamilton and Hepp (1984) and Hamilton (1983).

Table 2.2 Trends in Labor Supply Saginaw Valley Cash
          Crop Farms With Less Than 400 Tillable
          Acres (hours).

LABOR	1987	1986	1985	1984	1983	AVERAGE
Operator	1555	1416	2230	1670	1565	1687
Family		127	159	307	417	253
Hired	425	503	519	479	257	437
TOTAL	1980	2046	2908	2456	2239	2376

SOURCE :Hepp (1985, 1986, 1987), Hamilton and Hepp (1984)
        and Hamilton (1983).

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In the last three years, wheat acreage has consistently occupied less than 10% of the total acreage in all farm categories. Sugar beet acreage remains constant at approximately 20% of the total tillable area in groups 1 and 2, and 15% in group 3.

Table 2.2 summarizes trends in labor use over the same period for cash crop farms with less than 400 tillable acres. On average, over 81% of the labor has been provided by family members; moreover, the operator on average is responsible for 72% of the total work load.

The maximum proportions of total tillable acreage devoted to corn and wheat over the 1983-87 period have been 29% and 15% respectively. Therefore, the maximum acreages allowed for growing these crops are set at 112 and 60 acres in the farm planning application of Chapter 4. Similarly, total labor supply over the cropping year is estimated to be the average labor supply of this period or approximately 2300 hours.

CHAPTER 3

INCOME VARIABILITY ANALYSIS

Future events are never known with absolute certainty by
farmers. Therefore, in order to assess the impact of
planning decisions on net farm incomes over the planning
horizon, farmers need objective measures of the degree of
risk associated with the cropping strategy in the farm
plan.

Assuming that future income variability of the crops under
study is closely related to past variability, crop risk can
be estimated by income variability over some past time
period. For purposes of this study that period will be 1960
to 1987. Since yields and prices are two of the major
determinants of farm income and its variability, the
following analysis focuses on the behavior of these
variables.

This chapter looks at understanding the degree of income
variability of the most common field crops grown in
Michigan's Saginaw Valley, as well as of the rotations in
which they are grown. It identifies data sources and
background required for an application, developed in Chapter
4, of how risk fits into the farm planning process. Results
of this chapter allow the assessment of cropping strategies

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presented in Chapter 5.

3.1 MEASUREMENT OF VARIABILITY

Carter and Dean (1960) characterize the income variability level associated with crops and cropping sequences as the variance of the random portion of the historical series of net returns. As discussed in their study (1960), as well as in Chen (1971), Young (1980, 1984) and Dalziell (1985), a distinction must be made between predictable and unpredictable variability, the latter which Dalziell terms instability. Predictable variability is determined by long run biological, technological and economic trends. Since a trend can be estimated and projected into the future, the change in a variable resulting from trend cannot be considered unexpected. The assumption is that farmers do recognize long-run trends in yields and relative prices, and therefore view deviations from trend as a random element. Thus, historical changes in prices and yields must be adjusted for their time dependency so that the unpredictable component can be estimated. This is especially relevant when we are designing a long-term farm plan based on past experience (Chen, 1971).

There are several empirical procedures to estimate the true random component. They are reviewed by Carter and Dean

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(1960), Young (1980, 1984) and Dalziell (1985); applications in a farm planning setting can be found in Persaud (1980), Adams et al. (1980) and Hoskin (1981). The rationale of these historical risk measures, as explained by Young (1980), is that they should be more than descriptive statistics of a historical time series; they should be computed in a way that is compatible with procedures which farmers might use to formulate subjective risk assessments. A simple approach is to assume that the current value of a variable in a time series is identical to that of the previous year so that the random element would be represented by first differences. Another technique is to approximate the current level of the time series by a fitted trend line, and then assume that deviations from the trend represent the random component. A third procedure is to employ some form of moving average as an estimate for the current value; the differences between observed values and estimated values then represent the random element. Finally, a series might be deflated by some general index to arrive at "real" values of the series; deviations from the long run mean of the deflated series represent the random element.

In section 3.3 four alternative risk measures based upon historical time series (1960 - 1987) are computed; these risk indices result from combining the last two approaches

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described above and a modification of the first one. The reason for computing four risk measures rather than one, comes from the fact that no general agreement has emerged in the literature about appropriate concepts and procedures for estimating these indices from historical data. Having four risk indices gives internal consistency to the results of this paper.

The first procedure was modified following Dalziell (1985). His work focuses on sources of agricultural market instability. He develops an index, called INS, to rank commodities by their degree of price, yield, revenue and acreage instability. He argues that this index measures not only variability but also unpredictability. In addition, the INS emphasizes short term variability rather than cyclical phenomena. The measure is defined as the variance of annual percentage changes, and mathematically is Var[100 * dQ/Q], making the INS dimensionless, i.e., that data of different units and magnitudes can be compared on equal terms.

For empirical applications Dalziell proposes the following numerical approximation for the INS index:

$$\frac{dQ}{Q} = \frac{2(Q_t - Q_{t-1})}{(Q_t + Q_{t-1})}$$

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where Q_t is the value taken by the price, yield or net returns series in year t.

As Dalziell points out, using the midpoint of the change gives symmetrical treatment to increases and decreases. Moreover, it provides some intuitive appeal to the index as an unpredictability measure because it implicitly assumes that the next period will grow from the current period at the average rate of growth of the series. The INS gives more weight to period-to-period fluctuations (which have more meaning to assess instability), and relatively less weight to long term cycles (Dalziell, 1985). Another advantage is that it exponentially detrends the series. Thus, if a series increases by a constant percentage each year, there would be a zero variance. The economic implication of this sort of measure is that farmers can readily adjust to constant percentage increases each year, but they will have difficulties if period to period changes are highly variable, which, again relates to the qualities of an index of unpredictability as well as variability.

Dalziell applied this method in the assessment of market instability for more than 100 commodities. Hebert and Jacobs (1988) and Jacobs (1988) also applied it to market instability in the navy bean and sugar beet industries.

This paper uses this approach to assess income variability and unpredictability of five Saginaw Valley field crops and seven cropping sequences.

The other three procedures of ranking rotations by deviations from estimated moving averages and the long-term deflated sample mean are based upon the "variability coefficient" originally suggested by Carter and Dean (1960). This index is used to measure the variability of one crop relative to another. The mathematical formulation is:

$$\text{Variability Coefficient} = \frac{(\text{Variance})^{1/2}}{\text{Expected Value}} * 100 ,$$

where "variance" refers to the variance of the random portion of a time series, and the expected value results from either a moving average of the most recent information or the long term mean. In the latter case, the above index reduces to the widely-used coefficient of variation.

According to the above formulation, the variability coefficient measures the standard deviation as a percentage of expected mean levels for each series.

In this study three alternative ways of forming price, yield and net return expectations are explored: 1) long-run detrended mean; 2) five-year equally weighted moving

averages; and 3) three-year decreasingly weighted moving averages. In the first case, it is implicitly assumed that each of the past observations has equal importance. The second approach supposes decision making is based on an average of the last five years. Mathematically the model is expressed as:

$$\hat{Y}_t = (Y_{t-1} + Y_{t-2} + Y_{t-3} + Y_{t-4} + Y_{t-5}) / 5 \qquad (3.1)$$

The third method assumes that only the most recent information is relevant in farm planning. Mathematically this moving average model is expressed as:

$$\hat{Y}_t = .5Y_{t-1} + .3Y_{t-2} + .2Y_{t-3} \qquad (3.2)$$

where the Y's are the actual prices, yields or net returns for years t-1 up to t-j, with j=5 in equation (3.1), and j=3 in equation (3.2). $\hat{Y}_t$ is the expected value for year t. Variability is defined in terms of differences between the actual and the expected value for prices, yields and/or net returns.

The balance of this chapter classifies crops and cropping sequences according to their degree of income variability. Four alternative indices of price, yield and net return variability are calculated for each crop. They are the INS

instability index based upon deviations from the average annual rate of growth; the coefficient of variation based upon deviations from the long-term mean; the coefficient of random variability based upon deviations from a five-year moving average; and the coefficient of variability based upon deviations from a three-year weighted moving average. Similarly, in the case of crop sequences, these same indices are applied to the net return series of each sequence.

3.2 DATA SOURCES AND ADJUSTMENT PROCEDURES

PRICE SERIES

Crop prices from 1960 to 1987 were compiled from various issues of Michigan Agricultural Statistics (Table 3.1). These figures correspond to prices received by farmers in each marketing year. Price support or certificate payments are not included in these prices. Crop prices are adjusted to the 1988 price level using the Consumer Price Index. Figures 3.1 and 3.2 present price behavior for the period under analysis.

VARIABLE COSTS

The variable cost series data from 1960 - 1987 were obtained from Dr. John Ferris, Professor of Agricultural Economics,

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TABLE 3.1 PRICE SERIES SELECTED CROPS

YEAR	CORN ($/bu.)	DRY BEANS ($/cwt.)	SOYBEANS ($/bu.)	SUGAR BEETS ($/ton)	WHEAT ($/bu.)
1960	0.99	5.90	2.08	11.70	1.75
1961	0.99	6.40	2.23	9.70	1.73
1962	1.05	6.30	2.33	12.10	1.95
1963	1.08	6.50	2.50	13.00	1.76
1964	1.15	6.70	2.64	10.50	1.30
1965	1.15	8.20	2.56	10.60	1.40
1966	1.22	6.40	2.72	13.40	1.65
1967	0.97	8.40	2.47	13.00	1.26
1968	1.03	8.00	2.39	10.70	1.07
1969	1.14	6.30	2.33	13.10	1.20
1970	1.32	9.70	2.84	12.20	1.40
1971	1.03	11.50	3.05	13.40	1.34
1972	1.49	9.70	4.60	12.40	1.67
1973	2.52	27.30	5.73	30.50	4.30
1974	2.91	14.80	6.28	47.50	3.64
1975	2.35	25.90	4.78	24.80	3.22
1976	2.04	16.10	7.22	22.40	2.53
1977	1.92	18.30	5.54	20.10	2.02
1978	2.22	14.80	6.81	23.50	3.30
1979	2.48	18.50	6.13	38.90	3.82
1980	3.07	26.40	7.49	40.70	3.60
1981	2.35	25.60	6.04	26.50	3.47
1982	2.48	13.70	5.46	35.80	3.31
1983	3.20	23.20	7.82	36.20	3.39
1984	2.56	19.60	5.79	34.40	3.18
1985	2.14	15.00	4.93	29.60	2.84
1986	1.43	23.75	4.67	30.00	2.38
1987	1.88	12.68	5.48	30.00	2.65

SOURCE: MICHIGAN AGRICULTURAL STATISTICS, various issues; and
Dr. John Ferris. Professor MSU Dept. of Ag. Economics

PRICE SERIES
1988 DOLLARS

($./unit.)

80 81 82 83 84 65 86 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87

YEAR
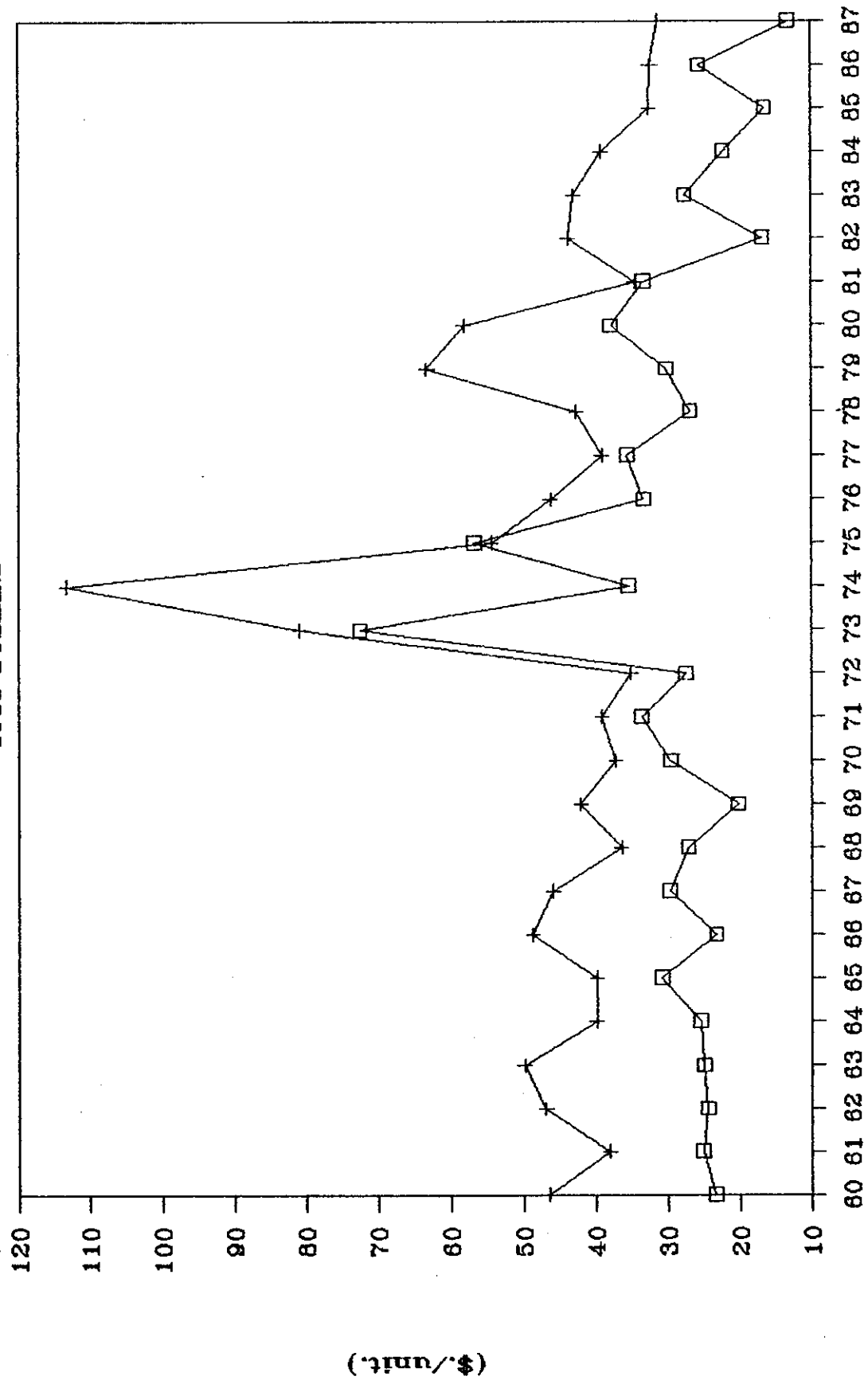
□ DRY BEANS   + SUGAR BEETS

FIGURE 3.1

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PRICE SERIES
1988 DOLLARS

FIGURE 3.2

□ CORN   ◇ SOYBEANS   × WHEAT

YEAR

($./bu.)

25
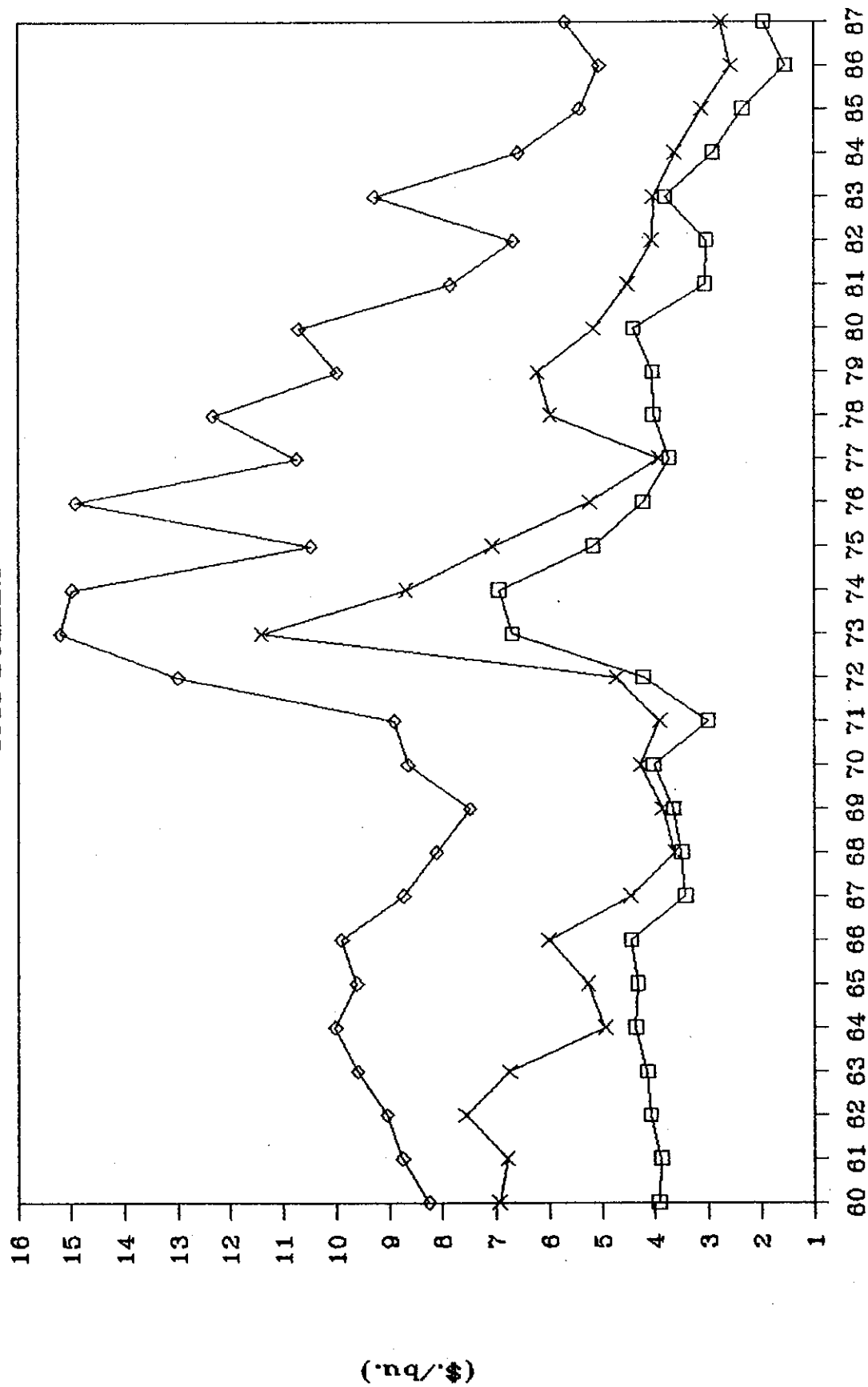
Michigan State University (See Table 3.2). These figures include cash expenses, interest charge on annual operating capital and unpaid labor. The underlying methodology for their calculation is the same as followed in the Costs of Production publications of USDA-ERS. Figures for navy beans were calculated taking soybeans as a proxy. Variable costs are adjusted to the 1988 price level using the Consumer Price Index. Figure 3.3 presents variable cost behavior for the period under consideration.

YIELDS

Annual yield data for the different crops were obtained from published county estimates for the Saginaw Valley. A time series from 1960 to 1987 was compiled (Table 3.3). A test was undertaken for the different yield series to see whether or not the underlying random process that generated the yield series can be assumed to be invariant with respect to time. A simple linear regression was estimated for each crop; all crops except dry beans have statistically significant trend values at the 5% significance level (Table 3.4). The resulting estimated equations are used to adjust corn, soybean, sugar beet and wheat yield series.

It is recognized however, that by using county aggregated data, yield variability is underestimated. Hence, the

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TABLE 3.2 VARIABLE COST SERIES SELECTED CROPS ($/acre.)

YEAR	CORN	DRY BEANS	SOYBEANS	SUGAR BEETS	WHEAT
1960	19.85	20.77	14.62	39.64	16.19
1961	20.45	21.63	15.22	40.83	16.30
1962	20.59	21.03	14.80	41.12	16.35
1963	22.00	22.35	15.73	43.92	16.68
1964	22.64	22.74	16.00	45.20	16.29
1965	26.93	25.50	17.94	53.77	17.14
1966	29.16	26.95	18.96	58.22	18.31
1967	31.03	28.93	20.36	61.95	18.96
1968	32.31	30.60	21.54	64.52	19.20
1969	33.09	32.84	23.11	66.07	19.87
1970	37.96	36.44	25.64	75.79	21.04
1971	39.21	39.30	27.65	78.28	22.25
1972	42.54	41.70	29.35	84.93	24.30
1973	45.71	50.59	35.60	91.27	31.39
1974	66.86	65.90	46.38	133.50	42.21
1975	83.18	76.07	53.54	166.09	53.34
1976	85.26	75.85	53.38	170.24	57.76
1977	89.33	85.60	60.24	178.37	52.61
1978	89.73	91.87	64.65	179.17	52.11
1979	103.16	103.83	73.07	205.97	64.23
1980	122.67	115.23	81.09	244.94	80.33
1981	140.00	126.33	88.83	279.54	93.61
1982	137.06	119.06	83.79	273.35	96.53
1983	130.49	114.97	80.91	270.72	93.14
1984	135.98	117.86	82.94	240.18	91.35
1985	135.51	111.96	78.79	233.35	89.42
1986	123.34	103.15	72.59	224.43	79.84
1987	121.30	102.74	72.30	220.71	79.73

SOURCE: Dr. John Ferris. Professor MSU Dept. Ag. Economics and
"Costs of Production" USDA-ERS, various issues.

VARIABLE COSTS SERIES

1988 DOLLARS
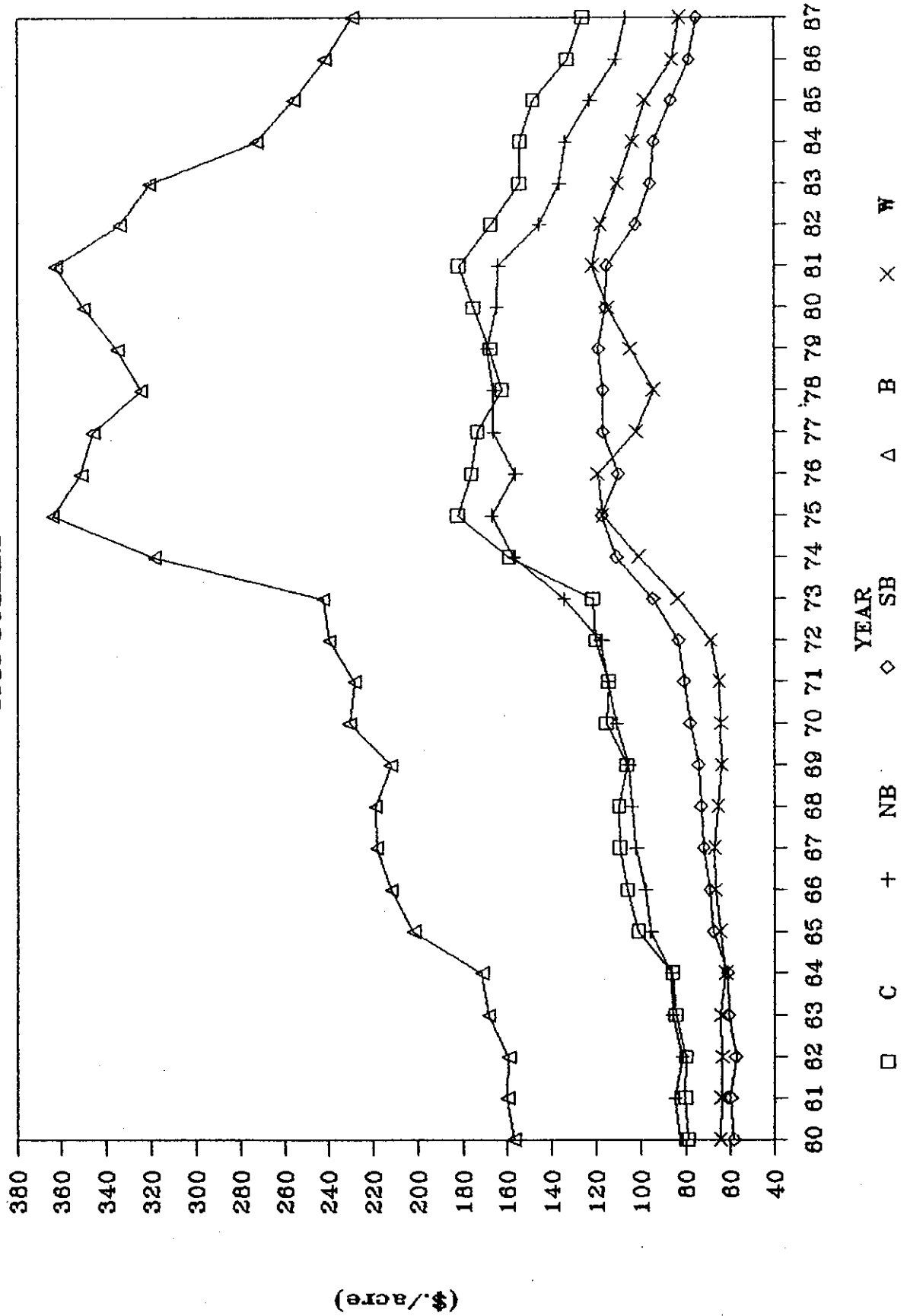
FIGURE 3.3

TABLE 3.3 YIELD SERIES SELECTED CROPS

YEAR	CORN (bu./acre)	DRY BEANS (cwt./acre)	SOYBEANS (bu./acre)	SUGAR BEETS (ton/acre)	WHEAT (bu./acre)
1960	54.6	13.5	18.4	13.9	34.9
1961	70.2	15.4	24.9	16.3	42.8
1962	64.5	15.5	23.4	16.3	34.4
1963	77.8	16.5	23.7	15.0	45.1
1964	72.6	13.5	22.4	16.3	47.8
1965	59.3	9.5	17.3	16.4	33.4
1966	65.0	12.0	19.9	15.4	45.8
1967	77.0	11.5	20.4	17.4	43.7
1968	77.5	11.5	20.4	19.0	43.5
1969	83.0	14.3	23.5	16.2	43.3
1970	82.0	11.6	27.7	21.3	46.0
1971	66.0	10.3	22.0	17.1	41.0
1972	87.2	12.7	27.7	21.0	43.6
1973	82.3	9.6	24.5	19.0	42.1
1974	78.1	13.6	25.8	19.0	47.3
1975	81.1	8.2	25.0	19.4	43.9
1976	72.4	8.8	21.1	16.9	43.3
1977	71.0	10.6	30.1	21.5	46.3
1978	83.6	11.1	24.6	19.8	48.1
1979	100.0	15.2	29.8	19.0	48.5
1980	90.6	12.7	33.3	19.2	48.1
1981	109.4	12.7	33.6	21.3	56.9
1982	124.0	15.4	32.4	20.0	50.5
1983	97.6	13.4	34.7	19.0	59.2
1984	102.0	10.3	30.7	20.5	66.5
1985	107.7	11.7	30.2	20.8	70.6
1986	106.5	8.1	28.7	21.8	54.3
1987	106.5	13.1	37.0	21.8	65.2

Source: MICHIGAN COUNTY STATISTICS-FIELD CROPS various issues.
MICHIGAN AGRICULTURAL STATISTICS 1982-1988.
Dr. John Ferris. Professor Agricultural Economics MSU.

Table 3.4 Linear Trend Analysis of County Yield Data 1960-87 1/

Crop	a	b	R-Square	t-Value 2/
Corn	58.40	1.76	0.71	7.89
Navy beans	13.84	(0.08)	0.09	(1.56)3/
Soybeans	18.70	0.52	0.65	7.00
Sugar beets	15.40	0.22	0.65	7.02
Wheat	34.87	0.89	0.65	6.89

1/ The regression equation is $Y = a + bX$, where Y is yield per acre
   and X is year with 1960 equal to 1.
2/ t-Value b coefficient.
3/ Not significant at 5% level

historical risk indices presented in Tables 3.13, 3.16 and
3.19, later on in this chapter, must be interpreted as lower
bounds to the actual values for a given farm. To diminish
this problem, variability indices are also calculated using
an alternative yield time series.

The second yield time series for the Saginaw Valley
corresponds to average figures of a sample of six Telfarm
cash crop farms presented in Hoskin (1981).   Since this
series only covers 1960 to 1976, it was complemented with
Telfarm data for the same type of farms for the years 1977-
87.   Table 3.5 presents average figures for the farms
considered. Again, each of the yield time series was tested
for linear trend. In this case, all crops except sugar beets
have statistically significant trend values at the 5%
significance level (Table 3.6).   Thus, yield series for
these crops were detrended using the estimated equations.

According to results in Table 3.4 and 3.6 both yield series
present a negative trend for navy beans.   This pattern is
accentuated in the case of Telfarm yield data where a 19%
annual decrease is estimated, against an 8% when using
Michigan Agricultural Statistics.

A t-statistical test was undertaken to establish if the two
yield samples were statistically different, and then to

Table 3.5

TELFARM YIELD SERIES SELECTED CROPS

YEAR	CORN (bu./acre)	DRY BEANS (cwt./acre)	SOYBEANS (bu./acre)	SUGAR BEETS (ton/acre)	WHEAT (bu./acre)
1967	86.5	14.2	20.4	19.6	50.1
1968	100.5	16.8	20.4	18.7	43.0
1969	93.3	17.9	23.5	15.1	49.4
1970	108.0	15.2	27.7	25.6	46.2
1971	87.2	14.0	22.0	18.3	43.5
1972	96.8	13.4	27.7	18.7	43.3
1973	89.8	13.4	24.5	20.0	38.0
1974	77.7	16.8	25.8	18.7	57.1
1975	115.4	14.9	25.0	20.6	57.8
1976	110.2	14.5	21.1	18.5	57.3
1977	92.3	12.9	38.1	20.1	61.6
1978	94.7	11.8	29.3	19.1	55.3
1979	113.1	16.1	33.0	18.1	64.8
1980	121.8	13.8	39.3	19.0	67.5
1981	129.3	13.0	34.5	20.0	72.6
1982	129.4	15.5	37.4	19.5	62.1
1983	113.7	16.5	43.2	19.3	72.4
1984	110.5	12.9	42.5	19.9	74.5
1985	113.7	12.6	31.9	20.4	77.7
1986	130.3	6.8	32.3	16.5	48.8
1987	110.3	12.8	46.5	20.9	58.8

SOURCE: Hoskin (1981), Hamilton (1983-1984), Hepp (1985-1987) Brown (1980-1983), Kelsey (1978-1979).

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Table 3.6 Linear Trend Analysis of Telfarm Yield Data 1967-87 1/

Crop	a	b	R-Square	t-Value 2/
Corn	76.40	1.65	0.45	3.98
Navy beans	17.50	(0.19)	0.26	(2.57)
Soybeans	11.60	1.06	0.68	6.30
Sugar beets	19.70	(0.03)	0.01	(0.35)3/
Wheat	33.60	1.32	0.50	4.37

1/ The regression equation is Y = a + bX, where Y is yield per acre
   and X is year with 1960 equal to 1.
2/ t-Value b coefficient.
3/ Not significant at 5% level

Table 3.7 Comparison of Telfarm Yield Data v.s. Michigan
           Agricultural Statistics Yield Data

Crop	t-Value
Corn	(4.08)
Navy beans	0.39 1/
Soybeans	(6.08)
Sugar beets	(1.00)1/
Wheat	(4.69)

1/ Not significant at the 5%

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determine whether or not the calculation of risk indices using Telfarm yield data would shed light on the analysis. The null hypothesis states that the population means of both yield series are equal for each crop, while the alternative hypothesis is that the population mean of the Telfarm yield series is greater than the corresponding one with the Michigan Agricultural Statistics yield series. Results (Table 3.7) at the 5% significance level suggest to accept the null hypothesis for sugar beets and navy beans, but not for corn, soybeans an wheat.

NET RETURNS SERIES

Estimated annual net returns per acre for each crop are calculated under a free-market scenario. These figures are calculated by multiplying detrended annual yields per acre times market price per unit less total variable costs. The annual net return is a return to land, non-land capital, management and risk before deducting interest, taxes, insurance and general farm overhead. Table 3.8 presents the net return series in 1988 dollars per acre for each crop.

Net returns for each cropping sequence are calculated by taking the summation of net returns per acre for each of the crops in the sequence, and dividing by the number of crops. This serves as a proxy for the level of income variability

TABLE 3.8 NET RETURNS TO LAND, NON-LAND CAPITAL AND
          MANAGEMENT OF SELECTED CROPS ($/acre) 1/

YEAR	CORN	NAVY BEANS	SOYBEANS	SUGAR BEETS	WHEAT
1960	310.65	233.54	207.72	747.09	346.03
1961	400.84	301.74	311.57	698.60	416.01
1962	370.98	297.22	293.96	885.75	356.45
1963	454.04	325.76	307.97	840.42	416.11
1964	429.52	257.01	294.13	692.35	301.60
1965	304.82	196.78	189.35	653.52	200.24
1966	339.99	181.41	228.03	756.72	338.85
1967	288.16	238.88	190.29	801.37	213.60
1968	289.37	208.41	165.42	648.25	158.13
1969	330.68	183.72	173.64	635.96	167.15
1970	347.69	231.52	252.44	738.31	201.98
1971	158.35	230.91	183.97	582.73	148.41
1972	373.57	230.13	393.70	639.92	199.81
1973	603.68	561.32	389.20	1,575.53	532.20
1974	539.71	322.90	381.26	2,195.14	415.71
1975	345.67	298.87	209.73	853.03	265.75
1976	201.62	135.89	275.07	539.74	155.05
1977	147.83	210.21	272.09	598.83	114.14
1978	237.77	131.08	241.06	614.25	242.23
1979	303.73	288.53	225.79	989.55	242.58
1980	280.75	314.48	290.32	866.58	165.46
1981	194.19	257.99	179.71	426.42	163.98
1982	248.24	112.28	135.59	598.03	105.91
1983	247.67	232.07	252.24	538.10	146.15
1984	162.37	95.37	120.78	562.07	151.26
1985	116.89	69.66	84.70	440.57	131.87
1986	36.60	96.03	70.68	477.05	57.35
1987	85.33	65.79	138.72	456.89	99.27

1/ In 1988 dollars

SOURCE: Compiled from Tables 3.1, 3.2, 3.3 .

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associated with each crop sequence over time, given the fact that technical complementarities between crops are not taken into account. Table 3.9 presents these figures for the period 1960 - 1987.

3.3 INCOME VARIABILITY INDICES

This section derives empirical estimates of the relative yield, price, and net return variability for five Saginaw Valley field crops. Net return variability indices for seven cropping sequences including these crops are also presented. In addition, the degree of association of the above variables among crops and crop sequences is evaluated by means of correlation analysis.

Results are based upon historical data documented in the previous section. The objective here is to rank each crop and crop sequence based on the methods discussed in section 3.1. Crop indices are discussed first, followed by indices associated with crop sequences.

As an aside, it should be noted that the indices presented in this section, with the exception of the coefficient of variation, have to be interpreted in relative terms to the same indices for other crops. On their own they are only measures of variability that allow ranking crop

TABLE 3.9 NET RETURNS TO LAND, NON-LAND CAPITAL AND MANAGEMENT OF SELECTED
CROP SEQUENCES ($/acre) 1/ 2/

YEAR	C-NB	C-NB-B	NB-C-SB	C-C-NB-B	C-NB-W-B	C-C-NB-W	C-NB-NB-B
1960	272.09	430.42	250.63	400.49	409.33	300.22	381.20
1961	351.29	467.06	338.05	450.50	454.30	379.86	425.73
1962	334.10	517.99	320.72	481.24	477.60	343.91	462.79
1963	389.90	540.07	362.59	518.56	509.08	412.48	486.49
1964	343.26	459.63	326.88	452.10	420.12	354.41	408.97
1965	250.80	385.04	230.32	364.99	338.84	251.67	337.98
1966	260.70	426.04	249.81	404.53	404.24	300.06	364.88
1967	263.52	442.80	239.11	404.14	385.50	257.20	391.82
1968	248.89	382.01	221.06	358.85	326.04	236.32	338.61
1969	257.20	383.45	229.35	370.26	329.38	253.06	333.52
1970	289.60	439.17	277.22	416.30	379.87	282.22	387.26
1971	194.63	323.99	191.08	282.58	280.10	174.00	300.72
1972	301.85	414.54	332.46	404.27	360.86	274.27	368.43
1973	582.50	913.51	518.07	836.05	818.18	575.22	825.46
1974	431.30	1,019.25	414.62	899.36	868.36	454.51	845.16
1975	322.27	499.19	284.75	460.81	440.83	313.99	449.11
1976	168.76	292.42	204.20	269.72	258.08	173.54	253.29
1977	179.02	318.96	210.04	276.17	267.75	155.00	291.77
1978	184.42	327.70	203.30	305.22	306.33	212.21	278.54
1979	296.13	527.27	272.68	471.38	456.10	284.64	467.59
1980	297.62	487.27	295.18	435.64	406.82	260.36	444.07
1981	226.09	292.87	210.63	268.20	260.65	202.59	284.15
1982	180.26	319.52	165.37	301.70	266.11	178.66	267.71
1983	239.87	339.28	243.99	316.38	291.00	218.39	312.48
1984	128.87	273.27	126.17	245.55	242.77	142.84	228.79
1985	93.27	209.04	90.42	186.00	189.75	108.83	174.19
1986	66.31	203.23	67.77	161.57	166.76	56.64	176.43
1987	75.56	202.67	96.61	173.34	176.82	83.93	168.45

1/ In 1988 dollars
2/ Assuming same proportion of land for each crop.

SOURCE: Compiled from Tables 3.1, 3.2, 3.3 .

performance.

3.3.1 CROPS

The general perception held by most observers that the navy
bean business is highly unstable is supported by evidence of
unpredictable movements in prices, yields and net returns.
In fact, all four indicators of variability identify navy
beans as the most unstable and unpredictable enterprise in
the grower's rotation. Results for price, yield and income
variations for each crop are discussed below.

PRICES

Table 3.10 presents price variability indices for each crop
ranked by the INS index from high to low variability. Sugar
beets follow navy beans in terms of price instability based
on year-to-year variability. However, when looking at
deviations from an expected mean level, wheat is second to
navy beans. By either criterion, the crop with most stable
prices is soybeans.

Table 3.11 shows price correlation coefficients between
crops. This figure measures the degree of association of
the random portion of the price series for each pair of

Table 3.10 Price Variability Indices Selected Crops

Crop	Coefficient Of Variation 1/	Coefficient Of Random Variability 5-Year M.A. 2/	Coefficient Of Random Variability 3-Year M.A. 2/	Instability Coefficient INS 3/
Navy beans	40%	61%	69%	38.2
Sugar beets	36%	56%	61%	28.3
Wheat	37%	65%	67%	24.7
Corn	29%	46%	53%	21.0
Soybeans	28%	41%	39%	20.0

1/ Measures the standard deviation of the time series as a
   percentage of the long-term mean for each series.
2/ Measures the standard deviation of the random portion of the
   time series as a percentage of recent mean levels for each series.
3/ Measures the standard deviation of annual percentage changes.

   M.A. = Moving Average.

Table 3.11 Price Correlation Coefficients.

1. Deviations from long-term mean

	Corn	Navy Beans	Soybeans	Sugar Beets	Wheat
Corn	1.00	0.67	0.84	0.82	0.85
Navy Beans		1.00	0.63	0.52	0.65
Soybeans			1.00	0.65	0.68
Sugar Beets				1.00	0.74
Wheat					1.00

2. Deviations from 5-Year moving average

	Corn	Navy Beans	Soybeans	Sugar Beets	Wheat
Corn	1.00	0.66	0.79	0.87	0.88
Navy Beans		1.00	0.51	0.50	0.74
Soybeans			1.00	0.62	0.70
Sugar Beets				1.00	0.80
Wheat					1.00

3. Deviations from 3-Year moving average

	Corn	Navy Beans	Soybeans	Sugar Beets	Wheat
Corn	1.00	0.45	0.66	0.82	0.81
Navy Beans		1.00	0.21	0.27	0.62
Soybeans			1.00	0.46	0.51
Sugar Beets				1.00	0.75
Wheat					1.00

Table 3.12 Price Correlation Coefficients Between Annual
          Percentage Changes

	Corn	Navy Beans	Soybeans	Sugar Beets	Wheat
Corn	1.00	0.05*	0.63	0.53	0.65
Navy Beans		1.00	0.01*	0.03*	0.28*
Soybeans			1.00	0.28*	0.36
Sugar Beets				1.00	0.60
Wheat					1.00

* Not significantly different from zero at the 5% level

crops. The three expectation methods indicate that navy beans have the lowest degree of association with other crops' prices, suggesting possibilities for income diversification when including this crop in the rotation. The lowest degree of association for all crops is found when the random portion of the price series is approximated by a three-year weighted moving average.

Correlation coefficients among price instability indices (Table 3.12) indicate that there is a significant degree of association between annual price variations for crops which have price support programs (all but navy beans) or common market exchange mechanisms (all but navy beans and sugar beets).

YIELDS

Table 3.13 presents yield variability indices for each crop ranked by the INS index from high to low instability levels. As noted before, the four methods and the two Saginaw Valley yield time series suggest that navy beans have higher yield variability. Soybeans are identified as the second crop in terms of yield variability, with wheat following third place. However, if the criterion of deviations from recent mean levels is observed and we only consider Michigan Agricultural Statistics (MAS) data, corn would be in third

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Table 3.13 Yield Variability Indices Selected Crops

Crop	Coefficient Of Variation 1/		Coefficient Of Random Variability 5-Year M.A. 2/		Coefficient Of Random Variability 3-Year M.A. 2/		Instability Coefficient INS 3/
	M.A.S.	TELFARM	M.A.S.	TELFARM	M.A.S.	TELFARM	
Navy beans	19%	15%	23%	19%	22%	22%	24.0
Soybeans	12%	14%	14%	17%	13%	19%	16.0
Wheat	11%	13%	10%	16%	11%	18%	15.3
Corn	11%	11%	13%	13%	12%	14%	13.9
Sugar beets	7%	11%	8%	9%	9%	14%	11.8

1/ Measures the standard deviation of the time series as a
   percentage of the long-term mean for each series.
2/ Measures the standard deviation of the random portion of the
   time series as a percentage of recent mean levels for each series.
3/ Measures the standard deviation of annual percentage changes.

M.A. = Moving Average.

M.A.S.=Michigan Agricultural Statistics

place.

Table 3.14 shows yield correlation coefficients based upon MAS data only since these figures were not statistically different from zero when considering Telfarm yield data. As indicated, there is a relatively high degree of association between the random components of the navy bean series and the soybean series, as well as between the corn series and the navy bean series. Similar relationships are found for the correlation coefficients between instability indices (Table 3.15).

Examining interactions between random components of price series and yield series reveals that the only crop with a correlation coefficient significantly different from zero at the 5% level is navy beans. With a value of -.47, this indicates that positive price fluctuations are associated with negative yield fluctuations, and vice-versa. This behavior is unique to navy beans because it is the only crop without overt price support programs, and because it is the only crop that is largely traded in spot markets.

NET RETURNS

Table 3.16 presents net returns variability indices ranked by the INS instability criterion from high to low

Table 3.14 Yield Correlation Coefficients.
```
--------------------------------------------------------------
 1. Deviations from long-term mean
--------------------------------------------------------------
            Corn   Navy Beans Soybeans Sugar Beets  Wheat

Corn        1.00      0.62      0.52       0.14*     0.44
Navy Beans            1.00      0.69      -0.15*     0.37
Soybeans                        1.00       0.28*     0.36
Sugar Beets                                1.00     -0.05*
Wheat                                                1.00
--------------------------------------------------------------
 2. Deviations from 5-Year moving average
--------------------------------------------------------------
            Corn   Navy Beans Soybeans Sugar Beets  Wheat

Corn        1.00      0.65      0.51       0.19*     0.25*
Navy Beans            1.00      0.72      -0.03*     0.30*
Soybeans                        1.00       0.37*     0.30*
Sugar Beets                                1.00      0.06*
Wheat                                                1.00
--------------------------------------------------------------
 3. Deviations from 3-Year moving average
--------------------------------------------------------------
            Corn   Navy Beans Soybeans Sugar Beets  Wheat

Corn        1.00      0.59      0.42       0.22*     0.27*
Navy Beans            1.00      0.64       0.05*     0.35
Soybeans                        1.00       0.42      0.33*
Sugar Beets                                1.00      0.06*
Wheat                                                1.00
--------------------------------------------------------------
 * Not significantly different from zero at the 5% level
```

Table 3.15 Yield Correlation Coefficients Between Annual
           Percentage Changes
```
--------------------------------------------------------------
            Corn   Navy Beans Soybeans Sugar Beets  Wheat

Corn        1.00      0.41      0.42       0.31*     0.41
Navy Beans            1.00      0.55      -0.06*     0.48
Soybeans                        1.00       0.52      0.53
Sugar Beets                                1.00      0.12*
Wheat                                                1.00
--------------------------------------------------------------
 * Not significantly different from zero at the 5% level
```

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Table 3.16 Net Return Variability Indices Selected Crops
===

Crop	Coefficient Of Variation 1/		Coefficient Of Random Variability 5-Year M.A. 2/		Coefficient Of Random Variability 3-Year M.A. 2/		Instability Coefficient INS 3/
	M.A.S.	TELFARM	M.A.S.	TELFARM	M.A.S.	TELFARM	
Navy beans	45%	63%	101%	137%	138%	254%	43.9
Corn	45%	45%	95%	84%	153%	133%	42.7
Wheat	51%	50%	97%	103%	116%	147%	41.1
Soybeans	37%	39%	65%	64%	71%	80%	36.3
Sugar beets	48%	59%	86%	114%	90%	111%	33.7

===

1/ Measures the standard deviation of the time series as a
   percentage of the long-term mean for each series.
2/ Measures the standard deviation of the random portion of the
   time series as a percentage of recent mean levels for each series.
3/ Measures the standard deviation of annual percentage changes.

   M.A. = Moving Average.

   M.A.S.=Michigan Agricultural Statistics

instability levels. Navy beans show the highest annual fluctuation levels as well as the highest percentage deviations from recent and long-term mean return levels. In contrast to the previous two cases, when looking at the composite behavior of prices and yields, and after substracting production costs, corn ranks second in terms of net return instability. However, from the point of view of deviations from recent and long-term expected mean levels, wheat would be in second place. Similarly, historical data suggest that sugar beets have the most stable year to year net return relative to the other four crops. On the other hand, when looking at deviations from long-term and recent mean levels, soybeans have the least variable net returns. Table 3.17 presents the Pearson correlation coefficients between the random components of each net returns series. These figures show a positive degree of association in the random behavior of net returns for the crops under consideration. That is, if net returns go up or down for one of the crops in the grower's rotation, historical evidence for the Saginaw Valley shows that the same pattern would be expected for other crops, though in a different proportion. For individual pairs of crops, based upon Michigan Agricultural Statistics yield data for the Saginaw Valley, the strongest degree of association is observed between corn and wheat, and the weakest is between soybeans and sugar beets. In contrast, when Telfarm yield data for

Table 3.17 Net Return Correlation Coefficients.
```
------------------------------------------------------------
```
1. Deviations from long-term mean - M.A.S.
```
------------------------------------------------------------
```

	Corn	Navy Beans	Soybeans	Sugar Beets	Wheat
Corn	1.00	0.80	0.78	0.74	0.87
Navy Beans		1.00	0.73	0.66	0.76
Soybeans			1.00	0.61	0.68
Sugar Beets				1.00	0.68
Wheat					1.00

```
------------------------------------------------------------
```
2. Deviations from 5-Year moving average - M.A.S.
```
------------------------------------------------------------
```

	Corn	Navy Beans	Soybeans	Sugar Beets	Wheat
Corn	1.00	0.76	0.70	0.81	0.86
Navy Beans		1.00	0.63	0.65	0.72
Soybeans			1.00	0.57	0.63
Sugar Beets				1.00	0.78
Wheat					1.00

```
------------------------------------------------------------
```
3. Deviations from 3-Year moving average - M.A.S.
```
------------------------------------------------------------
```

	Corn	Navy Beans	Soybeans	Sugar Beets	Wheat
Corn	1.00	0.66	0.63	0.78	0.83
Navy Beans		1.00	0.46	0.56	0.69
Soybeans			1.00	0.44	0.50
Sugar Beets				1.00	0.76
Wheat					1.00

```
------------------------------------------------------------
```
4. Deviations from long-term mean - Telfarm
```
------------------------------------------------------------
```

	Corn	Navy Beans	Soybeans	Sugar Beets	Wheat
Corn	1.00	0.84	0.71	0.69	0.77
Navy Beans		1.00	0.55	0.62	0.77
Soybeans			1.00	0.55	0.63
Sugar Beets				1.00	0.86
Wheat					1.00

```
------------------------------------------------------------
```
5. Deviations from 5-Year moving average - Telfarm
```
------------------------------------------------------------
```

	Corn	Navy Beans	Soybeans	Sugar Beets	Wheat
Corn	1.00	0.86	0.53	0.70	0.83
Navy Beans		1.00	0.37*	0.60	0.75
Soybeans			1.00	0.44*	0.46*
Sugar Beets				1.00	0.87
Wheat					1.00

```
------------------------------------------------------------
```
6. Deviations from 3-Year moving average - Telfarm
```
------------------------------------------------------------
```

	Corn	Navy Beans	Soybeans	Sugar Beets	Wheat
Corn	1.00	0.73	0.41*	0.63	0.74
Navy Beans		1.00	0.16*	0.43*	0.62
Soybeans			1.00	0.33*	0.28*
Sugar Beets				1.00	0.87
Wheat					1.00

```
------------------------------------------------------------
```
* Not significantly different from zero at the 5% level

the same region is used, sugar beets and wheat are the crops
with the strongest net returns association, and the smallest
correlation coefficients are not statistically different
from zero. This same relationship between crops is observed
when gross income (price * yield) is the basis for the
calculation of the correlation coefficients.

Correlation coefficients between net return instability
indices (Table 3.18) indicate that there is no association
in the year-to-year fluctuations of navy beans and those of
the other four crops. This means that if navy bean returns
unexpectedly go down in a given year, there is no empirical
evidence that the same pattern will be observed for the
other crops in the grower's rotation. However, empirical
evidence does exist that over the last twenty years
unexpected movements in net returns of corn, wheat and
soybeans have been associated in some degree. Similar
evidence exists in the case of corn, wheat and sugar beets,
though to a lesser extent. The meaning of these results is
that if net returns of corn go down, a similar pattern is
likely to be observed in wheat and soybeans, or in wheat and
sugar beets.

Therefore, based upon these empirical results only,
including navy beans in rotation with corn, soybeans, wheat
or sugar beets may be advantageous. For example, if in a

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Table 3.18 Net Return Correlation Coefficients Between Annual
Percentage Changes

	Corn	Navy Beans	Soybeans	Sugar Beets	Wheat
Corn	1.00	0.10*	0.59	0.42	0.73
Navy Beans		1.00	0.31*	0.33*	0.22*
Soybeans			1.00	0.25*	0.41
Sugar Beets				1.00	0.38
Wheat					1.00

* Not significantly different from zero at the 5% level

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given year net returns from any of these crops unexpectedly falls to some critical level, it is likely that the same will occur with other crops except navy beans. This stabilizes in some degree the cash flow level for that year. Contrarily, if navy bean returns unexpectedly fall in a given year, it is not necessarily expected that returns to the other crops in rotation will fall. In consequence, there is a potential for stabilizing net returns when navy beans are included in the rotation.

3.3.2 CROPPING SEQUENCES

Table 3.19 summarizes net returns variability indices for seven navy bean cropping sequences calculated over the period 1960 - 1987. As in previous cases, figures in this table are ranked by the INS instability index from high to low. The first point to note relates to the absolute values of the indices calculated. In every case, income variability indices are higher from individual crops than for combinations of them, meaning that by producing more than one crop the level of net returns instability can be lowered substantially as well as the relative deviations from mean expected values. That is, it is possible to achieve a more predictable and less variable net income.

From the point of view of year-to-year net return

Table 3.19 Net return Variability Indices Selected
          Crop Sequences

Crop	Coefficient Of Variation 1/	Instability Coefficient INS 2/
C-C-NB-W	42.8%	32.8
C-NB	43.1%	31.0
NB-C-SB	39.3%	29.7
C-NB-B	42.6%	29.0
C-NB-NB-B	43.0%	28.9
C-C-NB-B	43.9%	28.8
C-NB-W-B	42.4%	28.5

1/ Measures the standard deviation of the time series as a
   percentage of the long-term mean for each series.
2/ Measures the standard deviation of annual percentage
   changes.

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fluctuations, stability is gained by having sugar beets in the rotation (Table 3.19). In addition, the more diversified the sequence of crops, the more stable the net returns level realized. In general, with one exception, four year sequences are more stable.

Under the criterion of relative deviations from the long-term mean return level, the three-year sequence navy beans - corn - soybeans presents the lowest level of variability.

Correlation coefficients between net returns instability indices for each cropping sequence (Table 3.20) identify the following pairs of sequences as the ones with the lowest degree of association over time: C-NB-B and NB-C-SB; NB-C-SB and C-NB-W-B; C-NB-B and C-C-NB-W; and, C-C-NB-W and C-NB-NB-B.

Correlation coefficients between net return deviations from mean levels are presented in Table 3.21. In this case, given that sugar beets are a high value crop with profit levels quite high relative to the other crops (See Table 3.9), sequences including this crop have the highest correlation coefficients. This fact has a lesser effect in the previous case (Table 3.20) because instability indices are calculated in relative terms rather than absolute values. However, given that all crop sequences include corn

Table 3.20 Net Return Correlation Coefficients Between Annual
Percentage Changes - Cropping Sequences

	C-NB	C-NB-B	NB-C-SB	C-C-NB-B	C-NB-W-B	C-C-NB-W	C-NB-NB-B
C-NB	1.00	0.80	0.94	0.84	0.83	0.92	0.85
C-NB-B		1.00	0.72	0.98	0.98	0.74	0.98
NB-C-SB			1.00	0.78	0.76	0.89	0.76
C-C-NB-B				1.00	0.98	0.82	0.95
C-NB-W-B					1.00	0.82	0.96
C-C-NB-W						1.00	0.73
C-NB-NB-B							1.00

Table 3.21 Net Return Correlation Coefficients Between
Deviations From Long-Term Mean

	C-NB	C-NB-B	NB-C-SB	C-C-NB-B	C-NB-W-B	C-C-NB-W	C-NB-NB-B
C-NB	1.00	0.89	0.98	0.92	0.92	0.98	0.98
C-NB-B		1.00	0.88	0.99	0.99	0.89	0.99
NB-C-SB			1.00	0.91	0.90	0.97	0.91
C-C-NB-B				1.00	0.99	0.93	0.99
C-NB-W-B					1.00	0.92	0.99
C-C-NB-W						1.00	0.91
C-NB-NB-B							1.00

and navy beans (though in different proportions) by construction the degree of association of net returns over time between crop sequences has to be relatively high.

In order to establish the contribution of navy beans to net returns instability, Table 3.22 presents a relative decomposition of the net return variance associated with each cropping sequence. These figures are calculated following the definition of variance of a linear combination of random variables, that is:

$$Var[aX + bY] = a^2 Var[X] + b^2 Var[Y] + 2abCov[X,Y]$$

For example, for the sequence C-NB-B, of the total net returns variance, 24% is due to corn, 26% to navy beans, 15% to sugar beets, 5% to the interaction between corn and navy beans, 16% to the covariance between corn ans sugar beets, and 14% to the interaction between navy beans and sugar beets. These figures are calculated based upon the variance-covariance matrix of net returns instability indices.

The relative variability weights in Table 3.22 have some interesting implications. First, there is a clear contrast with results obtained for instability indices of individual crops. While individually navy beans have the highest

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Table 3.22 Relative Decomposition of Net Return Variance Associated With Each
          Cropping Sequence. 1/

	C-NB	C-NB-B	NB-C-SB	C-C-NB-B	C-NB-W-B	C-C-NB-W	C-NB-NB-B
	1	2	3	4	5	6	7
Var(C)	44%	24%	23%	50%	13%	41%	12%
Var(NB)	47%	26%	23%	13%	14%	11%	53%
Var(SB)			16%				
Var(B)		15%		8%	8%		8%
Var(W)					12%	10%	
Cov(C,NB)	9%	5%	5%	5%	3%	4%	5%
Cov(C,B)		16%		17%	9%		8%
Cov(NB,B)		14%		7%	7%		14%
Cov(NB,SB)			12%				
Cov(C,SB)			21%				
Cov(C,W)					19%	29%	
Cov(NB,W)					7%	5%	
Cov(W,B)					8%		
Total	100%	100%	100%	100%	100%	100%	100%

1/ These figures are calculated following the definition of variance
   of a linear combination of random variables, that is:

$$Var[aX + bY] = a^2 Var[X] + b^2 Var[Y] + 2ab\ Cov[X,Y]$$

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indices of income variability, within the context of a crop sequence their relative importance does not significantly outweigh that of other crops. Second, the effect of adding second year navy beans, sequence number 7, vis-a-vis sequence 2, increases (more than proportionally) the importance of navy beans as a source of income instability. That is, the more diversified the crop sequence, the less exposure to a single source of income instability. The latter point is also valid in the case of second year corn. Third, an important portion of the income instability level is due to interactions among corn, wheat and/or soybeans. Of lesser importance are interactions with navy beans.

This chapter reviewed theory of income variability analysis applied to farm cropping plans. Individual crops and crop sequences of Michigan's Saginaw Valley were ranked using four alternative indices of income variability. This analysis suggests that navy beans may contribute to stabilize net returns when they are included in rotation with other crops, because they have low degree of association with unpredictable income changes in these other crops. Chapter 4 develops a framework to look at income variability now incorporating resource constraints of a hypothetical Saginaw Valley cash crop farm.

CHAPTER 4

FARM PLANNING MODEL AND DATA DEVELOPMENT

In this chapter the concept of income variability is applied within the framework of a farm planning model. It formulates a linear programming model incorporating relationships between income stability and level of farm income, in addition to the specific set of interacting crop production constraints. The objective is to identify crop production plans that are efficient or optimum under two criteria: minimum income variability and maximum level of income generated.

Besides satisfying these two criteria, the crop production plans exploit the beneficial interactions that result from using well defined cropping sequences as bases for resource allocation decisions. Complementarities among crops are accounted for in the calculation of the input/output coefficients and account for most of the variation in fertilizer application rates and variations in expected yields.

4.1 PROBLEM SETTING

This chapter considers a 400 acre Saginaw Valley cash crop farm which produces navy beans in rotation with corn, wheat,

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soybeans and/or sugar beets. The yield level and variable cost structure of each crop depend upon the specific cropping sequence in which these crops are grown. Field operations are characterized by four major activities: land preparation, planting, cultivation and harvesting. Each operation must be accomplished within the time constraints imposed by Saginaw Valley's climate. Furthermore, field operations must be performed with a predefined field machinery set, assumed to be available in the hypothetical farm being considered. There is also a limited supply of available labor (operator, family and hired) to accomplish each of the crop production activities. All crops but sugar beets are sold in the cash market; if sugar beets are grown, they are grown under a contract for up to 80 acres. Finally, acreage allocated to each crop in each crop sequence must be in equal-sized parcels.

Therefore, the decision problem which this analysis assumes faces the producer is to design crop sequence mixes with minimum levels of income variability at given levels of income, such that all the resource constraints are satisfied.

4.2 MODELING APPROACH

The approach to a solution of this farm planning problem is

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an adaptation of Hazell's risk linear programming MOTAD model. In using this model it is recognized that since agricultural production takes place in a risky environment, a farm plan does not have a known income level each year. Hence, it is necessary to take into consideration income variability levels associated with alternative cropping plans. Hazell (1986) argues that a MOTAD formulation is most relevant when farm income variability is estimated using time series data, with procedures such as those reviewed in Chapter 3.

Hazell's variance estimator is based on the sample Mean Absolute Deviation instead of the more widely-used sum of square errors. This is a key point in his formulation that allows the derivation of a linear programming model after transforming some variables (Hazell, 1971; 1986). Since the objective function of this linear programming model is the Minimization Of the Total Absolute Deviation, Hazell termed it the MOTAD model. Further, he points out that the sum of the negative income deviations below the mean (Z_t^-) must always be equal to the sum of the positive deviations above the mean (Z_t^+). It is therefore sufficient to minimize only the sum of the absolute values of the negative total of net income deviations. The mathematical formulation of the MOTAD model is as follows (Hazell, 1986. Anderson et al., 1977):

Minimize $A = \sum_{t=1}^{T} Z_t^-$ (4.1)

Subject to

$$\sum_{j=1}^{n} (c_{tj} - f_j)X_j + Z_t^- >= 0 \quad t = 1,\ldots,T \quad (4.2)$$

$$\sum_{j=1}^{n} f_j X_j = E \quad (4.3)$$

$$\sum_{j=1}^{n} a_{ij}X_j <= b_i \quad\quad i = 1,\ldots,m \quad (4.4)$$

$$X_j, \; Z_t^- >= 0 \quad \text{for all } j, t \quad (4.5)$$

Where

Z_t^- = absolute value of the negative total net return deviation in year t, t = 1,...,T;

T = number of years of sample observations;

n = number of activities in the basic linear programming model;

c_{tj} = net return observation for the jth activity in the tth year;

f_j = expected net return per unit of the jth activity;

X_j = level of the jth farming activity;

E = expected total net return level to be parameterized over its feasible range through parametric procedures until attaining the maximum possible total net returns under the resource constraints;

a_{ij} = technical input/output coefficient specifying the amount of the ith resource required for a unit of product from the jth activity;

b_i = available stock of the ith resource.

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The solution to this problem identifies the most efficient farm plans in the sense that they generate a given level of farm income while minimizing the level of risk. That is, among all crop enterprise alternatives the one identified is superior to any other in that it is of minimum variance.

In this study, the procedure followed to solve the linear programming problem formulated in equations (4.1) to (4.5) includes two steps. First, the maximum level of net farm income that can be generated under the specific set of resource constraints is determined. Second, the scalar E, representing a given level of farm income, is parameterized between, say, $10000 up to the maximum income level obtained in the first step. Therefore, the first step corresponds to the solution of a standard profit maximization farm planning problem, equivalent to maximizing equation (4.3) subject to equation (4.4) and (4.5).

The rationale for deriving a set of efficient farm plans rather than a unique one is that the acceptability of any particular plan to an individual farmer will depend on his/her preference for various expected levels of income and associated risk. Thus, it allows the farmer to make the final tradeoff. As Hazell suggests, this approach compensates to some extent for situations where income variance is not the best measure of uncertainty. Further,

if other socioeconomic factors influence the farmer's attitude towards risk, the farmer is free to choose the plan he/she most prefers in relation to a multiplicity of goals.

Once the set of efficient farm plans has been obtained, the standard deviation of their income can be approximated by multiplying the optimum value of A in equation (4.1) by Fisher's constant F (Hazell, 1986), with

$$F = (2/T) * (T * \pi / 2 * (T-1))^{1/2}$$

where T is the number of years in the series, and π is the mathematical constant 3.1416. An alternative to this method is to estimate the standard deviation of farm income as an aggregation of the sample variances and covariances of the individual crops in the optimal solution. The latter is preferred statistically, and it also avoids any error that may arise from using Fisher's constant F when the net return distributions are not normal.

4.3 MODEL STRUCTURE

The linear programming problem as formulated in this paper is designed to provide a continuously repeatable crop sequence mix. This farm plan represents the optimum

resource allocation strategy which can be repeated year after year if resource availabilities, relative prices and risk level remain unchanged. The model represents production possibilities for navy beans, corn, wheat, soybeans, and sugar beets when they are grown in seven alternative cropping sequences. The production of each of these crops takes place within the yearly availability of resources. Due to the agronomic characteristics of the crops, the cropping year is disaggregated into 16 periods (Table 4.1). Cropping operations and their timing relationships are listed in Table 4.2.

The overall structure of the linear programming model is portrayed in Table 4.3. Each of the rows and columns represents a larger set of rows and columns in the empirical formulation. These items are defined for individual time periods consistent with Tables 4.1 and 4.2.

Overall, the formulation seeks to define farm plans that simultaneously improve income and risk performance. It generates a set of efficient farm plans that define optimal tradeoffs among these competing goals. The income objective is pursued through identifying a farm plan that yields the maximum level of net returns to land. The risk goal is accomplished through identifying the farm plan that generates the minimum level of income variability as defined

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Table 4.1 Time for Field Operations
```
-----------------------------------------------------------------
         PERIOD                        DATE 1/
-----------------------------------------------------------------
            1                        4/10-4/23*
            2                        4/24-5/14
            3                        5/15-5/21
            4                        5/22-5/28
            5                        5/29-6/05
            6                        6/06-6/19
           6A                        6/20-7/03
           6B                        7/04-7/10
            7                        7/15-8/06
            8                        8/28-9/24
            9                        9/25-10/01
           10                        10/02-10/08
           11                        10/09-10/16
           12                        10/17-10/22
           13                        10/23-11/12
           14                        11/13-11/27
-----------------------------------------------------------------
```

* April 10 to April 23.

SOURCE : Christenson et al. (1980).

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Table 4.2 Calendar of Operations

PERIOD	CORN 1/				NAVY BEANS				SOYBEANS				SUGAR BEETS				WHEAT			
	L.P.	P.	P.P.	H	L.P.	P.	P.P.	H	L.P.	P.	P.P.	H	L.P.	P.	P.P.	H	L.P.	P.	P.P.	H
4/10-4/23	X				X				X				X							
4/24-5/14	X	X			X				X				X					X		
5/15-5/21					X				X	X										
5/22-5/28					X	X			X	X					X					
5/29-6/05			X		X	X			X	X					X					
6/06-6/19			X		X	X					X				X					
6/20-7/03							X				X				X					
7/04-7/10							X								X					
7/15-8/06																				X
8/28-9/24								X				X		X			X			
9/25-10/01	X							X	X				X	X			X	X	X	
10/02-10/08	X								X				X	X			X	X	X	
10/09-10/16	X			X	X				X				X	X			X	X	X	
10/17-10/22	X			X	X				X				X	X			X			
10/23-11/12	X			X	X				X					X			X			
11/13-11/27	X				X				X					X						

1/ L.P. = Land preparation; P.= Planting; P.P.= Post-planting; H = Harvesting.

SOURCE: Christenson et al.(1980), Wolak (1981).

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Table 4.3.Linear Programming Model Schematic *

	Units	CORN [1] L.P.	P.	P.P.	H	ROTATION 1 ... 7	NAVY BEANS L.P.	P.	P.P.	H	ROTATION 1 ... 7	SOYBEANS L.P.	P.	P.P.	H	ROT. 3
Risk																
Net Returns		−	−	−	−	+ ... +	−	−	−	−	+ ... +	−	−	−	−	+
Field Work Time	hours	+	+	+	+	...	+	+	+	+	...	+	+	+	+	
Land	acres	+				...	+				...	+				
Acreage Planted	acres	−	+			...	−	+			...	−	+			
Acreage Cultivated	acres		−	+		...		−	+		...		−	+		
Acreage Harvested	acres			−	+	...			−	+	...			−	+	
Till. Tractor Time	hours	+	+	+	+	...	+	+	+	+	...	+	+	+	+	
Util. Tractor Time	hours	+	+	+	+	...	+	+	+	+	...	+	+	+	+	
Land Balance	acres				−	+ ... +				−	+ ... +				−	+
Rotation Restriction	acres					+ ...					− ...					
Contract Sugar Beets	acres					...					...					
Max. Acreage Corn	acres					+ ... +					...					
Max. Acreage Wheat	acres					...					...					
Risk Row 1	dollars					+ ... +					+ ... +					+
.	.	.	.	.	.	. . . . .	.	.	.	.	. . . . .	.	.	.	.	.
.	.	.	.	.	.	. . . . .	.	.	.	.	. . . . .	.	.	.	.	.
.	.	.	.	.	.	. . . . .	.	.	.	.	. . . . .	.	.	.	.	.
Risk Row T	dollars					+ ... +					+ ... +					+

	Units	SUGAR BEETS L.P.	P.	P.P.	H	ROTATION 1 ... 6	WHEAT L.P.	P.	P.P.	H	ROTATION 5 6	RISK BEARING Z1* ... Z1*	RIGHT HAND SIDE
Risk												+ ... +	MINIMIZE
Net Returns		−	−	−	−	+ ... +	−	−	−	−	+ +		MAXIMIZE
Field Work Time	hours	+	+	+	+	...	+	+	+	+			<= +
Land	acres	+				...	+						<= +
Acreage Planted	acres	−	+			...	−	+					= 0
Acreage Cultivated	acres		−	+		...		−	+				= 0
Acreage Harvested	acres			−	+	...			−	+			= 0
Till. Tractor Time	hours	+	+	+	+	...	+	+	+	+			<= +
Util. Tractor Time	hours	+	+	+	+	...	+	+	+	+			<= +
Land Balance	acres				−	+ ... +				−	+ +		= 0
Rotation Restriction	acres					...							= 0
Contract Sugar Beets	acres					+ ... +							= 80
Max. Acreage Corn	acres					...							<= +
Max. Acreage Wheat	acres					...					+ +		<= +
Risk Row 1	dollar					+ ... +					+ +	+	>= 0
.	.	.	.	.	.	. . . . .	.	.	.	.	. .	.	.
.	.	.	.	.	.	. . . . .	.	.	.	.	. .	.	.
.	.	.	.	.	.	. . . . .	.	.	.	.	. .	.	.
Risk Row T	dollar					+ ... +					+ +	+	>= 0

[1] L.P. = Land preparation; P.= Planting; P.P.= Post-planting; H = Harvesting.
* Pluses and minuses refer to signs of coefficients in cells.

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in the previous section.

The general structure of the linear programming problem presented in this section is an expansion and adaptation of a model developed by McCarl et al. (1977).

4.3.1 ACTIVITY TYPES

* Land Preparation (38 activities): This activity set pertains to chisel plowing and fertilizer spreading. Activities use land, labor, time for field operations (which accounts for use of machinery complements), and tractor time. Activities supply prepared land for the planting operation. The net return row-coefficients are machinery and labor costs per acre.

* Planting (12 activities): These activities refer to field cultivation, row planting and spraying. Activities use labor, time for field operations (which accounts for use of machinery complements) and tractor time; supply land for post-planting operations; and contribute machinery, labor and timeliness costs to the net farm returns.

* Post-planting (10 activities): This activity set includes row cultivation and ammonia application. Activities consume

the same resources as does the previous set. They also supply land for harvesting operations, and increase labor and machinery costs.

* Harvesting (15 activities): This activity set includes navy bean pulling, sugar beet topping and lifting operations, and combine harvesting. Activities use labor, time for field operations (which accounts for the use of harvesting equipment), and tractor time. The total acreage of each crop harvested is equated to the sum of acreages of that crop across the different rotations. Net return row-coefficients are machinery, labor and timeliness costs per acre.

* Rotation (24 activities): This activity set represents the acreage that is allocated to each crop in each cropping sequence. Activities use land that has received all the field machinery operations required to produce each crop and enter each of the risk rows. Net return row-coefficients are the net returns of each crop in each cropping sequence. These figures account for technical complementarities among crops, and account for most of the variation in recommended fertilizer application rates and expected yields. As discussed later, these coefficients are derived multiplying expected price by expected yields (the values of which vary for each cropping sequence) and substracting the variable

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cash production costs of each crop (again specific to each cropping sequence under consideration). Coefficients in the risk rows are derived from the net return series presented in Table 3.9. These coefficients represent deviations from expected values in each of the years of sample data.

* Transfer of Resources (17 activities): This activity set serves to transfer land that was not completely planted, cultivated or harvested in a given period to subsequent periods, so that required operations may be finished. (These activities are not shown in Table 4.3).

* Risk Bearing (23 activities): This activity set represents negative deviations from the expected value of net income. As shown in Table 4.3 and equation 4.2, these activities take a value greater than zero when the total sum of deviations associated with a given farm plan is negative for a given "state of nature". On the other hand, if this sum is positive, the corresponding Z_t^- variable will be zero. These activities contribute to the risk objective function (being minimized) in direct proportion to their value.

4.3.2 CONSTRAINTS

* Field Work Time Availability (16 constraints): Limits on the field work time available during each of the periods in

which the cropping year is disaggregated. Total time availability in each period results from the most binding value between predicted suitable time for field operations, and labor time availability. Right hand side coefficients associated with this set of constraints are presented in Table 4.10, while coefficients representing time requirements of each field operation are shown in Table 4.9.

* Land (12 constraints): This represents a control over total land use during each of the relevant time periods. These constraints stipulate that no more than 400 acres of land can be cultivated in each period.

* Land Use Precedence (37 constraints): This is a set of constraints which ensures that planting follows land preparation, cultivation follows planting, and harvesting follows cultivation.

* Tractor Time (2 constraints): This places limits on the number of hours of tillage and utility tractor use. The recommended number of hours of use is assumed to be no more than 1000 hours in the cropping year for both tractors (Al-Soboh, 1983). Tractor time requirements are presented in Table 4.9.

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* Sugar Beet Contract (1 constraint):   This constraint ensures that if sugar beets are grown, sugar beet acreage equals 80 acres.

* Crop Acreages (2 constraints):   These constraints limit the acreages of corn and wheat to less than the maximum allowed of 112 acres for corn and 60 acres for wheat. These maximum values are based upon trends in resource use in Saginaw Valley cash crop farms (Table 2.1), and correspond to 28% and 15% respectively of the total tillable acreage of the farms under study.

* Land Balance (5 constraints): These constraints equate the total area of land allocated to a given crop in the different cropping sequences to the total acreage of that crop that receives field machinery operations.

* Rotation (17 constraints):   This set of constraints forces the acreages allocated to crops in a given cropping sequence to be equal to each other.

* Risk Rows (23 constraints):   This set of constraints requires total deviations from expected net income for a given farm plan to be greater or equal than zero across the different "states of nature" under consideration.   These

"states of nature" correspond to each of the years of sample data in Table 3.9. Risk row-coefficients are presented in Table 4.14.

4.3.3 OBJECTIVE FUNCTION

Two alternative criteria of maximizing net returns to land and minimizing risk are used to identify the optimal crop sequence mix for the hypothetical farm under consideration. The first criterion is defined as gross income (price * yield) <u>less</u> costs categorized as 1) variable which include seed, fertilizer and chemical costs, and interest on working capital; 2) machinery costs such as depreciation, shelter, interest on investment, insurance, repairs, fuel and lubrication, maintenance and labor; 3) timeliness costs which is an estimate of losses due to sub-optimum timing of operations; 4) post-harvest costs such as drying, trucking freight and marketing; this value then estimates net returns to land.

Costs 2) and 3) above define the objective function coefficients for land preparation, planting, post-planting and harvesting activities, while the difference between gross income and costs 1) and 4) yields the objective function coefficients for the crop rotation activities.

For a given farm plan, the risk criterion is defined as the sum of total negative net income deviations from expected levels.

4.4 DATA DEVELOPMENT

4.4.1 YIELD RELATIONSHIPS

Table 4.4 depicts estimated yields under the alternative cropping sequences being considered for the fine textured soils of Michigan's Saginaw Valley. A thorough discussion of how these figures were derived is provided in Christenson et al. (1986). This source also provides a detailed analysis of the effects of rotation length, and of including other crops in the sequence such as alfalfa and oats.

Unlike yield relationships used by Hoskin (1981) in his work, these figures are based on the assumption that a fall chisel plow tillage rather than a conventional, fall moldboard plow tillage system is employed.

4.4.2 EXPECTED PRICES

As discussed in Chapter 3, this paper explores two alternative price scenarios (Table 4.5). Scenario 1 heavily weighs recent information, and is based upon a

Table 4.4
EXPECTED YIELDS UNDER ALTERNATIVE CROPPING SEQUENCES

NUMBER	DESCRIPTION	CORN (bu./acre)		NAVY BEANS (cwt./acre)		SOYBEANS (bu./acre)	SUGAR BEETS (ton/acre)	WHEAT (bu./acre)
		1st	2nd	1st	2nd			
1	C-NB	115		13				
2	C-NB-B	115		13			21	
3	NB-C-SB	115		13		38		
4	C-C-NB-B	115	103	14			20	
5	C-NB-W-B	115		14			21	60
6	C-C-NB-W	115	103	14				60
7	C-NB-NB-B	115		12	11		20	

1/ C = Corn; NB = Navy Beans; B = Sugar Beets; SB = Soybeans; W = Wheat.
SOURCE: Christenson et al (1986).

Table 4.5 Expected Product Prices

SCENARIO	CORN ($/bu.)	NAVY BEANS ($/cwt)	SOYBEANS ($/bu.)	SUGAR BEETS ($/ton)	WHEATS ($/bu.)
1	1.91	17.54	5.43	31.75	2.77
2	2.51	20.98	6.39	35.6	3.21

three-year weighted moving average (Equation 3.2). It assumes that next year prices will continue experiencing a downward trend (Figures 3.1 and 3.2).

In contrast, Scenario 2 relies relatively more on past data, and is based upon a five-year unweighted moving average (Equation 3.1). This scenario assumes that next years' product prices relate to price levels up to five years back.

4.4.3 CASH COSTS

Appendix 1 presents recommended fertilizer, herbicide and pesticide rates for each crop in the alternative cropping sequences. Fertilizer rates are based on the net nutrient removal of soil nutrients by each crop, these figures are taken from Hoskin (1981). Herbicide and pesticide recommendations vary from farm-to-farm depending on the particular disease and pest problems encountered. The regimes used in this paper are representative of those employed in the Saginaw Valley area; their formulation takes into consideration the effects of other crops in rotation and they are specifically derived for a chisel tillage system (Jenne, 1985).

Prices for seeds, fertilizers and herbicides are presented in Appendix 1. Post-harvest costs are taken from Nott et

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al. (1988), and are also presented in Appendix 1.

4.4.4 MACHINERY COMPLEMENT

Wolak (1981) developed unique machinery complements for each
of the navy bean cropping sequences under consideration in
this paper. His work was based upon a hypothetical 400 acre
farm in Michigan's Saginaw Valley, with production date
constraints for completion of operations similar to those
used here (Tables 4.1 and 4.2). Rotz and Black (1984) also
used similar constraints in this region and developed
machinery complements for conventional and conservation
tillage practices for rotations of the same crops used in
this study.

Therefore, in order to define the specific field machinery
complement to be considered in this farm planning
application, results from the above two studies were taken
into consideration. Table 4.6 presents assumed field
machinery resources.

In order to check the consistency between power sources and
implement size of the field machinery set in Table 4.6, the
tractor size required for operating each of the identified
implements was calculated. Table 4.7 presents results of

TABLE 4.6 FIELD MACHINERY RESOURCES

ACTIVITY	IMPLEMENT	SIZE	UNIT OF MEASURE	PRICE ($1988)
-Land Preparation	.Fertilizer Spreader	60	ft.	3,269
	.Chisel Plow	11	ft.	4,029
-Planting	.Field Cultivator	19	ft.	4,839
	.Row Planter	6	rows *	13,951
	.Grain Drill	20	ft.	10,970
	.Sprayer	30	ft.	3,452
-Post-Planting	.Row Cultivator	6	rows	3,395
	.Ammonia Applicator	6	rows	3,661
-Harvesting	.Combine	6	rows	59,671
	.Navy Bean Puller	6	rows	10,454
	.Sugar Beet Topper	3	rows	8,497
	.Sugar Beet Lifter	3	rows	24,963
	POWER SOURCES			
	.Primary Tractor	130	hp.	38,361
	.Secondary Tractor	53	hp.	7,823

SOURCE: Compiled by the author based upon work done by
        Wolak (1981) and Rotz and Black (1984).

* 1 row = 30 inches.

TABLE 4.7 TRACTOR POWER REQUIREMENTS FOR OPERATING VARIOUS FIELD MACHINERY
ON FINE (CLAY) TEXTURED SOILS

MACHINE TYPE	POWER SOURCE 1/ 2/	POWER REQUIREMENT 1/ (hp./ft.)	POWER CONSUMED 3/ (hp.)	ESTIMATED HOURS OF USE 4/
.Navy Bean Puller	U	2.41	45.2	53
.Sugar Beet Topper	U	4.17	39.1	52
.Sugar Beet Lifter	T	9.80	91.9	52
.Fertilizer Spreader	U	0.78	58.2	15
.Chisel Plow	T	9.52	130.8	113
.Field Cultivator	T	4.53	104.9	48
.Row Planter	U	2.66	49.8	98
.Grain Drill	U	1.76	43.9	22
.Sprayer	U	1.02	38.3	43
.Row Cultivator	U	1.47	27.6	61
.Ammonia Applicator	T	7.48	140.2	38

1/ SOURCE: Rotz and Black (1984).

2/ U = Utility Tractor; T = Tillage Tractor.

3/ Compiled by the author assuming Rotz et al.'s figures account for
   tractive efficiency, load factor and tractor PTO to axle power ratio.
   A power reserve of 25% is considered :
   Power Consumed = 1.25*(Power requirement per unit width*width).

4/ Estimated average for a 400 acre farm, based upon figures developed by
   Rotz and Black (1984) and Jenne (1985) for 490 acre farms in Eastern Michigan
   growing corn, navy beans, soybeans, sugar beets and wheat, under different
   crop sequences.

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this evaluation. As it is noted in this table, power requirements of the fertilizer spreader and ammonia applicator exceed the power provided by each of the sources.

However, given that a 25% power reserve was assumed and that a lower ground speed for these implements is feasible, this match between power sources and implement size is considered appropriate.

Table 4.8 presents effective field capacities of the available implements. Table 4.9 develops average yearly machinery cost per acre for ownership and operation. Depreciation, interest, repairs, insurance, shelter, labor and fuel costs are considered. Machinery costs are based on prices presented in Wolak (1981) which are adjusted by inflation to 1988 dollars (Table 4.6). Machinery is assumed to have an eight year service life. Techniques outlined by Bowers (1987) and Schwab et al. (1988) are used to calculate machinery cost. Like Wolak (1981), Hoskin (1981) and Al-Soboh (1983) a number of hours of annual use is assumed (Table 4.7) to estimate annual fixed costs per acre. Diesel fuel consumption is calculated based on estimates developed by Helsel et al. (1981). Average yearly costs result from summing average annual fixed costs divided by the effective field capacity; assigned tractor costs; fuel costs; lubrication and maintenance; and, labor costs.

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TABLE 4.8 EFFECTIVE FIELD CAPACITY OF THE AVAILABLE IMPLEMENTS 1/

ACTIVITY	IMPLEMENT	SPEED 2/ (miles/hour)	EFFICIENCY 2/	EFC (acres/hour)
-Land Preparation	.Fertilizer Sprea	5.0	70%	25.20
	.Chisel Plow	5.0	85%	5.61
-Planting	.Field Cultivator	5.5	85%	10.38
	.Row Planter	4.5	55%	4.46
	.Grain Drill	6.0	70%	10.09
	.Sprayer	5.0	65%	11.69
-Post-Planting	.Row Cultivator	4.6	80%	6.62
	.Ammonia Applicat	5.0	65%	5.85
-Harvesting	.Combine 2/			
	-Corn			3.20
	-Navy Beans			6.30
	-Soybeans			3.60
	-Wheat			4.10
	.Navy Bean Puller	5.0	80%	7.20
	.Sugar Beet Toppe	5.0	70%	3.15
	.Sugar Beet Lifte	5.0	70%	3.15

1/ Effective Field Capacity (EFC)= (speed*width*efficiency)/100   (White, 1976)
2/ Figures taken from Wolak(1981).

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TABLE 4.9 ANNUAL MACHINERY COSTS PER ACRE (1988 dollars)

MACHINE TYPE	FIXED COSTS AND REPAIRS FACTOR 1/	AVERAGE ANNUAL FIXED COSTS 2/ ($/hr/yr)	ASSIGNED TRACTOR COSTS 3/ ($/acre)	FUEL COSTS 4/ ($/acre)	LUBRIC. AND MAINTEN. 5/	LABOR COSTS 6/ ($/acre)	TOTAL ANNUAL MACHINERY COSTS 7/ ($/acre)	CUSTOM WORK RATES 8/ ($/acre)
Primary Tractor	0.598	22.94						..20.0
Secondary Tractor	0.598	4.68						20.0
Combine	2.270	135.45						
.Corn				1.51	0.23	2.23	46.30	NA
.Navy beans				1.23	0.18	1.13	24.05	NA
.Soybeans				1.51	0.23	1.99	41.35	NA
.Wheat				1.51	0.23	1.74	36.52	NA
Bean Puller	5.113	53.45	0.65	0.52	0.08	0.99	9.67	5.1
Beet Topper	5.113	43.45	1.49	0.83	0.12	2.27	18.50	NA
Beet Lifter	5.113	127.64	7.28	1.37	0.21	2.27	51.65	52.0
Fert. Spreader	10.048	32.84	0.19	0.30	0.05	0.28	2.12	8.1
Chisel Plow	2.334	9.40	4.09	1.36	0.20	1.28	8.61	10.3
Field Cultivator	5.053	24.45	2.21	0.78	0.12	0.69	6.15	4.6
Row Planter	2.870	40.04	1.05	0.51	0.08	1.60	12.23	14.4
Grain Drill	10.183	111.71	0.46	0.56	0.08	0.71	12.89	5.7
Sprayer	5.053	17.44	0.40	0.33	0.05	0.61	2.88	2.9
Row Cultivator	4.226	14.35	0.71	0.39	0.06	1.08	4.40	NA
NH3 Applicator	7.551	27.64	3.92	0.80	0.12	1.22	10.79	3.0

1/ SOURCE: Bowers (1987) Appendix. Each factor represents the cost per hour
   per $1,000 of initial list price, assuming 8 years of useful life and
   a number of hours of annual use equal to the figures presented in Table 4.7 .
2/ Factor*Initial list price. Includes : Depreciation, Shelter, Insurance,
   Interests and Repairs.
3/ Annual tractor costs / Effective field capacity of each implement.
4/ SOURCE: MSU Extension Bulletin E-1535 and Jenne (1985). Assuming $1/gallon of Diesel.
5/ Assumed to be 15% of fuel costs, as suggested by Schwab et al. (1988).
6/ Assuming labor requirements (in hours) are 30% higher than field machinery requirements (in hours),
   following Singh et al. (1979).
7/ Fixed plus variable costs.
8/ SOURCE: Schwab et al. (1988). Figures correspond to the Saginaw Valley.
   NA = Not Available.

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To validate the figures obtained, the last column of Table 4.9 shows the current custom work rates for 1988 (Schwab et al., 1988). With the exception of the ammonia applicator, navy bean puller and fertilizer spreader, the values calculated and the ones reported by Schwab et al. are approximately the same.

Table 4.10 presents the number of hours per acre required for each field operation. Given the activity types defined for the linear programming model, the number of hours per acre required for each production activity are presented in Table 4.10.

4.4.5 TIME FOR FIELD OPERATIONS

Table 4.11 gives the estimated number of hours available for field operations in each of the periods over which the cropping year is disaggregated. These figures result from multiplying the number of days in each period, times the proportion of days suitable for field work, times the estimated workday lengths.

Table 4.12 presents estimated workday lengths by type of operation. Since more than one type of operation needs to be accomplished in periods 8 to 12 (See Table 4.2), values reported in Tables 4.11 for these periods correspond to the

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TABLE 4.10 TIME REQUIREMENTS BY FIELD OPERATIONS (hours/acre)

ACTIVITY	OPERATION	CORN	NAVY BEANS	SOYBEANS	SUGAR BEETS	WHEAT
-Land Preparation	.Fertilizer Spreading	0.0397			0.0397	0.0397
	.Chisel Plowing	0.1784	0.1784	0.1784	0.1784	
	TOTAL LAND PREPARATION	0.2181	0.1784	0.1784	0.2181	0.0397
-Planting	.Field Cultivation 1.	0.0963	0.0963	0.0963	0.0963	0.0963
	.Field Cultivation 2.		0.0963		0.0963	
	.Row Planting	0.2245	0.2245	0.2245	0.2245	
	.Grain Drilling					0.0991
	.Spraying	0.0855	0.0855	0.0855	0.0855	0.0855
	TOTAL PLANTING	0.4063	0.5026	0.4063	0.5026	0.2810
-Post-Planting	.Row Cultivation	0.1510	0.1510	0.1510	0.1510	
	.Ammonia Application	0.1709			0.1709	
	TOTAL POST-PLANTING	0.3219	0.1510	0.1510	0.3219	
-Harvesting	.Combining	0.3125	0.1587	0.2778		0.2439
	.Navy Bean Pulling		0.1389			
	.Sugar Beet Topping				0.3175	
	.Sugar Beet Lifting				0.3175	
	TOTAL HARVESTING	0.3125	0.2976	0.2778	0.6349	

SOURCE: Compiled by the author based upon work done by Christenson et al. (1980),
Wolak (1981), and effective field capacties of Table 4.8.

Table 4.11 Time for Field Operations

PERIOD	NUMBER OF DAYS	PROBABILITY OF WORKING DAY 1/	ESTIMATED WORKDAY LENGTHS (hours)	NUMBER OF HOURS
1	14	0.42	12	71
2	7	0.42	12	122
	10	0.50		
	4	0.55		
3	6	0.55	12	48
	1	0.71		
4	8	0.71	12	68
5	3	0.71	12	69
	5	0.73		
6	10	0.73	12	114
	4	0.55		
6A	11	0.55	12	101
	3	0.78		
6B	7	0.78	12	66
7	17	0.48	8	92
	6	0.56		
8	4	0.76	9	181
	15	0.73		
	9	0.65		
9	6	0.65	9.25	42
	1	0.67		
10	7	0.67	10.3	49
11	7	0.67	10.25	55
	1	0.66		
12	6	0.66	10.25	41
13	9	0.66	11	151
	12	0.65		
14	3	0.65	12	49
	12	0.18		

1/ Predicted portion of days suitable for field
   work on a well drained sandy-loam soil in
   Bad Axe, Michigan at 0.8 probability level
   (Rosenberg, 1982; p.15).

Table 4.12 Estimated Workday Lengths

Operation	Field Work (hr/day)
Corn harvest	10.0
Soybean harvest	8.0
Navy bean harvest	6.0
Wheat harvest	8.0
Sugar beet harvest	11.0
Tillage	12.0

SOURCE: Wolak (1981)

average workday length of the different operations.

4.4.6 LABOR

According to the trends in labor use described in Chapter 2, labor availability is assumed to be 12 hours per day and 6 days per week, for a total of 2112 hours per cropping year. Table 4.13 (third column) shows estimated amounts of labor supply for each of the 16 cropping periods.

Field labor requirements (hours/acre) are assumed to be a function of the field machinery requirements for each crop. Consequently, the number of field machinery hours required by each crop in each period increases in 30% (Singh et al. 1979) to obtain field labor requirements. This allows accounting for the extra labor requirements of machine repair, maintenance and machine preparation.

Therefore, according to the above assumption, one field machinery hour is equivalent to 1.3 field labor hours. Hence, equivalent number of hours of labor supply can be obtained by dividing field machinery hours (column 3 of Table 4.13) by 1.3. The last column in Table 4.13 presents these calculations.

As previously discussed, the most binding value between

Table 4.13 Labor Supply

PERIOD	NUMBER OF WORKING DAYS	LABOR SUPPLY (hours)	EQUIVALENT LABOR SUPPLY 1/ (hours)
1	12	144	111
2	18	216	166
3	6	72	55
4	6	72	55
5	6	72	55
6	6	72	55
6A	12	144	111
6B	6	72	55
7	20	240	185
8	24	288	222
9	6	72	55
10	6	72	55
11	6	72	55
12	6	72	55
13	18	216	166
14	12	144	111

1/ It is assumed that 1.3 hours of labor are required
per hour of field machinery operation, following
Singh et al. (1979). Hence, equivalent labor supply
results from dividing labor supply by 1.3 .

predicted time for each field operation, and the equivalent number of hours of field labor supply for each period, defines the time availability to be used in the farm planning model. Therefore, comparing these two values for each period establishes that labor supply dominates suitable time for field operations in periods 4 to 6.

4.4.7 NET RETURN DEVIATIONS FROM EXPECTED VALUE

Table 4.14 presents deviations from expected net returns for each crop during the period 1965 to 1987. These figures represent the difference between the actual net returns of each crop in each of these years (Table 3.9) and a five-year unweighted moving average. For example, to derive results reported for 1965, the average net return between 1960 and 1964 is computed for each crop. This value estimates the expected net return value for 1965. Subsequently, the difference between the observed value for 1965 and the above expected value for this year is calculated for each crop.

The figures shown in Table 4.14 are the coefficients that enter into the risk row constraints of Table 4.3 under price scenario 2. Analogous coefficients are derived for scenario 1.

Table 4.14 Net Return Deviations From 5-Year Moving Average
               (1988 dollars / acre)

YEAR	CORN	NAVY BEANS	SOYBEANS	SUGAR BEETS	WHEAT
1965	-88.53	-86.27	-94.16	-110.18	-167.37
1966	-52.17	-94.29	-51.68	3.08	0.64
1967	-91.84	-12.76	-72.74	36.02	-109.3
1968	-74.06	-31.56	-76.87	-99.76	-136.21
1969	0.24	-32.78	-40.03	-73.69	-75.51
1970	37.05	29.68	63.11	39.55	-13.71
1971	-160.97	22.12	-18.14	-132.48	-67.67
1972	90.71	11.44	200.78	-40.79	21.93
1973	303.84	344.39	155.51	924.77	357.35
1974	176.95	35.38	102.73	1358.03	165.89
1975	-58.99	-16.49	-110.64	-292.31	-33.93
1976	-202.69	-192.93	-36.68	-627.82	-157.47
1977	-265.16	-99.61	-57.91	-560.19	-199.75
1978	-130.03	-174.76	-64.62	-536.52	-54.45
1979	9.16	68.74	-50.23	30.09	3.94
1980	33.4	101.57	45.49	147.84	-33.56
1981	-40.19	42.08	-81.32	-294.61	-19.96
1982	15.35	-128.21	-106.38	-100.5	-79.84
1983	-5.31	11.17	37.65	-160.24	-37.94
1984	-92.59	-145.73	-96.08	-121.06	-13.61
1985	-109.79	-132.81	-111.15	-157.04	-14.73
1986	-157.31	-58.78	-84.02	-35.61	-82.53
1987	-77.05	-55.03	5.86	-65.92	-19.27

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4.4.8 TIMELINESS COSTS

Table 4.15 presents penalty costs for untimely field operations. These coefficients enter the net farm income constraint as a cost component of planting and harvesting in the corresponding periods.

Appendix 2 includes a summary of machinery costs, input costs and post-harvest costs associated with the cropping sequences which are used in this paper's model.

In summary, this chapter developed a model of a 400 acre farm to estimate tradeoffs between risk and income. Chapter 5 presents empirical findings of the model.

Table 4.15 Penalty Costs for Untimely Field Operations

| CROP | PLANTING | | HARVESTING | |
	Lost % / day	Penalty $/acre/week	Lost % / day	Penalty $/acre/week
Corn	1% after 5/13	19.7	1% after 11/18	19.7
Navy Beans	0.7% before 6/04 or after 6/24	16.1	0.7% before 19/03 or after 9/17	16.1
Soybeans	1% after 5/20	16.1	1% before 10/01 or after 10/15	16.1
Sugar Beets	1% after 5/06 3% after 5/13	32.1 39.8	-	-
Wheat	1% after 9/30	14.2	0.5% after 9/30	14.2

Source: Estimated from Rotz and Black (1984)

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CHAPTER 5

MODEL RESULTS

This chapter identifies crop production options for a 400 acre Saginaw Valley cash crop farm growing corn, navy beans, soybeans, sugar beets and wheat. These cropping options, derived from the model in Chapter 4, offer farmers alternative levels of risk and income; they are determined by minimizing risk at alternative income levels.

This chapter presents results first determining profit maximization schemes. It includes a detailed discussion of the optimum time for field operations, resource use across the cropping year, and shadow prices of resources. Sensitivity analyses of the optimum farm plan, according to this criterion, are obtained for two price scenarios: scenario 1 a three-year moving average, and scenario 2 a five-year moving average (Section 4.4.2). Further analyses are also performed on participation in government price support programs for corn and wheat.

The discussion of profit maximization is followed by an analysis of a risk minimization strategy. Similarly, this discussion also includes sensitivity analyses on both participation in government price support programs, and for two price scenarios; conclusions are reached on the effect

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of these parameters on income variability. This section also emphasizes determining the trade-offs between net returns and risk.

Risk is measured as explained in Chapter 3. That is, as deviations from a five-year and a three-year moving average net return expectation. These historical risk measures are chosen because they have proven to be compatible with procedures which farmers might use to formulate subjective risk assessments, as explained by Young (1980). The same figures developed in Chapter 3 to compute net return variability indices based on these two methods, are now incorporated (in Section 5.2) as constraints to crop production according to the discussion in Chapter 4.

The last part of the chapter compares results obtained in this paper with those of other studies.

The linear programming computer code LP88 - Version 5.12 is used to solve the farm planning problem (Eastern Software Products, Inc; 1986).

5.1 CROPPING PLANS OF MAXIMUM NET RETURNS TO LAND

5.1.1 FIVE-YEAR MOVING AVERAGE PRICE PROJECTION

Table 5.1 presents results for the profit maximization problem assuming no participation in government programs, and based upon a five-year moving average price scenario (see section 4.4.2). As indicated, the optimal crop sequence mix includes 3 rotations. Consequently, the total tillable acreage is divided in 10 lots, 3 of 20 acres, 3 of 33 acres, and 4 of 60 acres. The corresponding optimal crop mix consists of 113 acres in corn, 113 in navy beans, 33 in soybeans, and 80 and 60 acres in sugar beets and wheat (the maximums allowed), respectively.

Given the agronomic characteristics of the crops, the suitable days for field work, machinery set, labor assumptions, timeliness costs, and other production conditions described in Chapter 4, Table 5.1 also indicates the optimal time for field operations (on the basis of profit maximization), and the associated acreages that should be undergoing in land preparation, planting, post-planting and harvesting operations at each period. The specific dates that correspond to each period are found in Table 4.1.

Table 5.1 Results Profit Maximization Problem Assuming No Participation In Government
        Programs and Price Scenario 2.

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OPTIMUM CROP SEQUENCES			:	OPTIMUM CROP MIX		
	LOT SIZE	AREA	:		ACREAGE	RELATIVE
	(acres)	(acres)	:			
1. C-NB	0.0	0.0	:	- Corn	113.3	28%
2. C-NB-B	20.0	60.0	:	- Navy Beans	113.3	28%
3. NB-C-SB	33.3	100.0	:	- Soybeans	33.3	8%
4. C-C-NB-B	0.0	0.0	:	- Sugar Beets	80.0	20%
5. C-NB-W-B	60.0	240.0	:	- Wheat	60.0	15%
6. C-C-NB-W	0.0	0.0	:	TOTAL	400.0	
7. C-NB-NB-B	0.0	0.0	:			
TOTAL		400.0	:			

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OPTIMUM TIME FOR FIELD OPERATIONS

CROP	PERIOD	A C T I V I T Y			
		LAND PREPARATION (acres)	PLANTING (acres)	POST-PLANTING (acres)	HARVESTING (acres)
.CORN	2	113.3	113.3		
	5			113.3	
	11				113.3
.NAVY BEANS	1	72.3			
	4	41.0			
	6		113.3		
	6A			113.3	
	8				113.3
.SOYBEANS	1	33.3			
	3		33.3		
	6			33.3	
	10				33.3
.SUGAR BEETS	1		80.0		
	4			80.0	
	8	80.0			
	9				17.4
	10				62.6
.WHEAT	7				60.0
	9	60.0	60.0		

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NET RETURNS TO LAND $66,314.7

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SHADOW PRICES
.Land $104.6 /acre
.Beet contract $280.4 /acre
.Max Wheat $33.8 /acre

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Table 5.2 presents the optimal resource use allocation associated with this crop production strategy. According to this analysis, time availability for field operations is a binding constraint in periods 1 and 10. In addition, there is little extra time availability in periods 2, 4, 5, 9 and 11. Furthermore, since suitable time for field operations has been obtained at an 80% probability level only, it is likely that in these periods slack times will be further reduced perhaps shifting field operations to other periods.

Patterns of land use are as follows (Tables 5.1 and 5.2). In period one, 62% of the total tillable acreage is allocated to wheat and sugar beet production, and to land preparation for navy bean production. Land preparation and planting for the other crops occurs between periods 2 and 4. From period 4 to 6B 100% of tillable acreage is under production. At year's end, there are 60 acres under wheat production and 80 acres have been plowed for sugar beets.

Patterns of labor use (Table 5.2) identify periods 4 to 6 and 9 to 11 as the most critical in terms of labor requirements. On the other hand, tractor time usage (219 hours per year for the utility tractor and 177 hours per year for the tillage tractor) is well below the maximums allowed.

Table 5.2 Resource Use Pattern Associated With the Crop Production Strategy
          Of Maximum Net Return Level 1/

Period	Time For Field Operations	Land	Labor
1	100%	62%	64%
2	62%	90%	46%
3	29%	90%	25%
4	60%	100%	60%
5	66%	100%	66%
6	57%	100%	56%
6A	17%	100%	16%
6B	0%	100%	0%
7	16%	· 85%	8%
8	27%	77%	22%
9	84%	87%	63%
10	100%	64%	88%
11	65%	35%	64%
12	0%	35%	0%
13	0%	35%	0%
14	0%	35%	0%

Tractor Use :	Utility Tractor	219 hours
	Tillage Tractor	177 hours

1/ Each entry represents resorce use as a percentage of total availability.
   Based on Table 5.1

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It should be noted that the above schedule of operations also minimizes timeliness costs. This results from the fact that field operations are determined by the model in such a way that each crop is planted and harvested within its optimal time period.

Another interesting feature of the farm plan presented in Table 5.1 is that it portrays how the rotation mechanism is working. For example, in the case of crop sequence 5, land preparation and planting of wheat begins in period 9, right after navy beans are harvested in period 8; similarly, after wheat is harvested in period 7, land preparation for sugar beets begins in period 8. In addition, the implications of being in a continuously repeatable crop rotation scheme of production (the "stable phase" or steady state discussed in Throsby (1967), El-Nazer (1986) and Hoskin (1981)) is seen in the case of sugar beets; wheat and navy beans harvested in periods 7 and 8 are plowed for sugar beets in period 8, and at the same time, there are other two lots with sugar beets which begin harvest in period 9. Similar behaviors occur with other crops within the crop production plan.

The amount of net returns to land achieved under this plan, given the resource constraints, is estimated to be $66300. The shadow price associated with the sugar beet contract is $280 per acre. This implies that if it were possible to

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contract for one more acre of beets, net returns would increase by $280. The shadow price associated with the land restriction implies that if an additional acre of land could be rented it would generate an estimate of $105 of net income. Hence, this figure represents the value of that acre to the farmer.

Table 5.3 presents the optimum crop sequence mix assuming both participation in government price support programs for corn and wheat and price scenario 2. It should be noted first that, although these government programs do not entail a direct cost, the farmer may have to comply with some type of acreage setaside requirement. This is captured in the model by reducing the total tillable acreage by 10% to 360 acres. Unlike crops grown under a free-market scenario where crops are sold at market prices without the intervention of government program payments, crops grown under a price support program scenario benefit from deficiency payments which serve to support the crops' market value. This is captured in the model by increasing corn and wheat revenues by the values obtained from Nott et al. (1988). Furthermore, under this scenario, acreage allocated to corn is restricted to no more than 112 acres.

Results from this scenario (Table 5.3) divide total tillable acreage into 9 lots: 2 of 30 acres, 3 of 20 acres and 4 of

Table 5.3 Results Profit Maximization Problem Assuming Participation In Government
Programs and Price Scenario 2.

```
===============================================================================
OPTIMUM CROP SEQUENCES             :     OPTIMUM CROP MIX
-----------------------------------:-------------------------------------------
             LOT SIZE    AREA      :                        ACREAGE  RELATIVE
             (acres)    (acres)    :
  1. C-NB        30        60      :   - Corn                 110      31%
  2. C-NB-B      20        60      :   - Navy Beans           110      31%
  3. NB-C-SB      0         0      :   - Soybeans               0       0%
  4. C-C-NB-B     0         0      :   - Sugar Beets           80      22%
  5. C-NB-W-B    60       240      :   - Wheat                 60      17%
  6. C-C-NB-W     0         0      :        TOTAL             360
  7. C-NB-NB-B    0         0      :
        TOTAL            360       :
===============================================================================
```

OPTIMUM TIME FOR FIELD OPERATIONS

CROP	PERIOD	A C T I V I T Y LAND PREPARATION (acres)	PLANTING (acres)	POST- PLANTING (acres)	HARVESTING (acres)
.CORN	2	110	110		
	5			110	
	11				110
.NAVY BEANS	1	105.7			
	4	4.3			
	6		110		
	6A			110	
	8				110
.SUGAR BEETS	1		80		
	4			80	
	8	80			
	9				2.8
	10				77.2
.WHEAT	7				60
	9	60	60		

```
===============================================================================
NET RETURNS TO LAND      $79,359.0
===============================================================================
SHADOW PRICES
 .Land                $160.0 /acre
 .Beet contract       $232.8 /acre
 .Max Wheat            $52.2 /acre      .Max Corn            $0.0 /acre
===============================================================================
```

60 acres. Of these, 3 are devoted to corn, 3 to navy beans, 2 to sugar beets, and 1 to wheat. Hence, given that crop production is taking place within strict rotational patterns and that corn and wheat revenues are increased under government support programs relative to other crops, farm income is improved by switching from rotation 3 to rotation 1. Thus, soybeans are left out of production.

This crop plan also results in more time available during period 1, and therefore the acreage prepared for navy beans in this period is increased. Field operations and resource use patterns are quite similar to the ones in the previous case.

Under this scenario that considers government payments, net returns improve by 20%. On the other hand, the unit worth of having an additional acre contracted to beets is reduced because of the higher relative revenues from corn and wheat. In contrast, shadow prices for total land resources and maximum acreage allowed in wheat increase, due to reduction in land resources and the higher wheat revenues. The shadow price associated with the maximum acreage allowed in corn is zero, meaning that by participating in the government price support program, farm income is not sacrificed.

5.1.2 THREE-YEAR MOVING AVERAGE PRICE PROJECTION

To establish the price sensitivity of the optimal solution in Table 5.1, Table 5.4 reports results under a three-year moving average price scenario (Section 4.4.2) assuming no participation in government price support programs. Under this scenario, crop sequences 3 and 5 again offer highest profits. Of the total tillable acreage available, 27% is allocated to corn, 27% to navy beans, 20% to sugar beets, 20% to wheat, and 7% to soybeans.

The optimal schedule of field operations change slightly, and involves land preparation for soybeans in period 11. As in the previous two scenarios, timeliness costs are not incurred for any of the crops as long as land, machinery, labor, and other resources are allocated across the cropping year according to the strategy presented in Table 5.4.

To complete the sensitivity analyses of the optimal crop production strategy, Table 5.5 presents analyses of the impact of low product price levels and participation in government corn and wheat programs on crop plans and farm income. As before, 40 acres are setaside. Results indicate that rotation 5 is in the optimum cropping plan, accounting for nearly 90% of the total production. Unlike previous results, rotation 6 is now included in the optimum crop

Table 5.4 Results Profit Maximization Problem Assuming No Participation In Government
        Programs and Price Scenario 1.

```
=================================================================================
OPTIMUM CROP SEQUENCES              :    OPTIMUM CROP MIX
-----------------------------------:---------------------------------------------
              LOT SIZE    AREA      :                         ACREAGE  RELATIVE
              (acres)    (acres)    :
1. C-NB         0.0        0.0      :     - Corn              106.7      27%
2. C-NB-B       0.0        0.0      :     - Navy Beans        106.7      27%
3. NB-C-SB     26.7       80.0      :     - Soybeans           26.7       7%
4. C-C-NB-B     0.0        0.0      :     - Sugar Beets        80.0      20%
5. C-NB-W-B    80.0      320.0      :     - Wheat              80.0      20%
6. C-C-NB-W     0.0        0.0      :         TOTAL           400.0
7. C-NB-NB-B      0          0      :
      TOTAL              400.0      :
=================================================================================
```

OPTIMUM TIME FOR FIELD OPERATIONS

CROP	PERIOD	A C T I V I T Y LAND PREPARATION (acres)	PLANTING (acres)	POST-PLANTING (acres)	HARVESTING (acres)
.CORN	2	106.7	106.7		
	5			106.7	
	11				106.7
.NAVY BEANS	1	83.5			
	3	23.2			
	6		106.7		
	6A			106.7	
	8				106.7
.SOYBEANS	3		26.7		
	6			26.7	
	10				26.7
	11	26.7			
.SUGAR BEETS	1		80		
	4			80	
	8	80			
	10				53.4
	11				26.6
.WHEAT	7				80
	9	80	80		

```
=================================================================================
NET RETURNS TO LAND       $40,349.9
=================================================================================
SHADOW PRICES
  .Land               $41.7 /acre
  .Beet contract     $295.7 /acre
=================================================================================
```

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Table 5.5 Results Profit Maximization Problem Assuming Participation In Government Program and Price Scenario 1.

```
=================================================================================
OPTIMUM CROP SEQUENCES                    :    OPTIMUM CROP MIX
---------------------------------------------:-----------------------------------
                                          :
               LOT SIZE    AREA           :                      ACREAGE  RELATIVE
               (acres)    (acres)         :
1. C-NB            0          0           :    - Corn              100      28%
2. C-NB-B          0          0           :    - Navy Beans         90      25%
3. NB-C-SB         0          0           :    - Soybeans            0       0%
4. C-C-NB-B        0          0           :    - Sugar Beets        80      22%
5. C-NB-W-B       80        320           :    - Wheat              90      25%
6. C-C-NB-W        10         40          :        TOTAL           360
7. C-NB-NB-B        0          0          :
     TOTAL                    360         :
=================================================================================
```

OPTIMUM TIME FOR FIELD OPERATIONS

CROP	PERIOD	A C T I V I T Y			
		LAND PREPARATION (acres)	PLANTING (acres)	POST-PLANTING (acres)	HARVESTING (acres)
.CORN	2	90	100		
	5			100	
	9	10			
	11				100
.NAVY BEANS	1	72.3			
	3	17.7			
	6		90		
	6A			90	
	8				90
.SUGAR BEETS	1		80		
	4			80	
	8	80			
	10				77.2
	11				2.8
.WHEAT	7				90
	9	90			
	9		90		

```
=================================================================================
NET RETURNS TO LAND        $56,578.7
=================================================================================
SHADOW PRICES
.Land                      104.8 $/acre
.Beet contract             235.6 $/acre
=================================================================================
```

production strategy.

5.1.3 "HAPHAZARD" STRATEGY

To complement the study of crop production strategies for the farm under consideration, Table 5.6 presents optimum cropping plans when a "haphazard" crop production system is followed (Christenson et. al, 1978). Under this strategy, resource allocation decisions are made on a yearly basis, based on price. Since this strategy does not consider the joint beneficial interrelationships among individual crops, the objective function coefficients do not include the effect of these interactions. Instead, the average yield of each crop is taken from Table 4.4, and average fertilizer and herbicide application rates are taken from Appendix 1. Before discussing the results of this scenario, it should be pointed out that the model assumes that the cropping plan identified is repeated year after year as long as resource availabilities and prices remain unchanged. This fact must be kept in mind in order to analyze the optimum schedule of operations.

As seen in Table 5.6, without deficiency payments, the optimum crop mix calls for 142 acres in navy beans, 118 acres in soybeans, 80 acres in sugar beets, and 60 acres in

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Table 5.6 Optimum Crop Mix Assuming No Participation In Government Programs, Price Scenario 2
and a "Haphazard" Crop Production System

===

OPTIMUM CROP MIX

	AREA (acres)	RELATIVE
- Corn	0.0	0%
- Navy Beans	142.0	36%
- Soybeans	118.0	30%
- Sugar Beets	80.0	20%
- Wheat	60.0	15%
TOTAL	400.0	

===

OPTIMUM TIME FOR FIELD OPERATIONS

CROP	PERIOD	A C T I V I T Y LAND PREPARATION (acres)	PLANTING (acres)	POST- PLANTING (acres)	HARVESTING (acres)
.NAVY BEANS	6		142.0		
	6A			142.0	
	8				142.0
	11	62.0			
	13	80.0			
.SOYBEANS	3		118.0		
	6			118.0	
	10				35.8
	11	118.0			82.2
.SUGAR BEETS	1		80.0		
	4			80.0	
	8	80.0			
	13				80.0
.WHEAT	7				60.0
	8	60.0			
	9		60.0		

===

NET RETURNS TO LAND	$64,840.5

===

SHADOW PRICES
.Land	$102.9 /acre	.Time for field
.Beet contract	$270.9 /acre	operations
.Max Wheat	$16.1 /acre	period 3 $21.6 /acre

===

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wheat. When deficiency payments are included, navy bean acreage is replaced with corn, and soybeans are reduced to 108 acres; sugar beets and wheat remain unchanged.

Under "haphazard" behavioral assumptions, optimal operations schedule differs from a long-term strategy (Table 5.1) in that land preparation for navy beans is undertaken in periods 11 and 13. Furthermore, land preparation for soybeans is performed in period 11, to avoid timeliness costs in the crop production system[1].

In reference to the unit worth of resources, an interesting result is obtained with implications for the design of the calendar of field operations. Specifically, the shadow price associated with period 3's time available for field operations indicates that a breakdown in field machinery would result in $22 less in profit for each hour of this breakdown (Table 5.6). Alternatively, if field machinery were made available in this period, profits would increase by $22 for each additional hour[2]. The reason for this is that the optimal plan for planting soybeans in the Saginaw Valley is before May 20 (period 3). After this date, yields are reduced and then a timeliness cost arises (see Table 4.15).

5.2 RISK EFFICIENT FARM PLANS

This section identifies crop production strategies which minimize risk for different levels of net income. Two alternative measures of risk are considered: 1) deviations from a five-year unweighted moving average over the period 1960-1987, and 2) deviations from a three-year weighted moving average over the same period. Expected total net return levels are parameterized over their feasible range, which corresponds to an arbitrary lower bound of $10,000 and an upper bound which reflects the maximum net return possible. This maximum value corresponds to the solution of the profit maximization problem, and thus, expected net returns are parameterized between $10,000 and the maximum net return levels established in the previous section.

Table 5.7 identifies risk efficient farm plans when risk is measured as deviations from five-year unweighted moving averages, assuming participation in government price support programs. These farm plans are considered "efficient" in the sense that net returns cannot be increased without an adverse effect on risk, and vice-versa. That is, each of these plans represents the resource allocation strategy resulting in minimum net return variability for each net return level since any other strategy will have a higher standard deviation of income at the level of net return.

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TABLE 5.7 Risk Efficient Farm Plans Assuming No Participation In Government Programs and
        Measuring Risk as Deviations From 5-Year Moving Average

EXPECTED NET RETURNS TO LAND (dollars)	TOTAL NEGATIVE ABSOLUTE DEVIATION (dollars)	STANDARD DEVIATION (dollars)	C R O P P I N G S E Q U E N C E						
			C-NB 1 (acres)	C-NB-B 2 (acres)	NB-C-SB 3 (acres)	C-C-NB-B 4 (acres)	C-NB-W-B 5 (acres)	C-C-NB-W 6 (acres)	C-NB-NB-B 7 (acres)
10,000	77,192	12,490					54.6		
30,000	231,575	37,469					163.8		
40,000	308,767	49,959					218.4 1/		
50,000	387,071	62,629		30.5			240.0		
60,000	470,959	76,202		60.0	39.7		240.0		..
66,314	528,246	85,471		60.0	100.0		240.0		

1/ Corn=54.6 acres, Navy beans=54.6 acres, Wheat=54.6 acres and Sugar beets=54.6 acres.

TABLE 5.8 Risk Efficient Farm Plans Assuming Participation In Government Programs and
        Measuring Risk as Deviations From 5-Year Moving Average

EXPECTED NET RETURNS TO LAND (dollars)	TOTAL NEGATIVE ABSOLUTE DEVIATION	STANDARD DEVIATION (dollars)	C R O P P I N G S E Q U E N C E						
			C-NB (acres) 1	C-NB-B (acres) 2	NB-C-SB (acres) 3	C-C-NB-B (acres) 4	C-NB-W-B (acres) 5	C-C-NB-W (acres) 6	C-NB-NB-B (acres) 7
10,000	61,145	9,893					43.2		
30,000	183,434	29,680					129.7 2/		
50,000	305,724	49,467					216.2		
60,000	368,992	59,704				31.2	240.0		
70,000	434,863	70,362			5.1	92.4	240.0		
79,359	501,829	81,197	60	60.0			240.0		

1/ Assuming 40 acres in setaside land.

2/ Corn=32.4 acres, Navy beans=32.4 acres, Wheat=32.4 acres and Sugar beets= 32.4 acres.

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Another property of this efficient set of farm plans is that no one plan is inferior to another with respect to both performance measures. That is, farm plans with higher net return levels also have higher measures of risk. It thus follows that cropping plans generating low net income also are associated with low measures of risk.

The first column in Table 5.7 presents the expected net return levels for which the linear programming problem was solved. Column two displays the associated total negative absolute deviation of net returns, which is the optimum (minimum) value of the risk objective function that can be attained for each income level. Column three includes an estimate (calculated as explained in Section 4.2) of the standard deviation of net returns associated with each farm plan at each net return level[3/]. Subsequent columns correspond to the optimal crop production strategies identified (blank cells are zeros). As indicated, cropping sequence 5 preferable by both measures of performance. As net return levels rise allowing the maximum acreage of wheat to be grown, cropping sequence 2 enters the optimal set of production plans. Crop sequence 3 is included only at the highest levels of net income; this is because its high relative risk associated.

As discussed earlier, the crop production strategy of

maximum net income corresponds to the optimal solution of
the profit maximization problem presented in Tables 5.1 and
5.2 and discussed in detail in the previous section.

It should be noted that the assumption of adhering to strict
rotational patterns results in diversified sources of income
for every farm plan identified. This is one reason that
risk indicators do not increase proportionally more than net
income, an assumption usually underlying risk analysis.

Table 5.8 identifies risk efficient farm plans using the
same risk indicator, assuming farmer participation in
government price support programs. In this case, for each
level of risk it is possible to attain higher net return
levels than without participation. Crop sequence 3 enters
the optimum set of production plans at net return levels
between $60,000 and $70,000. However, the crop sequence mix
that generates the maximum profit level (see Table 5.3)
includes rotations 1, 2 and 5 as previously discussed. The
coefficients of variation of cropping plans which include
deficiency payments are lower than in the free-market
scenario. This is because these payments (ex-ante) are
somewhat certain, unlike market prices (ex-post) which are
dependent on the vagaries of the weather and the behavior of
international and domestic markets.

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Tables 5.9 and 5.10 summarize results when risk is measured by a three-year weighted moving average. In comparison with the five-year average, the overall result is that cropping strategies are not as risk efficient for any given level of income. Yet by both measures of risk, rotation 5 appears in all the efficient sets of production plans.

In order to provide a more complete assessment of the risk-return implications of cropping strategies based on well defined cropping sequences vis-a-vis a "haphazard" cropping strategy, Table 5.11 summarizes the set of risk efficient farm plans when the activities in the farm planning model are defined in terms of individual crops rather than rotations. Expected yields and variable cash costs are redefined as explained in the last part of the previous section (Table 5.6).

The summary results in Table 5.11 reveals that the optimal portfolio of crops from a risk-return perspective includes soybeans, sugar beets, and to a lesser extent wheat. For strategies of high net return levels, navy beans are also included. However, when navy beans are incorporated into the production plan, the level of income and its associated variability rises. This is hence an important consideration on their cultivation out of the context of a continuously repeatable well defined crop sequence. For example, to

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Table 5.9 Risk Efficient Farm Plans Assuming No Participation In Government Programs and
　　　　Measuring Risk as Deviations From 3-Year Moving Average.

===

EXPECTED NET RETURNS TO LAND (dollars)	TOTAL NEGATIVE ABSOLUTE DEVIATION	STANDARD DEVIATION (dollars)	C R O P P I N G S E Q U E N C E						
			C-NB 1 (acres)	C-NB-B 2 (acres)	NB-C-SB 3 (acres)	C-C-NB-B 4 (acres)	C-NB-W-B 5 (acres)	C-C-NB-W 6 (acres)	C-NB-NB-B 7 (acres)
10,000	139,266	14,251					86.5 1/		
15,000	208,899	21,377					129.7		
20,000	278,532	28,503					172.9		
25,000	348,165	35,629					216.2		
30,000	417,798	42,754					259.4		
35,000	487,431	49,880					302.6		
40,000	584,199	59,783			71.6		320.0		
40,349	592,545	60,637			80.0		320.0		

1/ Corn=21.6 acres, Navy beans=21.6 acres, Wheat=21.6 acres and Sugar beets=21.6 acres.

Table 5.10 Risk Efficient Farm Plans Assuming Participation In Government Programs and
　　　　 Measuring Risk as Deviations From 3-Year Moving Average. 1/

===

EXPECTED NET RETURNS TO LAND (dollars)	TOTAL NEGATIVE ABSOLUTE DEVIATION	STANDARD DEVIATION (dollars)	C R O P P I N G S E Q U E N C E						
			C-NB (acres) 1	C-NB-B (acres) 2	NB-C-SB (acres) 3	C-C-NB-B (acres) 4	C-NB-W-B (acres) 5	C-C-NB-W (acres) 6	C-NB-NB-B (acres) 7
10,000	98,390	10,068					61.1 2/		
20,000	196,780	20,137					122.2		
30,000	295,169	30,205					183.2		
40,000	393,559	40,274					244.3		
50,000	491,949	50,342					305.4		
56,578	560,550	57,363					320.0	40.0	

1/ Assuming 40 acres in setaside land.

2/ Corn=15.3 acres, Navy beans=15.3 acres, Wheat=15.3 acres and Sugar beets=15.3 acres.

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TABLE 5.11 Risk Efficient Farm Plans For a "Haphazard" Crop Production System,
Assuming No Participation In Government Price Programs

EXPECTED NET RETURNS TO LAND (dollars)	TOTAL NEGATIVE ABSOLUTE DEVIATION	STANDARD DEVIATION (dollars)	CORN (acres)	NAVY BEANS (acres)	SOYBEANS (acres)	SUGAR BEETS (acres)	WHEAT (acres)
10,000	69,361	11,223	0	0	13	22	4
20,000	138,723	22,446	0	0	26	43	8
30,000	208,084	33,668	0	0	39	65	12
40,000	278,804	45,111	0	0	49	80	39
50,000	360,547	58,337	0	59	62	80	60
60,000	444,995	72,001	0	125	91	80	60
64,840	528,246	85,471	0	142	118	80	60

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increase net returns by 25% from $40,000 to $50,000, requires increasing the risk indicator by 29% (Table 5.11). Similarly, an 8% increase from $60,000 to $65,000 (the maximum net return level attainable under the resource constraints) can be achieved only by increasing the level of risk by 19%. Another interesting point is that navy beans have a greater potential to increase net returns than do soybeans.

5.3 DISCUSSION

Figure 5.1 presents optimal risk-return tradeoffs for the three sets of cropping plans identified: 1) assuming no deficiency payments ("NO PARTIC."); 2) assuming deficiency payments ("PARTIC."); and 3) assuming a "haphazard" crop production system and no deficiency payments ("NO PART. & NO ROTAT").

By participating in the government price support programs for corn and wheat, farmers can attain higher expected net returns for the same amount of risk over the entire range of feasible net return levels, even though the total tillable acreage is reduced. Assuming no deficiency payments where the only source of income is the market value of the crops grown, reduces the range of feasible net return levels. This results in shifting the efficient frontier of cropping

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EFFICIENT FRONTIERS OF CROPPING PLANS

(Deviations from 5-Year M.A.)

STD. DEVIATION NET RETURNS (dollars)
(Thousands)

EXPECTED NET RETURN LEVEL (dollars)
(Thousands)

+ PARTIC. □ NO PART.& NO ROTAT.

◇ NO PARTIC.

FIGURE 5.1

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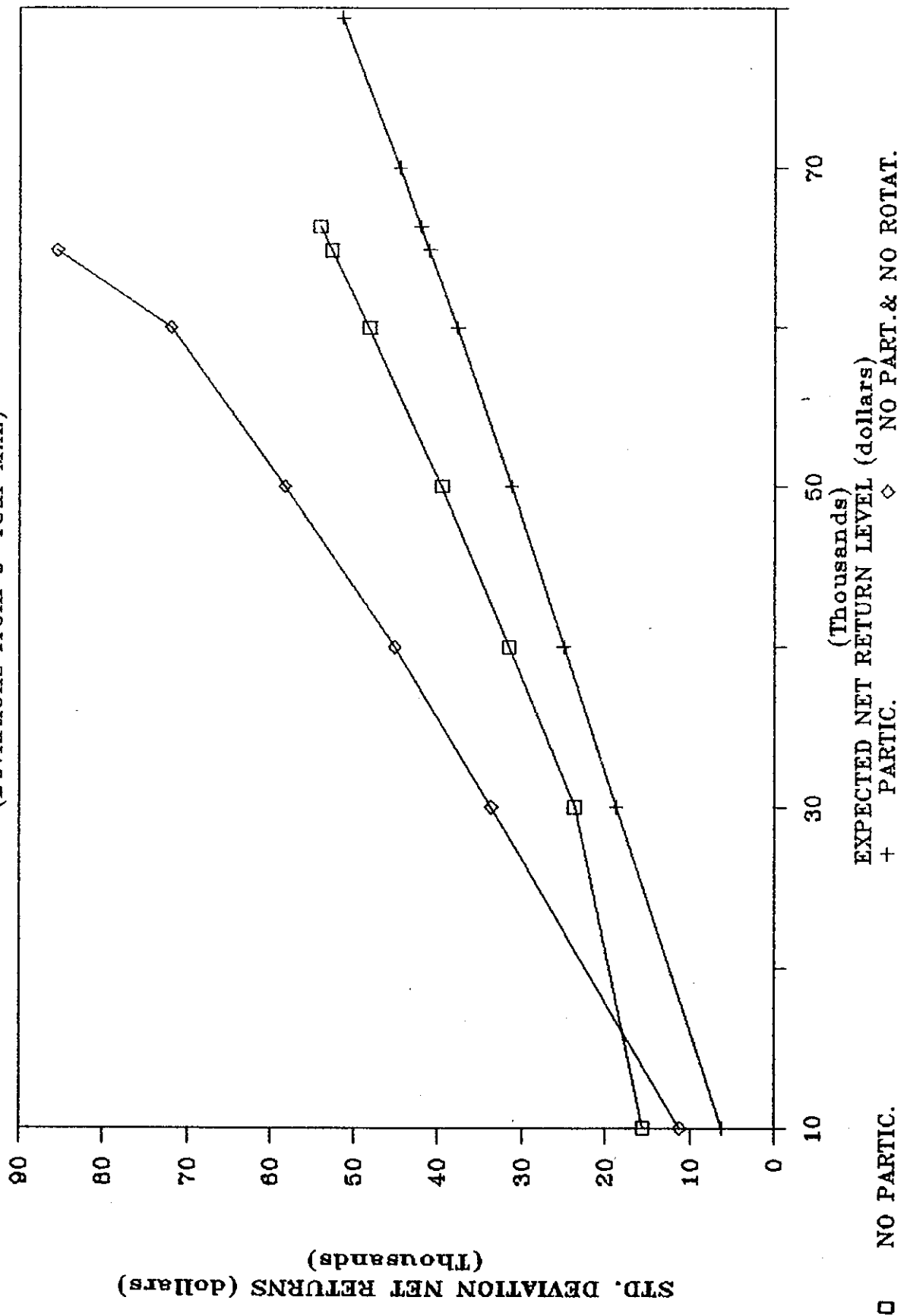
plans to the left.   That is, each net return level is achieved at a higher risk level, despite the fact that the acreage under cultivation increases by ten percent.

The optimal crop sequence mix assuming both participation and non-participation includes rotations C-NB-W-B, NB-C-SB, and C-NB-B, being C-NB-W-B the crop sequence with best potential to further net return and risk goals.   This is consistent with the findings in Chapter 3.   Addressing the issue of income instability (risk) within the context of the typical resource constraints of a cash crop farm in Michigan's Saginaw Valley, confirms the ranking of rotations given in section 3.3.2.   This fact gives validity to the farm planning model results derived in this paper.

Another point relates to the higher values of the risk indicators that are obtained when resources are allocated directly to individual crops, rather than through cropping sequences. It is clearly seen in Figure 5.1, that when the risk linear programming activities are defined in terms of individual crops, net return variability grows at an increasing rate as the expected net return level of the farm plan is increased. However, when model's decision variables are defined in terms of cropping sequences, the trade-off between net return level and income variability level is almost linear.

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For practical purposes, the value of identifying the risk-return efficient frontiers in Tables 5.7 and 5.8 is in reducing crop production options to a limited but efficient set[4]. This allows the decision maker to evaluate an optimum set of strategic alternatives. At the time of decision making, of course, other variables not considered here will be taken into account such as availability of financial resources, cash flow needs, and marketing opportunities. With these additional considerations, the farmer can then choose the appropriate cropping plan satisfying his/her risk preference function.

Finally, regarding the optimal schedule of field operations, a crop production system based upon well defined cropping sequences utilizes a fairly balanced set of resources over the cropping year, since there are no peaks in resource requirements. On the other hand, when there is no consideration for joint interactions between crops, the resource use pattern changes in such a way that there are periods where resources are idle, while limited in subsequent periods.

Based upon the two price scenarios and the two measures of risk for which efficient crop production frontiers are derived, some additional comments about the sensitivity of the model to these variables can be made. Considering first

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solutions to the profit maximization problem, it is clear that incorporating soybeans in the farm plan is highly sensitive to the gross income per acre of corn assumed. This is seen particularly when participation in the government programs is considered. In this case, even with the acreage setaside requirements, corn provides more attractive profit opportunities. Moreover, when the wheat restriction is relaxed, rotation 6 is preferred to rotation 3, leaving soybeans out of the optimal cropping plan.

With respect to the sets of efficient farm plans identified, independently of the risk measure and price forecasting scheme, the more diversified cropping sequence i.e., C-NB-W-B, offers the best opportunities for profit maximization and risk minimization.

5.4 MODEL VALIDATION

The cropping sequences that consistently are present in the alternative optimal crop production strategies which this paper identifies are: C-NB-W-B, NB-C-SB and C-NB-B. Hoskin, using a different risk-return ranking criteria, ranked these crop sequences second, fourth and first, respectively. Therefore, despite a difference in methodological approaches (considering yield relationships

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within a conservation tillage scheme, and different assumptions about resource availability), the results of this paper are consistent with Hoskin's findings.

According to the discussion in Chapter 2, there are some differences between the optimum crop mixes identified in this paper and those found in Saginaw Valley cash crop farms. Specifically, recent trends in resource use indicate a higher relative proportion of land allocated to soybeans, and a lower proportion to corn for farms with less than 400 acres and between 400 and 800 tillable acres. Three possible explanations for these differences are proposed. First, this analysis has assumed that strict rotational patterns are being adhered to; in actuality this is not necessarily true. Second, the fact that only one of the seven possible cropping sequences includes soybeans, reduces the opportunities for choosing this crop. Finally, resource allocation decisions are affected by other resources not incorporated into the model such as availability of financial resources, and the behavioral variables inherent to individual decision makers. Together, these three observations may explain some of the existing discrepancies between tis paper's findings and empirical evidence.

END NOTES

1/ Since in the original formulation sugar beets always followed either navy beans or wheat, the earliest date for land preparation was set after the harvest of these crops, that is, period 8. For this reason, in the optimal solution of this particular case, land preparation of sugar beets is scheduled for this period. Hence, to be consistent with the assumptions of the model, it is noted that this farm plan is feasible only if sugar beets follow navy beans, which are harvested in period 8, and 80 acres of navy beans follow sugar beets, which are harvested in period 13 (see Table 5.6).

2/ This figure might also be associated with the maximum custom work rate to be paid for using this service, or the minimum work rate to be charged if the service is provided by the operator of the hypothetical farm.

3/ If we assume net returns follow a normal probability distribution, then the last row in Table 5.8 indicate that two thirds of the time net returns would be between $79359 plus or minus $85471.

4/ There is an infinite number of crop production alternatives that are feasible, given the resource

constraints. They are located to the left of the efficient frontiers in Figure 5.1. However, only those crop production plans on the efficient frontier are optimum from a risk-return perspective.

CHAPTER 6

CONCLUSIONS

6.1 SUMMARY

This paper develops a framework for resource allocation decisions in Saginaw Valley cash crop farms with navy beans in their rotation. This paper assumes that crop production decisions are made for strict rotational patterns, and that these patterns are adhered to. Therefore, the analysis focuses on the risk, net income, and other farm planning issues associated with seven different navy bean cropping sequences which are representative of Michigan's Saginaw Valley.

First, this paper assesses the degree of income variability and unpredictability of each crop and crop sequence under consideration. This assessment also examines the extent to which unpredictable movements in net returns of navy beans are related to those of other crops in the grower's rotation.

Second, the concept of income variability is incorporated within the context of a farm planning model to allow uncertainty constraints to interact with the specific set of crop production constraints. The paper then develops a

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risk linear programming model which determines resource allocation decisions throughout the cropping year. The model is solved assuming both participation and no participation in government price support programs for corn and wheat. The specific set of interacting production constraints include tillable acreage, field machinery resources, suitable days for field work, labor supply, sugar beet contract, rotation restrictions and land use precedence. Risk is measured by two indicators: 1) as deviations from a five-year unweighted moving average, and 2) as deviations from a three-year weighted moving average. The optimum crop mix and the optimum time for field operations for a 400 acre Saginaw Valley cash crop farm growing navy beans in rotation with sugar beets, corn, soybeans and wheat are determined.

6.2 CONCLUSIONS

The general perception held by most observers that the navy bean business is highly unstable is confirmed by evidence of unpredictable movement in prices, yields and net returns. For individual crops and using four alternative indicators of variability, navy beans prove to be the single most unstable and unpredictable enterprise in the grower's rotation.

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However, this paper's analysis also reveals that there is low correlation between unexpected navy bean net income variation, and variation in the net incomes of the other crops (corn, soybeans, wheat and sugar beets). This indicates that there is no empirical evidence to suggest that unexpected movements in navy bean returns in a given year are associated with similar patterns for the other field crops being studied. In contrast, empirical evidence does suggest that over the last twenty years, there is a positive correlation between the unexpected movements in net returns of corn, wheat, and soybeans, and less strongly with corn, wheat and sugar beets.

Therefore, this paper concludes that by having navy beans in rotation with corn, wheat, soybeans and/or sugar beets, unpredictable net return fluctuations may be attenuated. To illustrate, if net returns for corn, for example, unexpectedly falls to some critical level, a negative trend in the income of all other crops can be expected with the exception of navy beans. Navy beans therefore serve to stabilize the cash flow level for that year. Contrarily, if navy bean returns unexpectedly fall, it is not necessarily expected that returns to the other crops in the rotation will fall. Hence because of its statistical independence from other crops, net returns may be stabilized when navy beans are included in the rotation.

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Assessing income instability through the joint behavior of crops within a specified cropping sequence, reveals that a more predictable and less variable level of income can be attained through diversification. This paper has established that the most diversified crop sequences have the highest potential for income stability.

Although individually navy beans have the highest indices of income variability, within the context of a crop sequence their relative importance as a source of income instability does not significantly outweigh that of other crops. Moreover, it was found that an important component of the income instability in navy bean cropping sequences is attributed to the interaction among corn, wheat and/or soybean crops, and less so to navy beans.

Both the income instability analysis based upon net return series (1960 - 1987) for each crop sequence, and the risk-return linear programming model based upon a set of interacting resource constraints identify C-NB-W-B, NB-C-SB and C-NB-B as the crop sequences with best opportunities for net returns stability.

Participation in government price support programs allows farmers to attain higher net return levels at lower levels of net return variability. If crop production takes place

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according to strict rotational patterns, vis-a-vis a "haphazard" crop production system (Christenson et. al, 1978), the level of income variability is lowered for each level of expected net returns. This is a direct consequence of having a more diversified portfolio of enterprises.

Applying the model to a particular farm indicates that incomes are constrained by land availability and the maximum acreage allowed for wheat and sugar beets. It is highly probable that by considering other assumptions about land availability and other production constraints like machinery size, labor and suitable days for field work, these would become active constraints to raising net returns.

An important feature of the farm planning model is that it provides the schedule of field operations that minimizes timeliness costs, based upon disaggregating the cropping year into sixteen periods, and the estimated penalties associated with suboptimal field operations.

The maximum net return cropping plan, assuming no deficiency payments, calls for dividing the total tillable acreage into ten parcels: three of 20 acres, three of 33 acres, and four of 60 acres. Of these three are planted to corn, three to navy beans, two to sugar beets, one to wheat, and one to

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soybeans. If deficiency payments and acreage setaside requirements are incorporated in the farm planning model, the acreage in soybeans is replaced by corn.

Overall, the risk linear programming model developed is not sensitive to the specification of the risk measure. Furthermore, minor modifications in the optimal level of decision variables result under different derivations of product price levels. However, this situation might be different if a different size of machinery complements is assumed, or if a different probability level is employed to predict suitable days for field operations.

Finally, the empirical validity of the model was established by comparing results with those of a previous study. The studies are complementary in identifying the same navy bean cropping sequences as the most desirable from a risk-return point of view.

6.3 FURTHER RESEARCH

This research paper identifies the following areas as priorities for further research:

1. The farm planning model developed in this paper should be incorporated within the framework of a decision support

system. In this way, it would be possible recompute and update systematically all the coefficients required by the model. In addition, through the interaction with other planning models in the financial and operations management areas, it would be possible to generate for the whole farm pro forma financial statements associated with each crop production strategy, as well as input requirements discriminated by period, kind, volume and supplier.

2. The model developed can be easily expanded or adapted to consider a broader set of crops and cropping sequences.

3. Alternative risk management strategies might be incorporated into the model by redefining variables or defining new ones. For instance, forward contracting of navy beans, participation in the futures market for corn, wheat or soybeans, or other marketing alternatives are all options which the model might consider.

4. Within the context of mixed integer programming, by defining additional activities in terms of alternative machinery sets, the farm planning model developed here could be applied to jointly select both machinery and crop plans.

5. Research needs to be done in techniques for the simultaneous determination of machinery costs and optimum

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cropping plans. That is, in such a way that there is no
need to assume ex-ante a predetermined number of hours of
annual use to estimate ownership and operating costs per
acre, rather this must be an endogenous variable to the
model.

FERTILIZER AND HERBICIDE RECOMMENDATIONS (lb./acre) 1/

CROP : Corn

ITEM / CROP SEQUENCE	C-NB	C-NB-B	NB-C-SB	C-C-NB-B 1st.	C-C-NB-B 2nd.	C-NB-W-B	C-C-NB-W 1st.	C-C-NB-W 2nd.	C-NB-NB-B
-SEED 2/	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5
-FERTILIZER 2/									
.Nitrogen 82-0-0	130.0	124.3	130.0	124.3	124.3	124.3	124.3	124.3	124.3
.Phosphate	40.3	38.5	40.3	38.5	38.5	38.5	38.5	38.5	38.5
.Potash	31.1	29.7	31.1	29.7	29.7	29.7	29.7	29.7	29.7
FERTILIZER COSTS ($/acre)	29.0	27.7	29.0	27.7	27.7	27.7	27.7	27.7	27.7
-HERBICIDES 3/									
.Atrazine	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
.Lasso	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
.Bladex	1.50	1.50	1.50		1.50	1.50		1.50	1.50
.Sutan				0.50			0.50		
.Furadan					0.75			0.75	
HERBICIDE COSTS ($/acre)	22.3	22.3	22.3	17.8	29.6	22.3	17.8	29.6	22.3

1/ Based upon net nutrient removal rates and a Conservation Tillage system.
2/ SOURCE: Hoskins (1981)
3/ SOURCE: Jenne (1985)

FERTILIZER AND HERBICIDE RECOMMENDATIONS (lb./acre) 1/

CROP : Navy beans

ITEM / CROP SEQUENCE	C-NB	C-NB-B	NB-C-SB	C-C-NB-	C-NB-W-B	C-C-NB-W	C-NB-NB-B 1st.	C-NB-NB-B 2nd.
-SEED 2/	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
-FERTILIZER 2/								
.Nitrogen 46-0-0	40.0	37.6	37.6	43.8	43.8	43.8	40.0	34.4
.Phosphate	10.8	10.0	10.0	11.6	11.6	11.6	10.8	9.1
.Potash	10.8	10.0	10.0	11.6	11.6	11.6	10.8	9.1
FERTILIZER COSTS ($/acre)	10.3	9.6	9.6	11.2	11.2	11.2	10.3	8.8
-HERBICIDES 3/								
.Eptan	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25
.Amiben	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
.Treflan	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
HERBICIDE COSTS ($/acre)	29.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8

1/ Based upon net nutrient removal rates and a Conservation Tillage system.
2/ SOURCE: Hoskins (1981)
3/ SOURCE: Jenne (1985)

FERTILIZER AND HERBICIDE RECOMMENDATIONS (lb./acre) 1/

CROP : Soybeans

ITEM	CROP SEQUENCE	NB-C-SB

-SEED 2/	50.0

-FERTILIZER 2/

.Phosphate	31.5
.Potash	49.0
FERTILIZER COSTS ($/acre)	13.4

-HERBICIDES 3/

.Lasso	2.50
.Lorox	0.75
HERBICIDE COSTS ($/acre)	23.5

1/ Based upon net nutrient removal rates and a Conservation Tillage system.
2/ SOURCE: Hoskins (1981)
3/ SOURCE: Jenne (1985)

FERTILIZER AND HERBICIDE RECOMMENDATIONS (lb./acre) 1/

CROP : Sugar beets

ITEM	CROP SEQUENCE	C-NB-B	C-C-NB-	C-NB-W-	C-NB-NB-B

-SEED 2/	1.0	1.0	1.0	1.0

-FERTILIZER 2/

	C-NB-B	C-C-NB-	C-NB-W-	C-NB-NB-B
.Nitrogen 46-0-0	105.0	100.0	105.0	100.0
.Phosphate	27.3	26.0	27.3	26.0
.Potash	69.3	66.0	69.3	66.0
FERTILIZER COSTS ($/acre)	31.7	30.2	31.7	30.2

-HERBICIDES 3/

	C-NB-B	C-C-NB-	C-NB-W-	C-NB-NB-B
.Pyramin	3.00	3.00	3.00	3.00
.Nortron	2.00	2.00	2.00	2.00
.Antor	2.00	2.00	2.00	2.00
HERBICIDE COSTS ($/acre)	120.5	120.5	120.5	120.5

1/ Based upon net nutrient removal rates and a Conservation Tillage system.
2/ SOURCE: Hoskins (1981)
3/ SOURCE: Jenne (1985)

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FERTILIZER AND HERBICIDE RECOMMENDATIONS (lb./acre) 1/
---------------------------------------------------------
CROP :   Wheat
---------------------------------------------------------
        CROP SEQUENCE      C-NB-W-B C-C-NB-W
  ITEM
---------------------------------------------------------
-SEED 2/                     120.0  120.0

-FERTILIZER 2/
 .Nitrogen 46-0-0             90.0   90.0
 .Phosphate                   37.2   37.2
 .Potash                      22.8   22.8
  FERTILIZER COSTS ($/acre)   26.1   26.1
-HERBICIDES 3/
 .2-4D                        0.50   0.50
  HERBICIDE COSTS ($/acre)    1.33   1.33
---------------------------------------------------------

  1/ Based upon net nutrient removal rates and a Conservation Tillage system.
  2/ SOURCE: Hoskins (1981)
  3/ SOURCE: Jenne (1985)
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EXPECTED INPUT COSTS          $/lb.
----------------------------------------

SEEDS 1/
-Corn                          1.4
-Navy beans                    0.5
-Soybeans                      0.2
-Sugar beets                    15
-Wheat                        0.08


-FERTILIZER 1/
 .Nitrogen 82-0-0             0.12
 .Nitrogen 46-0-0             0.16
 .Phosphate                   0.24
 .Potash                      0.12


-HERBICIDES 2/ *
 .Atrazine                    2.27
 .Lasso                       5.85
 .Bladex                      3.99
 .Sutan                       2.96
 .Furadan                     9.72
 .Eptan                       3.61
 .Amiben                      8.88
 .Treflan                     7.78
 .Lorox                       11.8
 .Pyramin                    14.47
 .Nortron                    29.26
 .2-4D                        2.66
 .Antor                       9.29
----------------------------------------
```

1/ Source: Nott et al (1988).
2/ Source: Jenne (1985), Jenne and Tschirley (1986).
* Adjusted to 1988 prices.

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-------------------------------------------------
POST - HARVEST COSTS
-------------------------------------------------
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CROP	DRYING	TRUCKING, FREIGHT	MARKETING
	($/acre)	($/acre)	($/acre)
Corn grain	33.00	23.00	1.10
Navy beans		4.35	0.65
Soybeans		8.00	0.60
Sugar beets		69.70	
Wheat		12.00	0.60

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SOURCE: Nott et al (1988).

ASSUMING NO DEFICIENCY PAYMENTS AND 3-YEAR MOVING AVERAGE PRICE PROJECTION

TECHNICAL COEFFICIENTS L.P. MATRIX
CROP SEQUENCE #1. C-NB

CROP: COEFFICIENT	CORN	NAVY BEANS
-Gross income	218.5	169.0
-Input costs		
.Seed costs	18.9	20.0
.Fertilizer costs	29.0	10.3
.Herbicide costs	22.3	29.8
-Post - harvest costs	57.1	5.0
TOTAL NON-MACHINERY COSTS	127.3	65.1
GROSS MARGIN	91.2	103.9
-Machinery costs		
.Land preparation	10.7	8.6
.Production	32.1	27.4
.Harvesting	46.3	33.7
TOTAL MACHINERY COSTS	89.1	69.7
NET RETURNS TO LAND	2.1	34.2

CROP SEQUENCE #2. C-NB-B

CROP: COEFFICIENT	CORN	NAVY BEANS	SUGAR BEETS
-Gross income	218.5	169.0	672.0
-Input costs			
.Seed costs	18.9	20.0	15.0
.Fertilizer costs	27.7	9.6	31.7
.Herbicide costs	22.3	29.8	120.5
-Post - harvest costs	57.1	5.0	69.7
TOTAL NON-MACHINERY COSTS	126.0	64.4	236.9
GROSS MARGIN	92.5	104.6	·435.1
-Machinery costs			
.Land preparation	10.7	8.6	10.7
.Production	32.1	27.4	38.2
.Harvesting	46.3	33.7	70.2
TOTAL MACHINERY COSTS	89.1	69.7	119.1
NET RETURNS TO LAND	3.4	34.9	316.0

CROP SEQUENCE #3. NB-C-SB

CROP: COEFFICIENT	CORN	NAVY BEANS	SOYBEANS
-Gross income	218.5	169.0	228.0
-Input costs			
.Seed costs	18.9	20.0	10.0
.Fertilizer costs	29.0	9.6	13.4
.Herbicide costs	22.3	29.8	23.5
-Post - harvest costs	57.1	5.0	8.6
TOTAL NON-MACHINERY COSTS	127.3	64.4	55.5
GROSS MARGIN	91.2	104.6	172.5
-Machinery costs			
.Land preparation	10.7	8.6	8.6
.Production	32.1	27.4	21.3
.Harvesting	46.3	33.7	41.3
TOTAL MACHINERY COSTS	89.1	69.7	71.2
NET RETURNS TO LAND	2.1	34.9	101.3

TECHNICAL COEFFICIENTS L.P. MATRIX

CROP SEQUENCE #4.: C-C-NB-B

CROP:	CORN	CORN	NAVY BEANS	SUGAR BEETS
COEFFICIENT				
-Gross income	218.5	195.7	182.0	640.0
-Input costs				
.Seed costs	18.9	18.9	20.0	15.0
.Fertilizer costs	27.7	27.7	11.2	30.2
.Herbicide costs	17.8	29.6	29.8	120.5
-Post - harvest costs	57.1	57.1	5.0	69.7
TOTAL NON-MACHINERY COSTS	121.5	133.3	66.0	235.4
GROSS MARGIN	97.0	62.4	116.0	404.6
-Machinery costs				
.Land preparation	10.7	10.7	8.6	10.7
.Production	32.1	32.1	27.4	38.2
.Harvesting	46.3	46.3	33.7	70.2
TOTAL MACHINERY COSTS	89.1	89.1	69.7	119.1
NET RETURNS TO LAND	7.9	(26.7)	46.3	285.5

CROP SEQUENCE #5.: C-NB-W-B

CROP:	CORN	NAVY BEANS	WHEAT	SUGAR BEETS
COEFFICIENT				
-Gross income	218.5	182.0	180.0	672.0
-Input costs				
.Seed costs	18.9	20.0	9.6	15.0
.Fertilizer costs	27.7	11.2	26.1	31.7
.Herbicide costs	22.3	29.8	1.3	120.5
-Post - harvest costs	57.1	5.0	12.6	69.7
TOTAL NON-MACHINERY COSTS	126.0	66.0	49.6	236.9
GROSS MARGIN	92.5	116.0	130.4	435.1
-Machinery costs				
.Land preparation	10.7	8.6	2.1	10.7
.Production	32.1	27.4	21.9	38.2
.Harvesting	46.3	33.7	36.5	70.2
TOTAL MACHINERY COSTS	89.1	69.7	60.6	119.1
NET RETURNS TO LAND	3.4	46.3	69.8	316.0

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TECHNICAL COEFFICIENTS L.P. MATRIX

CROP SEQUENCE #6.: C-C-NB-W

CROP:	CORN	CORN	NAVY BEANS	WHEAT
COEFFICIENT				
-Gross income	218.5	195.7	182.0	180.0
-Input costs				
.Seed costs	18.9	18.9	20.0	9.6
.Fertilizer costs	27.7	27.7	11.2	26.1
.Herbicide costs	17.8	29.6	29.8	1.3
-Post - harvest costs	57.1	57.1	5.0	12.6
TOTAL NON-MACHINERY COSTS	121.5	133.3	66.0	49.6
GROSS MARGIN	97.0	62.4	116.0	130.4
-Machinery costs				
.Land preparation	10.7	10.7	8.6	2.1
.Production	32.1	32.1	27.4	21.9
.Harvesting	46.3	46.3	33.7	36.5
TOTAL MACHINERY COSTS	89.1	89.1	69.7	60.6
NET RETURNS TO LAND	7.9	(26.7)	46.3	69.8

CROP SEQUENCE #7.: C-NB-NB-B

CROP:	CORN	NAVY BEANS	NAVY BEANS	SUGAR BEETS
COEFFICIENT				
-Gross income	218.5	156.0	143.0	640.0
-Input costs				
.Seed costs	18.9	20.0	20.0	15.0
.Fertilizer costs	27.7	10.3	8.8	30.2
.Herbicide costs	22.3	29.8	29.8	120.5
-Post - harvest costs	57.1	5.0	5.0	69.7
TOTAL NON-MACHINERY COSTS	126.0	65.1	63.6	235.4
GROSS MARGIN	92.5	90.9	79.4	404.6
-Machinery costs				
.Land preparation	10.7	8.6	8.6	10.7
.Production	32.1	27.4	27.4	38.2
.Harvesting	46.3	33.7	33.7	70.2
TOTAL MACHINERY COSTS	89.1	69.7	69.7	119.1
NET RETURNS TO LAND	3.4	21.2	9.7	285.5

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ASSUMING DEFICIENCY PAYMENTS AND 3-YEAR MOVING AVERAGE PRICE PROJECTION

TECHNICAL COEFFICIENTS L.P. MATRIX
CROP SEQUENCE #1. C-NB

CROP:	CORN	NAVY BEANS
COEFFICIENT		
-Gross income	337.0	169.0
-Input costs		
.Seed costs	18.9	20.0
.Fertilizer costs	29.0	10.3
.Herbicide costs	22.3	29.8
-Post - harvest costs	57.1	5.0
TOTAL NON-MACHINERY COSTS	127.3	65.1
GROSS MARGIN	209.6	103.9
-Machinery costs		
.Land preparation	10.7	8.6
.Production	32.1	27.4
.Harvesting	46.3	33.7
TOTAL MACHINERY COSTS	89.1	69.7
NET RETURNS TO LAND	120.6	34.2

CROP SEQUENCE #2. C-NB-B

CROP:	CORN	NAVY BEANS	SUGAR BEETS
COEFFICIENT			
-Gross income	337.0	169.0	672.0
-Input costs			
.Seed costs	18.9	20.0	15.0
.Fertilizer costs	27.7	9.6	31.7
.Herbicide costs	22.3	29.8	120.5
-Post - harvest costs	57.1	5.0	69.7
TOTAL NON-MACHINERY COSTS	126.0	64.4	236.9
GROSS MARGIN	210.9	104.6	435.1
-Machinery costs			
.Land preparation	10.7	8.6	10.7
.Production	32.1	27.4	38.2
.Harvesting	46.3	33.7	70.2
TOTAL MACHINERY COSTS	89.1	69.7	119.1
NET RETURNS TO LAND	121.8	34.9	316.0

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CROP SEQUENCE #3. NB-C-SB
              CROP:        CORN    NAVY BEANS  SOYBEANS
COEFFICIENT

-Gross income            337.0    169.0      228.0
-Input costs
 .Seed costs             18.9      20.0       10.0
 .Fertilizer costs       29.0       9.6       13.4
 .Herbicide costs        22.3      29.8       23.5
-Post - harvest costs    57.1       5.0        8.6
  TOTAL NON-MACHINERY COSTS 127.3   64.4       55.5
  GROSS MARGIN           209.6    104.6      172.5
-Machinery costs

 .Land preparation       10.7       8.6        8.6
 .Production             32.1      27.4       21.3
 .Harvesting             46.3      33.7       41.3
  TOTAL MACHINERY COSTS  89.1      69.7       71.2
  NET RETURNS TO LAND    120.6     34.9      101.3
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TECHNICAL COEFFICIENTS L.P. MATRIX

CROP SEQUENCE #4.: C-C-NB-B

CROP:	CORN	CORN	NAVY BEANS	SUGAR BEETS
COEFFICIENT				
-Gross income	337.0	301.8	182.0	640.0
-Input costs				
.Seed costs	18.9	18.9	20.0	15.0
.Fertilizer costs	27.7	27.7	11.2	30.2
.Herbicide costs	17.8	29.6	29.8	120.5
-Post - harvest costs	57.1	57.1	5.0	69.7
TOTAL NON-MACHINERY COSTS	121.5	133.3	66.0	235.4
GROSS MARGIN	215.4	168.5	116.0	404.6
-Machinery costs				
.Land preparation	10.7	10.7	8.6	10.7
.Production	32.1	32.1	27.4	38.2
.Harvesting	46.3	46.3	33.7	70.2
TOTAL MACHINERY COSTS	89.1	89.1	69.7	119.1
NET RETURNS TO LAND	126.3	79.4	46.3	285.5

CROP SEQUENCE #5.: C-NB-W-B

CROP:	CORN	NAVY BEANS	WHEAT	SUGAR BEETS
COEFFICIENT				
-Gross income	337.0	182.0	253.8	672.0
-Input costs				
.Seed costs	18.9	20.0	9.6	15.0
.Fertilizer costs	27.7	11.2	26.1	31.7
.Herbicide costs	22.3	29.8	1.3	120.5
-Post - harvest costs	57.1	5.0	12.6	69.7
TOTAL NON-MACHINERY COSTS	126.0	66.0	49.6	236.9
GROSS MARGIN	210.9	116.0	204.2	435.1
-Machinery costs				
.Land preparation	10.7	8.6	2.1	10.7
.Production	32.1	27.4	21.9	38.2
.Harvesting	46.3	33.7	36.5	70.2
TOTAL MACHINERY COSTS	89.1	69.7	60.6	119.1
NET RETURNS TO LAND	121.8	46.3	143.6	316.0

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TECHNICAL COEFFICIENTS L.P. MATRIX

CROP SEQUENCE #6.: C-C-NB-W

CROP:	CORN	CORN	NAVY BEANS	WHEAT
COEFFICIENT				
-Gross income	337.0	301.8	182.0	253.8
-Input costs				
.Seed costs	18.9	18.9	20.0	9.6
.Fertilizer costs	27.7	27.7	11.2	26.1
.Herbicide costs	17.8	29.6	29.8	1.3
-Post - harvest costs	57.1	57.1	5.0	12.6
TOTAL NON-MACHINERY COSTS	121.5	133.3	66.0	49.6
GROSS MARGIN	215.4	168.5	116.0	204.2
-Machinery costs				
.Land preparation	10.7	10.7	8.6	2.1
.Production	32.1	32.1	27.4	21.9
.Harvesting	46.3	46.3	33.7	36.5
TOTAL MACHINERY COSTS	89.1	89.1	69.7	60.6
NET RETURNS TO LAND	126.3	79.4	46.3	143.6

CROP SEQUENCE #7.: C-NB-NB-B

CROP:	CORN	NAVY BEANS	NAVY BEANS	SUGAR BEETS
COEFFICIENT				
-Gross income	337.0	156.0	143.0	640.0
-Input costs				
.Seed costs	18.9	20.0	20.0	15.0
.Fertilizer costs	27.7	10.3	8.8	30.2
.Herbicide costs	22.3	29.8	29.8	120.5
-Post - harvest costs	57.1	5.0	5.0	69.7
TOTAL NON-MACHINERY COSTS	126.0	65.1	63.6	235.4
GROSS MARGIN	210.9	90.9	79.4	404.6
-Machinery costs				
.Land preparation	10.7	8.6	8.6	10.7
.Production	32.1	27.4	27.4	38.2
.Harvesting	46.3	33.7	33.7	70.2
TOTAL MACHINERY COSTS	89.1	69.7	69.7	119.1
NET RETURNS TO LAND	121.8	21.2	9.7	285.5

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ASSUMING NO DEFICIENCY PAYMENTS AND 5-YEAR MOVING AVERAGE PRICE PROJECTION

TECHNICAL COEFFICIENTS L.P. MATRIX
CROP SEQUENCE #1. C-NB

CROP:	CORN	NAVY BEANS
COEFFICIENT		
-Gross income	288.7	272.7
-Input costs		
.Seed costs	18.9	20.0
.Fertilizer costs	29.0	10.3
.Herbicide costs	22.3	29.8
-Post - harvest costs	57.1	5.0
TOTAL NON-MACHINERY COSTS	127.3	65.1
GROSS MARGIN	161.3	207.7
-Machinery costs		
.Land preparation	10.7	8.6
.Production	32.1	27.4
.Harvesting	46.3	33.7
TOTAL MACHINERY COSTS	89.1	69.7
NET RETURNS TO LAND	72.3	137.9

CROP SEQUENCE #2. C-NB-B

CROP:	CORN	NAVY BEANS	SUGAR BEETS
COEFFICIENT			
-Gross income	288.7	272.7	747.6
-Input costs			
.Seed costs	18.9	20.0	15.0
.Fertilizer costs	27.7	9.6	31.7
.Herbicide costs	22.3	29.8	120.5
-Post - harvest costs	57.1	5.0	69.7
TOTAL NON-MACHINERY COSTS	126.0	64.4	236.9
GROSS MARGIN	162.6	208.4	510.7
-Machinery costs			
.Land preparation	10.7	8.6	10.7
.Production	32.1	27.4	38.2
.Harvesting	46.3	33.7	70.2
TOTAL MACHINERY COSTS	89.1	69.7	119.1
NET RETURNS TO LAND	73.5	138.6	391.6

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CROP SEQUENCE #3. NB-C-SB

CROP:	CORN	NAVY BEANS	SOYBEANS
COEFFICIENT			
-Gross income	288.7	272.7	242.8
-Input costs			
.Seed costs	18.9	20.0	10.0
.Fertilizer costs	29.0	9.6	13.4
.Herbicide costs	22.3	29.8	23.5
-Post - harvest costs	57.1	5.0	8.6
TOTAL NON-MACHINERY COSTS	127.3	64.4	55.5
GROSS MARGIN	161.3	208.4	187.3
-Machinery costs			
.Land preparation	10.7	8.6	8.6
.Production	32.1	27.4	21.3
.Harvesting	46.3	33.7	41.3
TOTAL MACHINERY COSTS	89.1	69.7	71.2
NET RETURNS TO LAND	72.3	138.6	116.1

TECHNICAL COEFFICIENTS L.P. MATRIX

CROP SEQUENCE #4.: C-C-NB-B

CROP:	CORN	CORN	NAVY BEANS	SUGAR BEETS
COEFFICIENT				
-Gross income	288.7	258.5	293.7	712.0
-Input costs				
.Seed costs	18.9	18.9	20.0	15.0
.Fertilizer costs	27.7	27.7	11.2	30.2
.Herbicide costs	17.8	29.6	29.8	120.5
-Post - harvest costs	57.1	57.1	5.0	69.7
TOTAL NON-MACHINERY COSTS	121.5	133.3	66.0	235.4
GROSS MARGIN	167.1	125.2	227.8	476.6
-Machinery costs				
.Land preparation	10.7	10.7	8.6	10.7
.Production	32.1	32.1	27.4	38.2
.Harvesting	46.3	46.3	33.7	70.2
TOTAL MACHINERY COSTS	89.1	89.1	69.7	119.1
NET RETURNS TO LAND	78.0	36.1	158.0	357.5

CROP SEQUENCE #5.: C-NB-W-B

CROP:	CORN	NAVY BEANS	WHEAT	SUGAR BEETS
COEFFICIENT				
-Gross income	288.7	293.7	192.6	747.6
-Input costs				
.Seed costs	18.9	20.0	9.6	15.0
.Fertilizer costs	27.7	11.2	26.1	31.7
.Herbicide costs	22.3	29.8	1.3	120.5
-Post - harvest costs	57.1	5.0	12.6	69.7
TOTAL NON-MACHINERY COSTS	126.0	66.0	49.6	236.9
GROSS MARGIN	162.6	227.8	143.0	510.7
-Machinery costs				
.Land preparation	10.7	8.6	2.1	10.7
.Production	32.1	27.4	21.9	38.2
.Harvesting	46.3	33.7	36.5	70.2
TOTAL MACHINERY COSTS	89.1	69.7	60.6	119.1
NET RETURNS TO LAND	73.5	158.0	82.4	391.6

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TECHNICAL COEFFICIENTS L.P. MATRIX

CROP SEQUENCE #6.: C-C-NB-W

CROP:	CORN	CORN	NAVY BEANS	WHEAT
COEFFICIENT				
-Gross income	288.7	258.5	293.7	192.6
-Input costs				
.Seed costs	18.9	18.9	20.0	9.6
.Fertilizer costs	27.7	27.7	11.2	26.1
.Herbicide costs	17.8	29.6	29.8	1.3
-Post - harvest costs	57.1	57.1	5.0	12.6
TOTAL NON-MACHINERY COSTS	121.5	133.3	66.0	49.6
GROSS MARGIN	167.1	125.2	227.8	143.0
-Machinery costs				
.Land preparation	10.7	10.7	8.6	2.1
.Production	32.1	32.1	27.4	21.9
.Harvesting	46.3	46.3	33.7	36.5
TOTAL MACHINERY COSTS	89.1	89.1	69.7	60.6
NET RETURNS TO LAND	78.0	36.1	158.0	82.4

CROP SEQUENCE #7.: C-NB-NB-B

CROP:	CORN	NAVY BEANS	NAVY BEANS	SUGAR BEETS
COEFFICIENT				
-Gross income	288.7	251.8	230.8	712.0
-Input costs				
.Seed costs	18.9	20.0	20.0	15.0
.Fertilizer costs	27.7	10.3	8.8	30.2
.Herbicide costs	22.3	29.8	29.8	120.5
-Post - harvest costs	57.1	5.0	5.0	69.7
TOTAL NON-MACHINERY COSTS	126.0	65.1	63.6	235.4
GROSS MARGIN	162.6	186.7	167.2	476.6
-Machinery costs				
.Land preparation	10.7	8.6	8.6	10.7
.Production	32.1	27.4	27.4	38.2
.Harvesting	46.3	33.7	33.7	70.2
TOTAL MACHINERY COSTS	89.1	69.7	69.7	119.1
NET RETURNS TO LAND	73.5	117.0	97.5	357.5

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ASSUMING DEFICIENCY PAYMENTS AND 5-YEAR MOVING AVERAGE PRICE PROJECTION

TECHNICAL COEFFICIENTS L.P. MATRIX
CROP SEQUENCE #1. C-NB

CROP:	CORN	NAVY BEANS
COEFFICIENT		
-Gross income	407.1	272.7
-Input costs		
.Seed costs	18.9	20.0
.Fertilizer costs	29.0	10.3
.Herbicide costs	22.3	29.8
-Post - harvest costs	57.1	5.0
TOTAL NON-MACHINERY COSTS	127.3	65.1
GROSS MARGIN	279.8	207.7
-Machinery costs		
.Land preparation	10.7	8.6
.Production	32.1	27.4
.Harvesting	46.3	33.7
TOTAL MACHINERY COSTS	89.1	69.7
NET RETURNS TO LAND	190.7	137.9

CROP SEQUENCE #2. C-NB-B

CROP:	CORN	NAVY BEANS	SUGAR BEETS
COEFFICIENT			
-Gross income	407.1	272.7	747.6
-Input costs			
.Seed costs	18.9	20.0	15.0
.Fertilizer costs	27.7	9.6	31.7
.Herbicide costs	22.3	29.8	120.5
-Post - harvest costs	57.1	5.0	69.7
TOTAL NON-MACHINERY COSTS	126.0	64.4	236.9
GROSS MARGIN	281.1	208.4	510.7
-Machinery costs			
.Land preparation	10.7	8.6	10.7
.Production	32.1	27.4	38.2
.Harvesting	46.3	33.7	70.2
TOTAL MACHINERY COSTS	89.1	69.7	119.1
NET RETURNS TO LAND	192.0	138.6	391.6

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CROP SEQUENCE #3. NB-C-SB

CROP:	CORN	NAVY BEANS	SOYBEANS
COEFFICIENT			
-Gross income	407.1	272.7	242.8
-Input costs			
.Seed costs	18.9	20.0	10.0
.Fertilizer costs	29.0	9.6	13.4
.Herbicide costs	22.3	29.8	23.5
-Post - harvest costs	57.1	5.0	8.6
TOTAL NON-MACHINERY COSTS	127.3	64.4	55.5
GROSS MARGIN	279.8	208.4	187.3
-Machinery costs			
.Land preparation	10.7	8.6	8.6
.Production	32.1	27.4	21.3
.Harvesting	46.3	33.7	41.3
TOTAL MACHINERY COSTS	89.1	69.7	71.2
NET RETURNS TO LAND	190.7	138.6	116.1

TECHNICAL COEFFICIENTS L.P. MATRIX

CROP SEQUENCE #4.: C-C-NB-B

CROP:	CORN	CORN	NAVY BEANS	SUGAR BEETS
COEFFICIENT				
-Gross income	407.1	364.6	293.7	712.0
-Input costs				
.Seed costs	18.9	18.9	20.0	15.0
.Fertilizer costs	27.7	27.7	11.2	30.2
.Herbicide costs	17.8	29.6	29.8	120.5
-Post - harvest costs	57.1	57.1	5.0	69.7
TOTAL NON-MACHINERY COSTS	121.5	133.3	66.0	235.4
GROSS MARGIN	285.6	231.3	227.8	476.6
-Machinery costs				
.Land preparation	10.7	10.7	8.6	10.7
.Production	32.1	32.1	27.4	38.2
.Harvesting	46.3	46.3	33.7	70.2
TOTAL MACHINERY COSTS	89.1	89.1	69.7	119.1
NET RETURNS TO LAND	196.5	142.2	158.0	357.5

CROP SEQUENCE #5.: C-NB-W-B

CROP:	CORN	NAVY BEANS	WHEAT	SUGAR BEETS
COEFFICIENT				
-Gross income	407.1	293.7	266.4	747.6
-Input costs				
.Seed costs	18.9	20.0	9.6	15.0
.Fertilizer costs	27.7	11.2	26.1	31.7
.Herbicide costs	22.3	29.8	1.3	120.5
-Post - harvest costs	57.1	5.0	12.6	69.7
TOTAL NON-MACHINERY COSTS	126.0	66.0	49.6	236.9
GROSS MARGIN	281.1	227.8	216.8	510.7
-Machinery costs				
.Land preparation	10.7	8.6	2.1	10.7
.Production	32.1	27.4	21.9	38.2
.Harvesting	46.3	33.7	36.5	70.2
TOTAL MACHINERY COSTS	89.1	69.7	60.6	119.1
NET RETURNS TO LAND	192.0	158.0	156.2	391.6

TECHNICAL COEFFICIENTS L.P. MATRIX

CROP SEQUENCE #6.: C-C-NB-W

CROP: COEFFICIENT	CORN	CORN	NAVY BEANS	WHEAT
-Gross income	407.1	364.6	293.7	266.4
-Input costs				
.Seed costs	18.9	18.9	20.0	9.6
.Fertilizer costs	27.7	27.7	11.2	26.1
.Herbicide costs	17.8	29.6	29.8	1.3
-Post - harvest costs	57.1	57.1	5.0	12.6
TOTAL NON-MACHINERY COSTS	121.5	133.3	66.0	49.6
GROSS MARGIN	285.6	231.3	227.8	216.8
-Machinery costs				
.Land preparation	10.7	10.7	8.6	2.1
.Production	32.1	32.1	27.4	21.9
.Harvesting	46.3	46.3	33.7	36.5
TOTAL MACHINERY COSTS	89.1	89.1	69.7	60.6
NET RETURNS TO LAND	196.5	142.2	158.0	156.2

CROP SEQUENCE #7.: C-NB-NB-B

CROP: COEFFICIENT	CORN	NAVY BEANS	NAVY BEANS	SUGAR BEETS
-Gross income	407.1	251.8	230.8	712.0
-Input costs				
.Seed costs	18.9	20.0	20.0	15.0
.Fertilizer costs	27.7	10.3	8.8	30.2
.Herbicide costs	22.3	29.8	29.8	120.5
-Post - harvest costs	57.1	5.0	5.0	69.7
TOTAL NON-MACHINERY COSTS	126.0	65.1	63.6	235.4
GROSS MARGIN	281.1	186.7	167.2	476.6
-Machinery costs				
.Land preparation	10.7	8.6	8.6	10.7
.Production	32.1	27.4	27.4	38.2
.Harvesting	46.3	33.7	33.7	70.2
TOTAL MACHINERY COSTS	89.1	69.7	69.7	119.1
NET RETURNS TO LAND	192.0	117.0	97.5	357.5

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