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AN ECONOMIC ANALYSIS OF ALTERNATIVE SAGINAW
VALLEY CROP ROTATIONS--AN APPLICATION
OF STOCHASTIC DOMINANCE THEORY

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AN ECONOMIC ANALYSIS OF ALTERNATIVE SAGINAW VALLEY CROP ROTATIONS--AN APPLICATION OF STOCHASTIC DOMINANCE THEORY

By

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AN ABSTRACT

AN ECONOMIC ANALYSIS OF ALTERNATIVE SAGINAW VALLEY CROP ROTATIONS--AN APPLICATION OF STOCHASTIC DOMINANCE THEORY

By

Roger L. Hoskin

Michigan's Saginaw Valley, with a fine textured lake plain soil, is one of the most productive agricultural areas in the United States. Over the past three decades there has been a shift from mixed livestock/crop farming to intensive cash crop farming with emphasis on corn, Navy beans, soybeans, sugarbeets, and small grains. During this period, there has been a marked decline in average Navy bean yields.

Agronomists contend that perhaps the single most important reason for declining Navy bean yields is deteriorating soil structure brought on by overproduction of cash crops, particularly Navy beans and sugarbeets. One proposed remedy for the problem is a return to the practice of including green manure crops, especially alfalfa, in cropping rotations. Agronomists have identified sixteen cropping rotations that are considered to be representative of those appropriate to Saginaw Valley.

The objective of this study is the following: To rank these sixteen rotations in terms of their relative risks and returns to the farmer. The approach to a solution involves a comparative budget analysis with simulation of the two main stochastic elements, crop yields and product prices.

Gross income was simulated as a multivariate probability distribution in which the marginal distributions (prices and yields) were beta distributed. The beta distributions were defined in terms of the expected values, variances, upper bounds, and lower bounds. Betas were employed as the assumption of normality, particularly of yields, and not considered valid except as a special case. Gross income distributions were developed for each of the sixteen rotations and one hundred "draws" were taken from each to represent one hundred possible "states of nature" of gross income. The resulting states of nature were ranked from lowest to highest with the i^{th} state of nature representing the i^{th} percentile of gross income.

Cash costs were developed for each rotation. Fertilizer usage varies from rotation to rotation and reflects usage based on net removal, adjusted for losses. For example, the nitrogen required on corn after alfalfa is less than that required on corn after corn. Similarly, the impact of nutrients contained in the organic matter plowed down from crop residues was taken into account. The cost of operating capital was specifically included at this point.

Unique machinery complements were developed for each cropping sequence using a simulation model developed in the Department of Agricultural Engineering. The model specifically accounts for timeliness of field operations for each crop in each rotation. Historical weather data for the region was used in calculating the odds of alternative good weather days suitable for field operations. The budgeting procedure employed examines power requirements for each field operation, given the constraints outlined, then selects the tractor horsepower

and equipment size that will accomplish the most limiting of the field operations.

Analysis was done for 400 and 600 acre farm configurations. The 400 acre farm configuration assumes one full-time family laborer. The 600 acre farm configuration assumes two full-time family laborers. A $14,000 per year charge was made for family labor, this being approximately equal to the median Michigan family income, given appropriate adjustment for tax treatment of family farms. Hauling and drying costs were figured at custom rates.

Results indicate that a corn-Navy bean-sugarbeet rotation offered the best prospects under prevailing relative prices. One rotation that included alfalfa and Navy beans showed evidence of being economically viable for some decision makers. Rotations with Navy beans out performed similar rotations with soybeans. Rotations with sugarbeets were more profitable than those without sugarbeets.

Stochastic dominance theory offers a useful way to evaluate alternative risky prospects where decision makers' utility functions are unknown. Unfortunately, the resulting stochastic efficient set may include more than one alternative. Further work needs to be done to be able to further partition the set into efficient and inefficient alternatives.

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Finally, I thank my wife, Neesa, who shared all the good and bad days that come with an undertaking such as this.

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CHAPTER I

INTRODUCTION

Background

Michigan's Saginaw Valley represents one of the most productive agricultural areas in the United States. Over time there has been a shift from mixed livestock/crop farming to intensive cash crop farming emphasizing corn, Navy beans, sugarbeets, and small grains. Increased acreage of high value cash crops in a highly mechanized environment has become increasingly dominant.

Navy beans represent a crop unique to the area and of supreme importance. Navy beans rank third behind corn and wheat as a source of income among Michigan's agricultural crops. Michigan and a concentrated area of Ontario produce 95% of the world's Navy beans (Black and Love, 1978). In recent years, Navy bean yields have trended downward and appeared to plateau (Anderson et al., 1975) (see Figure 1.1).

Agronomics

Research conducted from 1940 to 1970 at Michigan State University's Ferden Farm (Robertson et al., 1976) included experiments on fertilizer application methods and rates, crop rotations, row spacing, and use of supplemental nitrogen. Comparisons of alternative cropping systems indicated improved yields of corn, Navy beans, and sugarbeets when grown in rotations which included alfalfa and green manure crop.

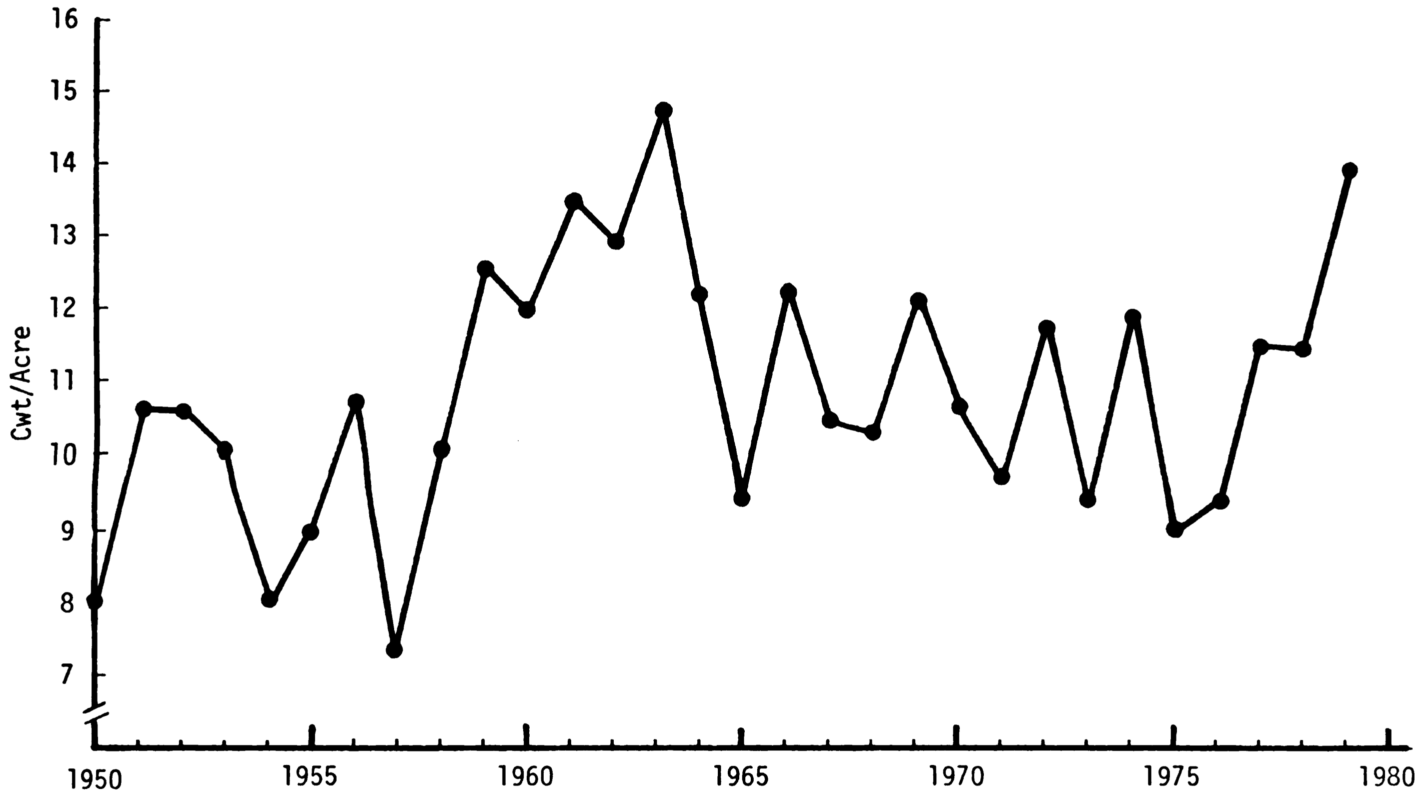

Figure 1.1 Michigan Dry Bean Yield per Acre.

(Source: Michigan Agricultural Statistics, various years.)

This was true even when nitrogen was not limiting. Inclusion of green manure crops and alfalfa was beneficial to soil structure and, in the case of Navy beans and sugarbeets, helped maintain soil organic matter levels.

Use of alfalfa or green manure cover crops in rotation with other crops is not common on Saginaw Valley cash crop farms. Agronomists maintain inclusion of alfalfa in crop rotations with Navy beans could reverse the Navy bean yield trend.

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Economics

Production decisions by farmers are made with the objective of making a profit. It is not sufficient that a proposed problem/solution actually solve the agronomic problem; it must also be economically viable. The degree of risk faced by farmers is influenced by cultural practices and cropping system. Thus, economic analysis must include consideration of risk associated with net income cash crop rotations.

Production decisions are made in an environment of uncertain outcomes; yields and prices are the main sources of variation. Farm prices were considerably more variable during the 1970s than during the 1950s and 1960s. During the decade of the 1960s, yield variability for all crops, except wheat, was greater than price variability, but during the 1970s price variability has been greater than yield variability for all crops (Knoblough, 1976).

In summary, Saginaw Valley cash crop farmers face a business environment in which increased integration of United States agriculture with international markets and the decline of the relative size of the

United States surpluses vis-à-vis world consumption, creates a potentially riskier environment; and there exists a trend toward stagnating if not declining per acre yields of navy beans, an important cash crop to the area.

Problem Statement

Ferden Farm research revealed higher yields and improved disease and pest control resulted from the inclusion of leguminous cover crops such as alfalfa in crop rotations. Research results also indicated the adverse impact on soil structure and soil organic matter level of continuous plantings of Navy bean and sugarbeet crops.

Soil scientists suggest that intensive cash crop agriculture is a cause of the declining Navy bean yields. Given the problems associated with intensive cash cropping systems and the results of agronomic research, the intent of this research to examine the economic viability of alternative cropping systems, particularly those that included legumenous cover crops as part of the rotation.

Research Objectives

The objectives of this study are:

1. to describe the present economic environment in which Saginaw Valley cash crop farmers operate;
2. to identify crop rotations which are agronomically feasible for the Saginaw Valley and illustrate a wide variety of agronomic practices; i.e., the range should be from intense cash crop rotations to agronomically desirable rotations

returning more organic matter and contributing to better soil structure;

3. to analyze, from a design perspective, the economic viability of selected crop rotation patterns from the farmers' viewpoint; and
4. to determine the sensitivity of the ranking of crop rotations to changes in prices and yields.

Methodology

There are numerous criteria by which cropping systems may be evaluated; the focus here is a risk-return perspective. The assumption is that farmers prefer more income to less and prefer less risk to more.

Crop rotations are evaluated using a design perspective. Consequently, the investigation considers: (1) yield relationships; (2) seed, fertilizer, and chemical regemines; (3) labor and machinery requirements; and (4) input and crop prices.

The measure of profitability used is returns to land; that is, gross revenue produced in a period less total in expenses incurred in the production period. From an accountant's perspective, it is assumed that all revenue produced is realized in the year in which associated costs are incurred. The analysis abstracts from storage, either of inputs or crops.

When comparing systems, relative returns are more important than absolute returns. Absolute returns are critical in evaluating debt capacity; but in the present context, it is relative returns, hence relative yields, prices, and costs that are significant. This study, while attempting to estimate absolute values as accurately as possible, focuses upon relative values.

The major source of risk associated with alternative cropping patterns is variability of yields and variability of prices. Variability of prices will be estimated using a historical measure of variability and estimates from the MSU Agricultural Forecasting Model. Variability of yields will be estimated using historical records of yields on Saginaw Valley farms. Sixteen alternative cropping systems appropriate to the Saginaw Valley are identified and evaluated in terms of the net returns and the variability of net return to land.

Construction of Enterprise Budgets

The approach adopted abstracts from the exigencies of any particular farm and examines the economic performance of each cropping system under the operating constraints typical of the Saginaw Valley area. Each system is presumed to be produced on a 400 and 600 acre family operated cash crop farm. Machinery costs reflect employment of a machinery complement tailored to each cropping system, and accounting for the technical complementarities in terms of yields and inputs inherent in each system.

Enterprise budgets are constructed for each of the cropping systems under consideration. The budget derived for each cropping system was unique; that is, the technical complementarities inherent in each system were accounted for economically. To illustrate: corn following alfalfa requires less fertilizer, a different herbicide regime, and has a higher yield per acre than does the corn following corn. These kinds of differences were accounted for in each cropping system.

The net return to land represents a measure of the residual remaining after cash costs, machinery costs, and living expenses have been deducted from gross income. There is no attempt to inpute wage rate for family labor or a return on land. Nor is there any attempt to estimate taxes or assume a particular financial structure for the farm. These characteristics are unique to each farm operation and desired rates of return on invested capital are, to some degree, set by management.

The impact of risk on production decisions will be evaluated using stochastic dominance criteria. To measure the production variability of crop enterprises, data on yields for individual farms over a number of years is needed. These data were obtained from a selection of Saginaw Valley farm records obtained from the TELFARM Records Project at Michigan State University. Price variability is measured from the series of prices received by Michigan farmers published in Michigan Agricultural Statistics.

Outline of Dissertation

Chapter II contains a presentation of the agronomic concepts necessary to develop the crop rotations for study, expected yields, and fertilizer and pesticide regimens. Chapter III contains a discussion of the relevant theory regarding decision making under uncertainty. Chapter IV presents development of the methodology employed in estimating commodity prices, input prices, price and yield variability, machinery and labor requirements. Chapter V describes the analytical model and the method of computing income variability. Chapter VI contains empirical findings and sensitivity analysis and implications. Chapter VII summarizes the study and includes suggestions for further research.

CHAPTER II

AGRONOMICS OF SAGINAW VALLEY CROPPING SYSTEMS

Two broad classifications of cropping systems are represented in the Saginaw Valley (Christensen, 1978). One is described as "haphazard"; acreage allocation decisions are made one year at a time on the basis of price expectations. This approach is a "problem creator." This is particularly true for Navy beans and sugarbeets since growing Navy beans and sugarbeets in successive years or in short rotations with other crops that return little organic matter to the soil has been shown to be associated with poor soil structure (Robertson et al., 1976), depletion of organic matter (Lucas and Vitosh, 1978), and disease and pest problems (Andersen et al., 1975). Furthermore, early research on the Ferden Farm indicated a trend toward declining average Navy bean yields when grown in systems where no effort was made to maintain soil structure and soil organic matter.

The yield trend for Michigan Navy beans was upward to the mid-sixties but recently has shown a declining trend (Andersen et al., 1975; Wright, 1978). In 1974, a 100 farm survey was conducted (Andersen, 1975) which indicated a trend among Michigan Navy bean producers to grow Navy beans on the same field in consecutive years and to exclude any soil building crops from their planting decisions. According to this survey, summarized in Table 2.1, almost one-fourth of the fields

Table 2.1 Crop Grown in Previous Years to 1974 Navy Bean Crop (Percent of Fields)

Previous Crop	1972	1973
Alfalfa	2	2
Navy beans	37	30
Corn	12	23
Small grains	13	17
Soybeans	1	3
Sugarbeets	21	15
Other	13	10

surveyed had been in beans the previous year and 37% had been in beans two years previously.

Two-thirds of the fields surveyed exhibited poor soil structure. Twenty-four percent showed a high enough degree of Fusaruim root rot to substantially impair yields, and an additional 27 percent exhibited a moderate degree of root rot, but still enough to impair yields. Rotation practices are partially to blame for declining Navy bean yields.

In contrast to the "haphazard" systems, some farmers plant acreage in a well defined rotation which changes little from year to year. The evidence indicates cropping rotations including crops which contriubute to good soil structure and high organic matter levels improve yields and reduce disease and pest problems.

Previous Research

Early research supporting the agronomic advantages of clearly defined cropping rotations which benefit soil structure was conducted on the Ferden Farm near Chesaning, Michigan. These experiments were begun in 1926 and concluded in 1970 when this research was moved to Saginaw Valley Bean and Beet Research Farm near Saginaw, Michigan.

In 1940, a series of experiments at the Ferden Farm was initiated to investigate the effect of different crop rotations on yield, soil structure, and disease incidence. The results of experiments conducted between 1940 and the mid-1950s indicated that the highest yields of Navy beans and sugarbeets were obtained from "livestock" cropping systems, i.e., those that included two years of alfalfa-brome hay as a soil building crop. The lowest yields were obtained in "cash" crop rotations where no effort was made to maintain soil structure (see Table 2.2).

Rotation B-Ba-A-A-NB, a "livestock" rotation, includes two years of alfalfa to maintain soil structure. Rotation W-C-C-Ba-NB, a "cash" crop rotation, includes fewer crops that contribute to soil organic matter and structure. Rotation #3 is identical to #2 except sweet clover was included as a companion crop with wheat and barley and left as a winter cover crop. The experiments included two levels of fertilizer. Plots receiving greater amounts of fertilizer had higher yields; the effects of fertilizer were similar in all three rotations. The average differences were equal to or less than 0.6 cwt. per acre of Navy beans.

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Table 2.2 Five Year Average Navy Bean and Sugarbeet Yields as Affected by Three Systems of Cropping[a]

	Rotation					
	B-Ba-A-A-NB		W-C-C-Ba-NB		W(gm)-C-B-Ba(gm)-NB	
Years	Navy Beans Cwt./A	Sugarbeets Ton/A	Navy Beans Cwt./A	Sugarbeets Ton/A	Navy Beans Cwt./A	Sugarbeets Ton/A
1941-1945	13.1	10.2	10.0	9.6	11.2	10.1
1946-1950	14.3	12.0	11.5	9.8	12.2	11.1
1951-1955	17.8	16.9	14.2	14.1	14.8	15.0
1956-1960	19.9	--	14.5	--	18.2	--
Mean	16.3	13.0	12.5	11.2	14.1	12.1

[a]B = sugarbeets; Ba = barley; A = alfalfa; NB = Navy beans; C = corn; W = wheat; gm = green manure (such as clover) winter cover crop.

Table 2.2 Five Year Average Navy Bean and Sugarbeet Yields as Affected by Three Systems of Cropping[a]

	Rotation					
	B-Ba-A-A-NB		W-C-C-Ba-NB		W(gm)-C-B-Ba(gm)-NB	
Years	Navy Beans Cwt./A	Sugarbeets Ton/A	Navy Beans Cwt./A	Sugarbeets Ton/A	Navy Beans Cwt./A	Sugarbeets Ton/A
1941-1945	13.1	10.2	10.0	9.6	11.2	10.1
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1951-1955	17.8	16.9	14.2	14.1	14.8	15.0
1956-1960	19.9	--	14.5	--	18.2	--
Mean	16.3	13.0	12.5	11.2	14.1	12.1

[a]B = sugarbeets; Ba = barley; A = alfalfa; NB = Navy beans; C = corn; W = wheat; gm = green manure (such as clover) winter cover crop.

Research at the Ferden Farm ended in 1970. However, crop rotation experiments have been continued at the Bean and Beet Farm in Saginaw County. The objectives of the cropping system portion of this research are: (1) to study the effect of length of rotation on yield and quality of navy beans and sugar beets, and (2) to evaluate the effect of the return of organic matter on yields and selected soil properties. Preliminary results indicate a significant affect of both rotation and length of rotation on Navy bean yields. The highest Navy bean yields were obtained on a four year rotation which included alfalfa, O-A-NB-B (see Table 2.3). Navy bean yields were greater where corn (stalks returned) was included than where it was not. The lowest yields were obtained from a three year system (NB-NB-B) where beans were grown in successive years and little organic matter was returned to the soil.

Table 2.3 Navy Bean Yields Versus Cropping System on Saginaw Bean and Beet Farm[a]

Cropping System[b]	Average Yield 1973-1976 Cwt./A
Two Year Rotation:	
C-NB	17.7
B-NB	16.4
O-NB	17.0
Three Year Rotation:	
C-NB-B	17.1
NB-NB-B	16.2
O-NB-B	17.5
Four Year Rotation:	
C-C-NB-B	17.9
C-NB-NB-B	17.3
O-A-NB-B	19.3

[a]Chairty Clay soil; Management Group 1cc.

[b]A = alfalfa, B = sugarbeets, NB = Navy beans, C = corn, and O = oats.

There was no rotational length effect on sugarbeet yields. Corn yields were more sensitive to nitrogen application than to rotational length or cropping system. Corn grown in successive years tended to be susceptible to corn root worm so an insecticice regimen was necessary.

An eight year rotation study was conducted in Wisconsin examining five year rotations including corn, soybean, oats, and alfalfa versus continuous corn (Higgs et al., 1974). Corn yields were significantly higher in rotation than for continuous corn. In rotations where corn followed alfalfa, yields were higher than for subsequent corn yields in the same rotation; however, second and third years of corn offered higher yields than did continuous corn (see Table 2.4).

Table 2.4 Average Corn Yields for Alternative Rotations with 150 Pounds of Nitrogen Applied

Rotation	Appearance		
	1st Year Bu./A	2nd Year Bu./A	3rd Year Bu./A
Continuous Corn	125.1		
C-S-C-O-A	133.6	133.6	
C-C-C-O-A	130.5	124.7	125.9
C-C-O-A-A	138.1	127.5	
C-O-A-A-A	137.6		

[a]Average yields for 1967-1974 on Rozetta Silt Loam soils, University of Wisconsin Experiment Station, Lancaster. One hundred-fifty pounds of nitrogen were applied per acre.

[b]S = soybeans, and O = oats.

These experiments were repeated at three different nitrogen application rates. Corn yields were sensitive to application of nitrogen, and there was a statistically significant interaction between nitrogen application rate and rotation. The average yield of 125.1 bushels per acre for continuous corn was 5 to 13 bushels per acre less than first year corn in rotation even when nitrogen was not limiting; 150 pounds of nitrogen per acre was applied to corn in all rotations.

Historically, specific crop rotations have been recommended to: (1) improve soil tilth and structure; (2) provide nitrogen to following crops; (3) improve infiltration of ground water and reduce erosion; and (4) improve disease, weed, and insect control (Higgs et al., 1974). With the advent of relatively inexpensive nitrogen fertilizers and chemical herbicides and pesticides, the importance of crop rotation as a standard cultural practice has declined. Widespread production of Navy beans and sugarbeets, two crops that provide little organic residue to the soil, make rotation practices more important in the Saginaw Valley than for the corn belt. Rotation practices will become of even greater value with rising real prices of fossil fuel based fertilizers and chemicals.

Sixteen Saginaw Valley Cropping Systems

Research documented above strongly suggests advantages to systematic crop rotation to include crops that contribute to soil structure and soil organic matter. Increased yields, reduced use of fertilizer, improved control of disease and pests, and reduced

tillage are the potential advantages accruing to appropriate crop rotation. The issue is whether these advantages are substantial enough to warrant a change from current production practice. This issue is of particular significance since alfalfa, a major soil building crop, is not a high value cash crop. The major focus of this research is to evaluate the benefits of crop rotation from a perspective of economic viability.

Agronomists, Drs. Don R. Christensen, Zane Helsel, and Vernon Meints, from Michigan State University, have drawn up sixteen cropping sequences which include alfalfa and six other commonly produced cash crops appropriate to conditions in the Saginaw Valley. The six cash crops included are: corn, Navy beans, soybeans, sugarbeets, oats, and wheat. In the context of this research, alfalfa will be considered as a cash crop. The sixteen rotations and their expected (in a probabilistic sense) yields are presented in Table 2.5. The yield relationships presented represent those obtainable to the top two-thirds to three-fourths of all operators. These rotations are assumed to be produced as typical Saginaw Valley lake plane soils with slope less than 3%. Tile and surface drainage are assumed functional and adequate and irrigation is not considered. The yields obtained reflect timely field operations and machinery systems designed to insure near optimum yields (see Table 2.5).

There is an 8 bushel per acre differential in corn yields among cropping systems depending on where corn appears in the rotation. The highest yields are expected in sequences 9, 10, and 16 where corn follows alfalfa. Field experiments at Michigan State University as well

Table 2.5 Expected Yield Under Alternative Saginaw Valley Crop Rotations[a]

Sequence		Corn (bu/A)			Soybeans (bu/A)	Navy beans (cwt/A)		Wheat (bu/A)	Oats (bu/A)	Sugarbeets (T/A)	Alfalfa (T/A)				
Rotation No.	Rotated Crops[b]	1st	2nd	3rd		1st	2nd				Seeding Year	1st	2nd	3rd	4th
1	C-NB	115	--	--	--	13	--	--	--	--	--	--	--	--	--
2	C-SB	115	--	--	35	--	--	--	--	--	--	--	--	--	--
3	C-C-SB	115	110	--	35	--	--	--	--	--	--	--	--	--	--
4	C-NB-B	110	--	--	--	12	--	--	--	21	--	--	--	--	--
5	C-SB-B	110	--	--	35	--	--	--	--	21	--	--	--	--	--
6	C-NB-W-B	110	--	--	--	14	--	60	--	20	--	--	--	--	--
7	C-SB-W-B	110	--	--	35	--	--	55	--	20	--	--	--	--	--
8	C-NB-NB-B	110	--	--	--	13	11	--	--	20	--	--	--	--	--
9	O/A-A-A-C-C-SB-C	118	115	115[c]	35	--	--	--	80	--	1.0	4.6	4.4	--	--
10	O/A-A-A-A-A-C-C-C	118	115	110	--	--	--	--	80	--	1.0	4.6	4.4	4.0	3.8
11	C-C-NB-W	110	110	--	--	14	--	60	--	--	--	--	--	--	--
12	NB-C-SB	115	--	--	35	12	--	--	--	--	--	--	--	--	--
13	C-C-NB-B	110	110	--	--	14	--	--	--	21	--	--	--	--	--
14	O/A-A-NB-B	--	--	--	--	16	--	--	80	22	1.0	4.6	--	--	--
15	O-NB-B	--	--	--	--	11	--	--	100	20	--	--	--	--	--
16	O/A-A-C-C-NB-C	118	115	115[c]	--	14	--	--	--	--	1.0	4.6	4.4	--	--

[a]Assumes fine textured Lake Plain soils, adequate tile and surface drainage and recommended cultural practices.

[b]C = corn; NB = Navy beans; SB = soybeans; B = sugarbeets; W = wheat; O = oats; A = alfalfa; and O/A = oats seeded with alfalfa.

[c]Corn following soybeans or Navy beans.

as other studies in the mid-west, e.g., Higgs et al. (1974) suggest that corn following alfalfa yields about 7% higher than continuous corn. Yields of corn after sugarbeets are less than expected after other crops due to moisture depletion of beets and soil compaction in harvesting operations. Yields in successive years, even after alfalfa, decline; this is attributed to increased disease problems associated with continuous corn.

A five hundredweight per acre differential is estimated for Navy beans. This estimate reflects observations on Saginaw Bean and Beet Farm and the Ferden Farm which indicate that longer intervals between successive bean crops and inclusion of crops that contribute to the soil and structure promote better yields. Sequence number 8 (C-NB-BN-B) which is similar to much of the actual practice in the Saginaw Valley represents the effect observed at the Ferden Farm--that successive crops of Navy beans will decline in yield. Finally, research results at the Bean and Beet Farm suggest that yield of Navy beans in longer rotations perform better then yields in shorter rotation. Thus, Navy bean yields in rotation 6, 11, and 13 outperform yields in rotations 1 and 15. The benefit that alfalfa provides to soil structure and consequently Navy bean yields is illustrated by rotation 14.

Yields of sugarbeets were assumed lower after wheat, due to the tendency of a straw mat forming under the plow layer. Work at the Ferden Farm suggests the inadvisability of planting sugarbeets after alfalfa as experiment plots showed some tendency toward black root in wet soils. However, the presence of alfalfa in the rotation was shown to be of benefit to sugarbeet yields. Wheat following soybeans are estimated to be depressed five bushels per acre due to the difficulty in getting wheat planted.

The expected yield of oats in the Saginaw Valley is 100 bushels per acre. In rotations 9, 10, and 14, the yield is reduced to 80 bushels per acre to reflect companion seeding with alfalfa. It is assumed that one ton per acre of alfalfa could be harvested after oats in the seeding year. Alfalfa yields decline as stands become older; this is reflected in the yield figures for subsequent years of alfalfa in rotations 9, 10, and 14. Two tons of oat straw is harvested and sold as a cash crop in those rotations where oats are companion seeded with alfalfa. In rotation 15 the oat straw is plowed down.

CHAPTER III

RISK, UNCERTAINTY, AND DECISION MAKING

Introduction

The impact of planning decisions on the variability of net farm incomes has been a management problem and has been the focus of much agricultural economics research for a number of years. "Risk" and "uncertainty" are terms associated with income variability and have been given specific technical meaning (Knight, 1921). The producer, under Knight's polar case taxonomy, faces two types of eventualities. Under risk, the probability of alternative outcomes can be measured. Risk can be described using the calculus of probability: Alternative outcomes (states of nature) have a frequency of occurrence in a large number of trials. Probability distributions can be established for situations involving risks. Variation in crop yields can be considered as risks where fluctuations in weather repeat frequently enough that farmers can establish a mean outcome and the range of possible outcomes.

The second type of eventuality decision makers face is designated as uncertainty and represents occurrences whose probability cannot be established in an empirical way. Uncertainty has been categorized as being subjective in nature (Heady, 1952). A decision maker is required to formulate some "image of the future" but there is no quantitative manner in which these hypotheses can be verified.

Yield and price variability are two phenomena which give rise to uncertainty in production planning. Yield variability is often treated as a risk, since the probability of alternative yield outcomes can be derived on the basis of past experience. If past experience is a "good" predictor of the future (as is often assumed and will be here), then the uncertainty of future yields can be treated analytically as risk. The same logic may also be applied to price variability although the assumption of the past being a good predictor of the future is much more tenuous.

Modern decision analysis (Anderson et al., 1977) proceeds on the assumption that the decision maker is able to form a subjective estimate of the probability of alternative outcomes, and to utilize these probabilities in making choices among risky alternatives. The difficulty is that managers may not have an adequate knowledge of the probability distributions, even for common random inputs and outputs, since the past may not be a good predictor of the future. And, even if it is, the decision maker's experience may not be sufficient to formulate adequate hypotheses. Even if the past is an adequate predictor of future possibilities and the decision maker has had adequate experience sufficient to formulate subjective probabilities as to outcomes, capital limitation represents an important reason many farmers do not maximize expected values. As Doll and Orazem suggest,

> An unlimited amount of capital would be needed to realize the expected earnings in a game of chance. No matter how large a player's stack of money might be, in theory there always exists a losing streak long enough to wipe him out. The same is true for a farm manager. . . . When a manager

> faces capital limitations, he may choose to adjust his production procedure to maximize some criterion other than expected value.

Friedman and Savage (1952) suggest that individuals choose among risky alternatives as if they were seeking to maximize the expected value of some other quantity which the authors refer to as "utility." The hypothesis of expected utility maximization is used to explain decision makers' behavior toward risky prospects. The concept of expected utility can be illustrated with the aid of the following simple example. Suppose a decision maker were faced with two alternative courses of action, A_1 and A_2, each with two equally likely outcomes. The expected payoff is represented in Table 3.1.

Table 3.1 Simple Decision Problem

State of Nature	$P(S_i)$	A_1 $	A_2 $
S_1	.5	200	900
S_2	.5	0	-700
Expected money value		100	100

Both courses of action have the same expected monetary value, $100, yet evidence suggests most decision makers would not be indifferent to the two courses of action. For most, the possibility of losing $700 would outweigh the prospect of winning $900. Selecting among alternative risky outcomes is a subjective mental process and depends

on the preferences of the decision maker. However, in analyzing uncertain alternatives, utility analysis provides a means whereby preferences may be expressed and choices simplified. The concept of a utility function is a device for assigning numerical values and consequences. The idea of a utility function is based on Bernoulli's principle or, as it is otherwise known, the expected utility theorem.

The following axioms represent a sufficient basis for the derivation of Bernoulli's principle for risky prospects with single dimensional consequences (Anderson, 1977).

1. Ordering and transitivity. A decision maker faced with two risky alternatives, A and B, can be said to order the alternatives such that A is preferred to B or B is preferred to A, or the decision maker is indifferent between A and B. Transitivity implies that among three risky prospects A, B, and C, if A is preferred or indifferent to B and B is preferred or indifferent to C, then A will be preferred or indifferent to C.

2. Continuity. If a decision maker prefers course of action a_1 to a_2 to a_3, a subjective probability $P(a_1)$ exists that is greater than zero such that he is indifferent between a_2 and a game of chance yielding a_1 with $P(a_1)$ and a_3 with $1 - P(a_1)$.

3. Independence. If a_1 is preferred to a_2 and a_3 is any other risky prospect, then a game of chance with a_1 and a_3 as its outcomes will be preferred to a game in which a_2 and a_3 are outcomes when $P(a_1) = P(a_2)$. Preference between a_1 and a_2 is independent of a_3.

These axioms form a sufficient basis for derivation of Bernoullian utility functions. Such a function can be said to exist for decision makers whose preferences are consistent with the axioms of ordering, transivity, continuity, and independence. The utility function, U(a), is a single valued function that associates a unique utility value with any risky prospect. It has the following properties:

1. If a_1 is preferred to a_2 then $U(a_1) > U(a_2)$.
2. The utility of a risky prospect is its expected utility value. In the case of discrete probabilities:

$$U(a_j) = \Sigma_i \; U(a_j | S_i) \; P(S_i)$$

   where S_i is a state of nature with probability of occurrence $P(S_i)$.
3. The scale on which utility is defined is arbitrary; there is no unique scale of utility and interpersonal comparisons of utility are analytically meaningless. Also, cardinal measures of utility are not defined, e.g., it makes no sense to speak of one prospect as having twice as much utility as another for a decision maker. Utility permits only an ordinal ranking of prospects not a scaling of their relative values.

For research purposes it is often desirable to be able to express utility functions in algebraic form. A common and popular way to do this is to represent the utility function as a polynomial. This can be justified on the basis that a polynomial is a Taylor series approximation to an unknown utility function over some small range of

values. Thus a utility function of any form may be approximated for any point U(x) in a neighborhood of U(x*) as:

$$U(x) = U(x^*) + \sum_{i=1}^{n-1} [U_i(x^*)\ (x-x^*)^i/i] + R$$

Following some manipulation U(x) is then approximately

$$U(x) + \alpha_o + \alpha_1 x + \alpha_2 x^2 + \ldots + \alpha_n x^n$$

From the exptected utility hypothesis, where E(x) is the expectation operator,

$$U(x) = E(x) = \alpha_1\ E(x^2) + \alpha_2\ E(x^3) + \ldots .$$

If x is a random variable with some probability distribution f(x) and M_j represents the j^{th} moment $E(x - E(x))^j$ about the mean of x then U(x) can be written

$$U(x) = E(x) + b[M_2(x) + E(x)^2] + C[M_3(x) + 3E(x)\ M_2(x) + E(x)^3] + \ldots .$$

Thus the utility of a risky prospect can be written as a function of its mean and moments about the mean. Empirically, the i^{th} moment appears to be less influenced than the (i - 1) moment; consequently, higher moments are usually ignored. A utility function often employed either explicitly or implicitly is the quadratic function, i.e.,

$$U(x) = x + bx^2.$$

This form assumes that the decision maker regards only mean and variance of the prospect in making decisions. This very often is not the case but use of quadratic utility may represent some

improvement over the linear utility function implied under the assumption of profit maximization.

Lin, Dean, and Moore (1974) sought to test the hypothesis that expected utility maximization represented a superior predictor of farmer planning decision behavior than expected profit maximization. The work was a case study of six large farms in the western San Joaquin Valley of California. The authors derived the mean-variance (EV) frontier for cropping systems for each farm using quadratic programming techniques. Bernoullian and lexicographic utility functions were estimated for the major decision maker on each farm. The Bernoullian utility functions for five of the six farmers was quadratic; one was linear. The expected profit maximization hypothesis implies a linear Bernoullian utility function and indifference curves which are linear in EV space.

The Bernoullian utility maximization hypothesis was superior to both expected profit maximization and lexicographic utility functions in predicting farmer behavior. None of the three were accurate predictors of actual farmer behavior in any absolute sense. There was a tendency for all three to predict more risky plans than those actually adopted. This study supports the conclusion that at the micro level, profit maximization is not an adequate predictor of firm behavior in a risky environment.

Previous Research in Agriculture

Much research has been conducted incorporating risk into the decision making process. The majority of the investigators have used variance as a measure of risk and, therefore, implied the outcome of risky prospects are normally distributed or the decision makers possess a quadratic utility function (Anderson et al., 1977).

The California study illustrates a standard method of incorporating risk in studying resource allocation decisions. The concept of using the variance of a risky prospect as a measure of risk has been widely applied in financial portfolio analysis and in economics to explain "diversification" of assets. Tobin (1958), in a classic article, uses the framework to explain liquidity preference for cash balances. Heady (1954), in one of the early studies, determined the variation in net farm income associated with growing different crops in selected areas and on selected soil types in Iowa. Detrended yield data from 14 townships in Iowa were used along with historical prices for crops and historical costs for inputs adjusted to "current" production methods to determine expected net income. The objective of the study was to determine the mix of crop enterprises that would effectively reduce income variability, and the optimum proportions in which they should be combined to achieve the greatest advantage of diversification. The EV space was developed for 14 selected geographical areas. The significance of the study is the illustration of a procedure for incorporation of risk into the decision making process, and general evidence that diversification is worthwhile.[1]

Carter and Dean (1970) estimated the benefits of diversification of cropping systems on farm income for six geographic areas of California. A wide variety of field and specialty crops are considered

using an approach similar to that used by Heady. Detrended yields, county data, and prices were used to estimate coefficients of variation. Expected yields were based on the mean of the most recent five years. Expected prices were based on the mean of recent years, on the assumption that farmers would base price expectations on recent experience. Gross income was defined as price times yield. Net income was defined as gross income less operating costs, which excluded depreciation, taxes, and other fixed charges. As in the earlier study, proportions of a fixed acreage devoted to different crops was varied to determine the impacts on expected net income and income variability. Numerous other studies have been undertaken to evaluate the impact of yield variability on farm income and evaluate the benefit of diversification as a risk reduction measure (e.g., Swanson, 1957; Anderud et al., 1966).

These studies presented production alternatives in terms of means and variances; no assumptions were made about which crops would be most desirable to produce and in which proportions. Presumably a decision maker could examine the EV frontiers presented and select a desirable one, but no behavioral assumption was made on the part of researchers about the group of decision makers.

Quadratic risk programming represented an early attempt to take account of risk within the framework of mathematical programming. Freund (1956), in a classic article, examines the selection of alternative enterprises on a representative North Carolina cash crop farm.[2] The algorithm maximized a quadratic utility function, while the coefficients matrix and resource constraints were deterministic and

unchanged from the standard linear programming format. A computational example was presented for a representative multi-crop North Carolina farm in which the optimum (profit maximizing) set of crops, generated by a standard linear programming procedure was compared with the optimum set (utility maximizing) of crops generated with the quadratic risk programming procedure. The optimum mix of crop activities selected in an LP context indicated high reliance on crops of potatoes and fall cabbage, profitable but risky enterprises; while completely by-passing corn, a common crop in the region. The risk programming solution presented a cropping mix much less reliant on "high risk" crops and closer to the cropping mix observed by farmers in the area.

This approach had the advantage of incorporating risk adverse behavior within the context of mathematical programming models. Unfortunately, application of quadratic risk programming has been difficult. Difficulties with quadratic programming algorithms, difficulty in eliciting utility function, and sparse data have been obstacles.

Many investigators have developed approximations to incorporate risk into the decision making optimization process, while maintaining the power of the simplex algorithm for the solution of linear programming problems. Boussard (1967) introduced the notion of "focus loss constraint." The approach involves determining the maximum admissable loss for a particular decision maker such that P is the difference between expected profit and the minimum level of returns necessary to avoid ruin. The objective function is then defined as:

$$P = E(\pi) - \pi_M = \sum_{j=1}^{n} E(c_j)x_j - E(F) - \pi_M$$

where π_M is the minimum level of profit acceptable. For each j activity there is an expected net revenue $E(c_j)$ and a possible deficiency in net revenue r_j, where r_j is represented as the difference between expected revenues and those obtained under adverse conditions; r_j is selected such that actual net revenue in each activity will be greater than or equal to $E(c_j) - r_j$ with some probability close to 1. The activity safety constraint will be satisfied if the conceivable deficiency of any activity's net revenue does not exceed some specified fraction, 1/K of the admissible loss, i.e.,

$$r_i x_j = L/K \quad j = 1, \ldots, n \text{ activities.}$$

Boussard and Petit (1967) show that if activity net revenues are independently normally distributed, the focus loss constraint restricts the chance that that profit will fall below a critical value to a maximum probability P.

The Assumption of Normality

Most previous studies incorporating risk have been conducted on the assumption that the random variables were normally distributed. The importance of the normality assumption to the EV approach can be illustrated with the aid of Figure 3.1. Suppose there are two alternative risky prospects, one given by (probability density function) PDF A and the other represented by PDF B. Assume also that the mean and variance of A and B are equal. Under the assumptions of EV analysis, a decision maker would be indifferent between the two

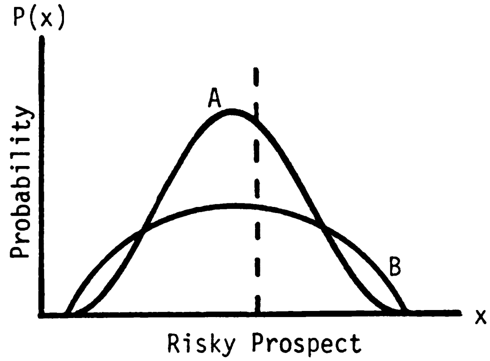

Figure 3.1 Comparison of Non-Normal Density Function.

prospects. This is so because moments higher than the second are not considered in the analysis. This is acceptable if the prospects are normally distributed, since all higher order moments of a Gaussian distribution are zero. In the example, differences between A and B are evident and the higher moments are not zero.

In previous studies, the normality assumption was made as a matter of consequence and because evidence to the contrary was not strong. Perhaps one of the reasons for this was that the yield data employed to estimate yield variability was always in aggregated form. That is, most time series used were county or township data. All authors recognized that the variances estimated from such a series would underestimate yield variability at the farm level; but the unavailability of field or experimental data necessitated reliance on the aggregated series. Such an aggregated series is most often some form of weighted average of data from individual farm yields which may be described as random variables. By appeal to the central limit theorem (Kreyszig, 1970), it is easy to see that the mean yield of a series of estimated yields would tend to be normally distributed regardless of the underlying distribution of the farm level yields.

Day (1965) examined the assumption of normality of the distribution of yield data from field experiments conducted by the Mississippi State Experiment Station. A time series of 36 years was obtained for cotton and corn yields at seven levels of nitrogen application. Twenty-one years of data were obtained for oats. Pearson's test for skewness and the Geary's test for kurtosis were employed. There was overwhelming evidence of positive skewness for cotton. The evidence was not as clear for corn and oats, yet positive (although statistically not significant) skewness was evident for the seven sample series of corn. Negative skewness, significant in only two of the seven series was evident for oats. The conclusion is that some evidence exists for skewness of corn and oat yield distributions although not to the degree evidenced by cotton. Geary's test of kurtosis offered strong evidence of kurtosis of cotton yields. The evidence of kurtosis in corn and oat yields although present was not as conclusive.

The same procedure was repeated for the crop yields transformed to logarithms. The author concludes that the log normal transformation has no general validity as a theoretical density function for field crop yields.

In light of the previous discussion concerning risk, its measurement and importance in farm planning, the evidence provided by Day suggests that at the farm level, planning decisions based only on expected yields and variances are not adequate. Tests conducted on the field data obtained for this study exhibit strong evidence of non-normality of Navy bean and sugarbeet yields. The evidence is less conclusive for the remaining crops.

The normality assumption is even less tenable in terms of prices. Corn, wheat, oats, and sugarbeets have government maintained price support programs. The program's effect is to truncate the lower tail of the distribution of prices while the upper bound is unconstrained.

The constituents of gross income, yield and price, cannot be assumed to be normally distributed. Furthermore, a quadratic utility function as is often assumed in mean-variance studies of risk has the theoretically undesirable property of exhibiting an increasing marginal utility of money. In light of these facts, employing a utility function or a risk efficient production set based only on the first two moments of the distribution is inadequate.

Stochastic Dominance as a Decision Criteria

Since this study is being conducted from a design perspective, i.e., a comparison of the relative merits of alternatives, the notion of specifying a unique algebraic form for a decision maker's utility function is unrealistic. Perhaps a better approach is to identify classes of decision makers based on behavioral assumptions about preferences in a decision making situation.

An alternative approach to ranking rotations from an economic perspective, when decision makers' preferences are unknown, is to use the concept of stochastic dominance. When individual decision makers'

preferences are unknown, it is not possible to generate an optimum decision. However, it is possible to develop an efficient set of decisions in the sense that an identified class of decision makers behaving in accordance with the presumed assumption will not select or prefer an alternative that is not part of the efficient set. The concept of stochastic efficiency further partitions the set of alternatives into efficient and inefficient as additional assumptions about decision maker preferences are introduced.

Quirk and Saposnik (1962) proved that given any two risky prospects P_1 and P_2, if P_1 is stochastically larger than P_2, then P_1 will be preferred to P_2 by all decision makers that prefer more to less, regardless of the specification of the utility function. Within the framework of the expected utility hypothesis this implies that the only restriction on the utility function for First Degree Stochastic Dominance, FSD, is that of a monotomically increasing utility function, i.e., $U'(x) > 0$.

Consider the case of two continuous Cumulative Density Functions (see Figure 3.2) defined on the interval [ab] and associated with the possible outcomes of two alternative risky prospects, then F is said to dominate G in the sense of first degree stochastic dominance if $F(x) \leq G(x)$ for all x in [ab] with at least one strong inequality holding, i.e., $F(x) < G(x)$ for at least one x.[3]

To illustrate more clearly, let F and G represent the cumulative distribution functions of two alternative farm production plans. Net income is measured along the horizontal axis and the cumulative probability is measured along the vertical axis over the range 0 to 1.0.

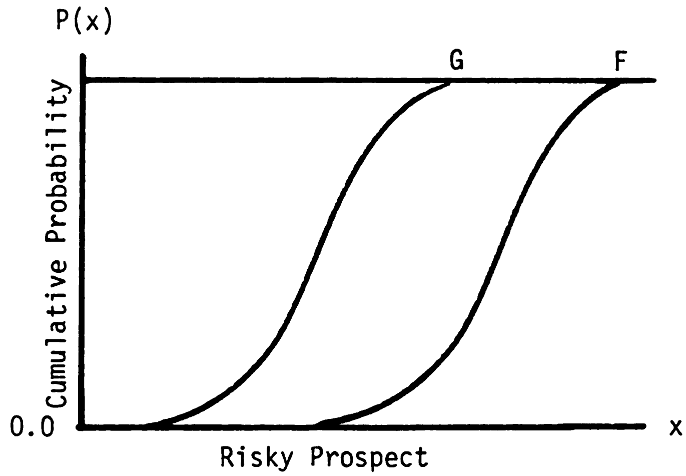

Figure 3.2 First Degree Stochastic Dominance Illustrated.

In this case, at every probability level over the entire range, the income of F exceeds that of G. It can then be said that F is first degree stochastic dominant over G. All decision makers who prefer more income to less will select F over G. This statement can be made regardless of the distributional shape of F or G. Stochastic efficiency concepts have been shown to exhibit the property of transitivity, i.e., if F dominates G and G dominates H, then F dominates H.

The converse of first degree stochastic dominance has also been established (Quirk and Saposnik, 1962). If the distribution of outcomes of a risky prospect is stochastically dominated by the distribution of outcomes of another risky prospect, then the first distribution is said to be stochastically inefficient and would never be preferred by a Bernoullian utility maximizing decision maker.

Usually, the set of first degree stochastic efficient alternatives is not unique. Second degree stochastic efficiency, SSE, provides a basis for further selection from the first degree efficient set. The rules for identifying second degree stochastic dominance, SSD, were established by Hadar and Russell (1969) and require the additional behavioral assumption that the decision maker is risk adverse. In terms of admissible utility functions, the assumption is that over the range of possible payoffs the utility function is monotomically increasing and concave, i.e., $U'(x) > 0$ and $U''(x) < 0$.

To illustrate, return to the example of two alternative production plans presented above. If the distribution of outcomes are as represented in Figure 3.3 instead of Figure 3.2, it is no longer clear that F is the preferred choice, since between points x and y, the distribution of F is to the right of G. With the additional behavioral assumption that decision makers are risk averse, a clear ordering of the alterantives F and G can be obtained, if it can be shown that F lies more to the right of G in terms of differences in the area between the two cumulative distribution functions. Referring to Figure 3.3, the area where F lies to the right of G, which is A plus C, is greater than the area where G is to the right of F, area B. This relationship can be determined most clearly by defining a cumulative function that measures the area under a cumulative distribution over the range of the uncertain quantity. Such a relationship is illustrated in Figure 3.4.

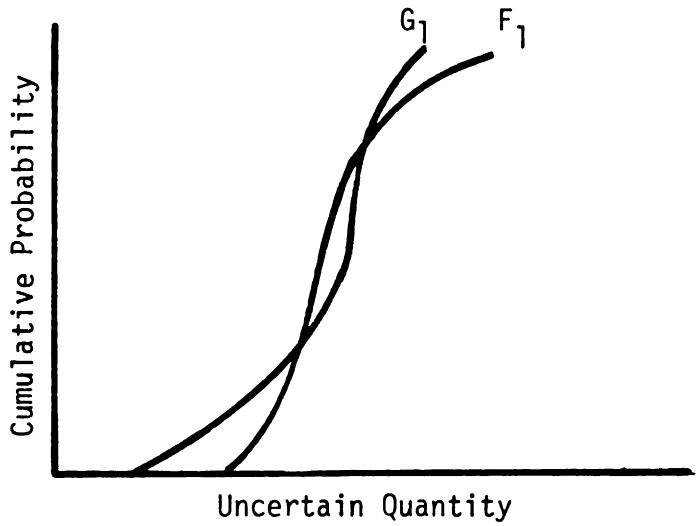

Figure 3.3 First Degree Stochastic Dominance Violated.

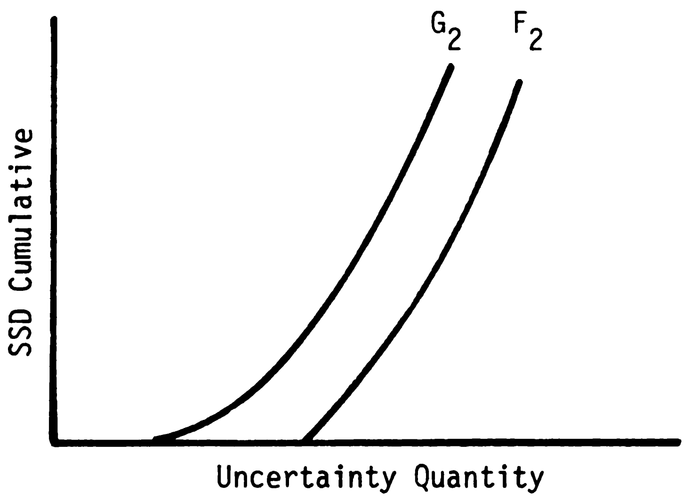

Figure 3.4 Second Degree Stochastic Dominance Functions.

In terms of cumulative distribution functions, CDF's, the distribution F dominates G by second degree stochastic dominance if the total area under F is less than the total area under G. The SSD-cumulative for F may be defined as,

$$F_2(x) = \int_a^R F(x)dx.$$

Then distribution F can be said to dominate G in the sense of SSD if

$$F_2(x) \leq G_2(x)$$

with at least one strong inequality holding.[4] Analogous to FSD the property of transivity holds and similar theorems may be proven for discrete distributions.

Dominated distributions in the sense of SSD are stochastically inefficient and would never be preferred by risk averse utility maximizing decision makers. The undominated distributions constitute the second degree stochastic efficient set, SSE. Further identification of choice within this set would require more explicit knowledge about decision maker preferences than simple risk averse behavior.

Whitmore (1970) introduced the concept of third degree stochastic dominance, TSD. This concept is based on the behavioral assumption that as people become wealthier they become decreasingly averse to risk. TSD implies a decision maker utility function where $U'''(x) > 0$. Analytically the TSD ordering rule follows from SSD rule. The third degree stochastic dominance function is defined as,

$$F_3(x) = \int_a^R F_2(x)dx.$$

According to the theorem, F dominates G in the sense of TSD if $F_3(x) \leq G_3(x)$ for all x with at least one strong inequality.[3] As in the case of SSD, the TSD leaves a third degree efficient set which cannot be larger than the SSD set. The principle of transitivity can also be shown to apply to TSD as it does to SSD and FSD.

The approach to evaluation adopted here will be to employ stochastic dominance criteria to identify first, second, and third degree stochastic efficient sets. The advantages of this approach over other methods are: (1) it is no longer necessary to make any prior assumptions as to the shape of the probability density functions describing yields, prices, or gross incomes. This is particularly important in light of evidence suggesting some degree of non-normality of some of the stochastic terms in the model. (2) It is possible using stochastic dominance criteria to select an efficient set without prior knowledge of a particular decision maker's utility function. In other words, the second degree stochastic efficient set is efficient for all risk averse decision makers regardless of the shape of or the algebraic expression of their individual utility functions.

The major drawback of this approach is that the risk efficient set selected under each of the dominance criteria may contain more than one possible alternative. In light of research objectives, this limitation may not be particularly burdensome since it is desired to select those cropping systems that are economically viable and examine their agronomic characteristics.

Footnotes--Chapter III

[1]Heady's approach has been standard practice in diversification studies. This may be illustrated by referring to a simple case of two alternatives. When two enterprises, A and B, with income variances σ_A^2 and σ_B^2 are combined, the variance for the total operation is:

$$\sigma_T^2 = \sigma_A^2 + \sigma_B^2 + 2_p\sigma_A\sigma_B.$$

If resources are constrained, say 500 acres is available and the decision is to determine the proportion of acreage allocated to A and the proportion to B, the equation of total variance becomes:

$$\sigma_T^2 = q^2\sigma_A^2 + (1-q)^2\sigma_B^2 + 2p\ q(1-q)\sigma_A\sigma_B.$$

Total variance is now a function of "q," the proportion of acreage allocated to enterprise A. Taking the derivative of the above expression results in:

$$\frac{d\sigma_T^2}{dq} = 2q\sigma_A^2 - 2(1-q)\sigma_B^2 + 2p(1-2q)\sigma_A\sigma_B.$$

Setting the derivative to zero and solving for q, one can determine the variance minimizing proportions to allocate between two enterprises. The approach employed by Heady was to increment q from 0 to 1 and trace out the production possibility in EV space.

[2]The standard linear programming problem

$$\max S'x$$
$$\text{subject to } TX \leq v$$
$$\text{and } x_i \geq 0$$

where S is a column vector of net revenues of unit levels of production. X represents a vector of the number of units of S to be included in the optimum set. T is a matrix of the coefficients of the amount of scarce resources necessary to produce one unit of X. V represents the limits of available scarce resources.

The quadratic risk approach implies a change in the objective function. Instead of maximizing profit, one maximizes profit subject to a level of variance. The utility function U(r), where r is the selected course of action, is assumed to be $U(r) = 1-e^{-ar}$; this function has $U^1(r) > 0$ and $U^{11}(r) < 0$. The objective then becomes to maximize expected distributed random variable.

$$E(u) = \int_{-00}^{00} (1-e^{-ar})\ e^{-(r-\mu)/2\sigma^2}\ dr.$$

Expected utility is maximized if the function

$$E(u) = S'X - a/2\ X^1\ (COV)X$$

is maximized. The problem in a quadratic risk context becomes:

$$\max\ S'X - a/2\ X^1(COV)X$$
$$\text{subject to } TX \le V$$
$$\text{and } X \ge 0.$$

[3]The proof of this proposition is presented by Hadar and Russell (1969) and Anderson (1974). It is required to prove if $F(X) \le G(X)$ or $G(X) - F(X) \ge 0$. Then $\bar{U}_f \ge \bar{U}_g$. Expected utility is defined as:

$$u = \int_a^b U(X)\ f(X)\ dx.$$

Thus,

$$\bar{U}_f - U_g = \int_a^b U(X)\ f(X)\ dx - \int_a^b U(X)\ g(X)\ dx.$$

The derivative of a cumulative density function is its probability density function.

$$\bar{U}_f - \bar{U}_g = \int_a^b U(X)[dF(X)]\ dx - \int_a^b U(X)[dG(X)]\ dx$$
$$= \int_a^b U(X)[dF(X) - dG(X)]\ dx.$$

Integrating by parts yields,

$$\bar{U}_f - \bar{U}_g + [U(X)\ [F(X) - G(X)]]_a^b - \int_a^b [F(X) - G(X)]\ U^1(X)\ dx.$$

Since the CDf is defined on the range (0,1) $a = 0$, $b = 1$. The first term equals zero.

$$\bar{U}_f - \bar{U}_g = - \int_a^b U'(X)\ [G(X) - F(X)]\ dx$$

or

$$\bar{U}_f - \bar{U}_g = \int_a^b U'(X)\ [G(X) - F(X)]\ dx.$$

Since U (X) 0 by assumption and G(X) - F(X) 0 by proposition the integral over a, b is also greater than zero, hence $\overline{U}_f - \overline{U}_g > 0$ or $\overline{U}_f > \overline{U}_g$. A similar result has also been established for discrete distributions.

[4]The proof for second degree stochastic dominance follows straightforwardly from the proof for first degree stochastic dominance.

$$\int_a^b U'(X)\ [G(X) - F(X)]\ dx.$$

The residual term from the integration in the first proof was declared to be non-negative as proof of FSD. Under second degree stochastic dominance, this assertion no longer holds. From the text $F_2(X)$ was defined as

$$\int_a^R F(X)\ dx$$

consequently $d[F_2(X)]/dx = f(X)$, so that

$$\int_a^b U'(X)\ [F(X) - G(X)]\ dx = \int_a^b U'(X)\ [d(F_2(X) - G_2(X))]\ dx.$$

Again, integrating by parts

$$U'(X)\ [F_2(X) - G_2(X)] - \int_a^b [F_2(X) - G_2(X)]\ U''(X)\ dx.$$

This expanded expression can be substituted in the original expression in footnote 3.

$$\overline{U}_f - \overline{U}_g = -[U\ (X)\ [F_2(X) - G_2(X)]]_a^b + \int_a^b U''(X)\ [F_2(X) - G_2(X)]\ dx \geq 0.$$

Since $F_2(a) = G_2(a) = 0$ and $F_2(b) = G_2(b) = 1$, the first expression is zero. Since $U''(X) < 0$ by assumption and $F_2(X) - G_2(X) \leq 0$ by proposition $\overline{U}_f - \overline{U}_g \geq 0$.

[5]The proof for third degree stochastic dominance proceeds from as for second degree stochastic dominance. From the first term

$$[-U'(X)\ [F_2(X) - G_2(X)]_a^b.$$

Evaluated at $F(a) = G(a) = 0$ and b

$$-U'(X)\ [F_2(b) - G_2(b)] + 0.$$

Since U, (b) > 0 by assumption and $[F_2(b) - G_2(b) \leq 0$ by assumption, the expression is non-negative. Recalling $d[F_3(X)]/d(X) = F_2(X)$, then

$$\int_a^b U''(X)\ [F_2(X) - G_2(X)]\ dx$$

$$= \int_a^b U''(X)\ \{d[F_3(X) - G_3(X)]/dx\}\ dx.$$

Integrating by parts

$$= [U''(X)\ [F_3(X) - G_3(X)]]_a^b - \int_a^b U'''(X)\ [F_3(X) - G_3(X)]\ dx.$$

Since $U''(X) < 0$, $[F_3(b) - G_3(b)] \leq 0$, $U'''(X) > 0$ and $[F_3(X) - G_3(X)] \leq 0$ implies $\overline{U}_f - \overline{U}_g \geq 0$.

CHAPTER IV

INPUT/OUTPUT RELATIONSHIPS, EXPECTED PRICES, AND FIELD WORK TIME CONSTRAINTS

Introduction and Chapter Objectives

Budgets are developed for the sixteen crop rotations described in Chapter II and the rotations are ranked according to their net return to land. Comparisons are made first on the basis of expected values of prices and yields. Final comparisons are made according to the stochastic dominance criteria outlined in the previous chapter. The ranking criteria is: Gross Income - Costs = Return to Land. The objectives of this chapter are:

1. Define the concept of "return to land";
2. Define the accounting procedures used to derive costs associated with each rotation; and
3. Describe the procedure employed to obtain estimates of expected commodity prices, input prices, machinery, labor, and fuel requirements.

The Design Perspective

Previously, it was stated that this analysis is conducted from the system "design" perspective. This method is often employed in developing economic models; that is, in order to understand the relationship among the variables under study, it is necessary to make many simplifying assumptions and consequently work with relatively simple models. Consequently, the approach used and the results obtained, abstracted from a particular farm setting, may appear to ignore some important variables. The aim here is to construct an economic model whose purpose is an understanding, at a conceptual level, of the interaction of a set of agronomic, physical, and economic variables.

The product of this approach is an abstract model which provides a degree of understanding of real world behavior and the interdependence of system structure, inputs, and performance. This is distinguished from the management or control function in which, given a model structure and a set of desired system outputs, a set of system inputs which achieve the desired objective can be determined.

The Enterprise Budgeting Approach

Farm production economics studies are often conducted using linear programming or a variant as a solution algorithm. However, there are several reasons why a mathematical programming approach is not appropriate for the problem at hand. There are sixteen cropping systems in which machinery complements, fertilizer, and chemical application rates are deterministic and unique, both to the particular cropping system and the assumed size of the farm; the additivity assumption is not met. For example, the budget presented for rotation #8, C-NB-NB-B, on a 400 acre operation is unique. A shift to less than 400 acres of this system modifies the a_{ij} in the activity matrix as the machinery complement would need to be re-specified. A further difficulty is encountered in specifying the objective function. In previous studies, the objective function was specified in terms of the unit contribution to income of a particular cropping enterprise such as corn or soybeans. As production of one crop was increased, that of the other must decrease. In the case under study, each of the systems represents a multi-crop farm plan where the complementarities of one crop to the output of another are expressly accounted for, e.g., the expected yield of corn following alfalfa is 118 bu./A whereas corn following Navy beans is 110 bu./A. The variable cost budgets, based on net nutrient removal are varied to expressly account for changes in expected yields and items such as nitrogen carryover from alfalfa to other crops. This implies that linear combinations of cropping systems, i.e., an optimal solution comprised of 0.8 C-NB and 0.2 C-SB-W-B would make no sense in a systems context; thus, an optimal solution would have to be an integer solution. The approach of considering each of the seven individual crops as "activities" in a programming sense is impossible as the production coefficients (the a_{ij} in an LP sense) are not mutually exclusive and additive; only the rotations themselves are mutually exclusive.

The problems encountered in a linear programming framework can be overcome by developing enterprise budgets for each of the sixteen crop rotations. Rotations are ranked according to net returns to land which is defined as: Gross income less (1) cash costs which include seed, fertilizer, chemical costs, and interest on working capital; (2) machinery costs which include depreciation, maintenance, housing, fuel costs, and interest on investment; (3) handling and drying costs; and (4) family labor, then equals net return to land.

Net return to land represents the residual return not allocated to production period inputs necessary to produce period revenues. Income and property taxes are excluded since the primary focus is upon design, not system management and debt service capacity. The objective of this accounting procedure is to match period revenues with period expenses in a flow sense and compare rotations on the basis of the size of the residual.

Variable Cash Costs

Cash costs in the model include charges for seed, fertilizer, chemicals, and a finance charge on borrowed working capital. Fuel, while cash cost, is included in machinery costs. Cash costs were calculated for each crop in each rotation. Fertilizer application rates (Table 4.1) are based on the net removal of soil nutrients by the crop; they represent the soil maintenance level recommendation. The fertilizer application rates assumed are presented in Table 4.1.

Herbicides and pesticide use varies from farm to farm depending on the particular disease and pest problems encountered. The herbicide and pesticide programs here are representative of those commonly employed in the Saginaw Valley area when no unusual disease or pest problems are encountered. The herbicide and pesticide regimens are presented in Table 4.2, in pounds per acre of active ingredient.

In an environment where strict rotational patterns are being adhered to, some crops can benefit from nutrients provided by previous crops in the rotation. These complementarities among crops are accounted for in the cash budgets and account for most of the variation

Table 4.1 Fertilizer Application Rates[a]

Crop	Nitrogen (N)	Phosphate (P_2O_5)	Potassium (K_2O)
Corn (grain)	1.13 lb/bu	0.35 lb/bu	0.27 lb/bu
Navy beans	3.13 lb/cwt	0.83 lb/cwt	0.83 lb/cwt
Soybeans	0	0.90 lb/bu	1.40 lb/bu
Sugarbeets	5.0 lb/ton	1.30 lb/ton	3.30 lb/ton
Oats	0.78 lb/bu	0.25 lb/bu	0.19 lb/bu
Oats (straw removed)	1.09 lb/bu	0.44 lb/bu	1.19 lb/bu
Alfalfa	0	10.00 lb/ton	45.00 lb/ton
Wheat	1.30 lb/bu	0.62 lb/bu	0.38 lb/bu

[a]Adapted from M. L. Vitosh and D. O. Warnke (1979). Nitrogen fertilizer rates are increased 25% over recommendation to compensate for leaching.

in recommended fertilizer application rates. The remainder of the variation is accounted for by variations in expected yields. Table 4.3 summarizes the guidelines used in evaluating the nitrogen contribution of alfalfa and soybeans to subsequent crops. For example, if 115 bushel per acre corn follows soybeans, 130 pounds of nitrogen per acre is the recommended nitrogen application rate (1.13 pounds of nitrogen is required per bushel of corn). Soybeans contribute 30 pounds of nitrogen per acre; therefore, the application rate recommended for corn following soybeans is 100 pounds per acre.

Table 4.2 Herbicide and Pesticide Application Rates[a]

Crop	Chemical	Application Rate lb/Aai	Comments
Corn	Atrazine	0.50	
	Sutan	0.50	
	Lasso	2.00	
	Bladex	1.00	On corn preceding another crop
	Furadan	0.75	On corn following corn
Soybeans	Lasso	2.00	
	Lorox	0.75	
Navy beans	Eptam	2.25	
	Amiben	2.00	
	Treflan	0.50	
Sugarbeets	Pyramin	3.00	
	TCA	6.00	
Oats	MCPA	0.19	Companion seeded with alfalfa half cost allocated to seeded alfalfa
Oats	MCPA	0.38	No companion seeding
Alfalfa	MCPA	0.19	Seeding year only, ½ cost allocated to oats companion crop
Wheat	2-4D	0.50	

[a]The chemical application rates and the weeds against which they are effective are from Schultz and Meggitt, 1978.

Table 4.3 Guidelines Used in Evaluating Nitrogen Contribution to Previous Crops to Subsequent Crops[a]

Crop	Contribution lb/A of N
Soybeans	30
Alfalfa	70

[a]The rates of nitrogen contribution are adapted from Warnke, Christensen and Lucas (1976). The values used were modified by Dr. Zane Helsel, Crops and Soils, Michigan State University.

Prices for seed and fertilizer are presented in Table 4.4. Use of herbicides and pesticides are given in pounds per acre of active ingredient. Prices for chemicals are an average of a sample of retail prices obtained by telephone survey of retail dealers in central Michigan. Prices were converted to values per pound of active ingredient using the known concentration of active chemical in various commercial preparations. Prices of herbicides used in this study are presented in Table 4.5

Machinery Costs

Per acre machinery charges and fuel consumption were derived for each rotation using a machinery simulation model developed in the Department of Agricultural Engineering (Wolak, 1980). The machinery complement selected for each of the sixteen cropping systems was unique. A "clean state" was assumed; that is, no current inventory of equipment was assumed to exist and the equipment complement was selected that

Table 4.4 Prices for Seed and Fertilizer

Item	Price per pound
Seed:	
Corn	1.00
Navy bean	0.30
Soybeans	0.28
Sugarbeets	5.00
Oats	0.13
Alfalfa	2.40
Wheat	0.14
Fertilizer:	
Nitrogen (Urea)	0.24
Nitrogen (Anhydrous NH_3)	0.14
Phosphorous (P_2O_5)	0.20
Potassium (K_2O)	0.11

Table 4.5 Prices of Herbicides and Pesticides[a]

Chemical	Price per pound
Atrazine	2.27
Sutan	2.27
Lasso	3.85
Lorox	3.34
Eptan	2.67
Amiben	6.02
Treflan	7.01
MCPA	0.68
2-4D	2.44
Pyramin	13.50
TCA	1.45
Furadan	7.48
Bladex	3.34

[a]The cash cost for each crop in each of the sixteen cropping systems is presented in Appendix B. These values were obtained from a survey conducted by Dr. Gerald Schwab, Agricultural Economics, Michigan State University, in the spring of 1980.

would efficiently accomplish the field operations for each rotation subject to the time and labor available.

The yield estimates presented in Table 2.5 are based upon timely field operations. Starting and ending dates for various field operations are incorporated into the machinery model as constraints (Table 4.6). These dates were reviewed and revised by growers and extension agents and, as a result, represent a consensus of opinion on the part of growers, extension agents, agronomists, and agricultural engineers as to appropriate timing of field operations in mid-Michigan.

Weather variability, labor supply, and workday length also affect the availability of time and required machinery productivity. An earlier edition of the machinery model assumed labor was readily available at a fixed wage rate. As a consequence, machinery complements selected by the model tended to be smaller than those observed on Saginaw Valley cash crop farms and hired labor input was substantial. This outcome was not in accordance with observed practices in the area. Informed opinion is that skilled farm labor is scarce, particularly at certain times of the year, e.g., at harvest. Farmers, therefore, tend to opt for larger machinery complements and minimize hired labor input. This approach may not be the least expensive but it would reduce the uncertainty of field operation scheduling.

In lieu of a labor market "model," and in light of the evidence set forth above, the machinery model was constrained as to labor input to "family" labor. The maximum labor input available on a 400 acre

Table 4.6 Timing of Field Operations

Operation	Crop: Corn	Navy Beans	Soybeans	Sugarbeets	Wheat	Alfalfa	Oats	Oats/ Alfalfa
Harvest	1009/1113	828/1002	925/1023	925/1113	717/807	710/724 821/904 522/612	724/814	724/814
Fertilizer	A/1127[a]	w/plant	w/plant	A/1127	A/1016 320/424	522/612	A/1127	A/1127
Fall disk[b]	1109/1127	1009/1127	1009/1127	1009/1127	A/1016	--	1009/1127	1009/1127
Plow	A/515	A/619	A/605	A/1127	--	00	A/1127	A/1127
Spring disk	--	410/619 515/619	410/605	410/515	--	--	410/588	410/508
Field cult.	424/515	522/619	515/605	410/515	925/1016	--	410/508	410/508
Plant	424/515	522/619	515/605	410/515	925/1016	--	410/508	410/508
Spray	424/515	515/619	515/605	--	501/508	--	--	--
Cultivate	529/619	619/710	612/703	522/619 612/703	--	--	--	--
NH_3	529/619	--	--	605/626	--	--	--	--
Bale straw	--	--	--	--	--	--	--	724/821

[a]A beginning date (A) equals previous crop's harvest date (911 for alfalfa).

[b]Fall disking only if preceding crop is corn, except for wheat which is always disked.

[c]These entries should be read as follows: 1009/1113--tenth month, ninth day (October 9th) to eleventh month thirteenth day (November 13th).

farm was one full time operator able to work up to 12 hours per day six days per week. Additional family labor is assumed to be available from a spouse or adolescent children during peak periods of labor demand. On a 600 acre operation, two full time labor operators were assumed.

The other major variable which affects field operations is weather availability. Weather variability is used to define sequences of daily work/no work sequences for various field operations. Much of this work is based on a workday simulation developed by Tulu (1973). Inputs to this model includes five weather descriptions and two soil parameters. The weather data are: (1) maximum daily temperature; (2) minimum daily temperature; (3) daily precipitation; (4) daily open pan evaporation; and (5) a binary snow condition (snow/no snow). The soil parameters are water holding capacity and soil moisture level criteria. Tulu's model develops a soil moisture "budget" which accounts for the level of moisture in the soil. If on any day the moisture budget indicates a moisture level below a specified critical level, a workday has occurred. Spring planting is also constrained by a minimum soil temperature of 50°F. Tulu's model continues to define work/no work days subject to the above criteria until the soil freezes in the fall.

Tulu's workday simulator is employed to generate sets of work/no work day data for 28 years of Saginaw Valley weather data. The machinery model then develops a complement that accomplishes the designated field operations given the workday sets for each of the

28 years of available data. In years in which weather is more adverse, larger sets of machinery are required than in those years of more favorable weather. The machinery sets are then ranked in descending order of cost. The 28 machinery sets are used to establish the percentiles of the design criteria cumulative distribution function. For example, a machinery complement ranked 14th out of 28 in cost (the 50th percentile) would be able to accomplish the designated field operations required for a given cropping system on average, half the time. In this study, a design criteria of 80% was adopted. This means that the machinery complements selected for the enterprise budgets developed here would, given that historical weather data is an accurate predictor of future weather patterns, accomplish the prescribed field operations within the established timeliness constraints in eight out of ten years.

An average annual cost per acre is computed for each machinery set. Depreciation, interest, repairs, insurance, shelter, and fuel cost are considered. Machinery costs are based on 1979 dealer list prices. Machinery is assumed to have an eight year useful life with a salvage value of 10% of original purchase price. Depreciation is calculated by the straight line method. Repairs are calculated on an annual use basis. Insurance and shelter costs are figured as a fixed percentage of original purchase price. Interest on the investment is computed at 13% on one-half the purchase price. Standard engineering calculations with respect to machinery size, load, and speed conditions were employed to calculate fuel consumption per acre for each rotation.

Diesel fuel is priced at $1.00 per gallon and presented separately in the budgets.

The machinery costs, in dollars per acre, and fuel consumption figures in gallons of diesel per acre for each rotation for the 400 acre and 600 acre configurations are given in Table 4.7. The design criteria employed is 80% except where noted.

Hauling and Drying Costs

Since the machinery simulation model makes no computations for hauling and drying costs, these figures were derived on a less formal procedure based on standard enterprise budget costs.

Corn was assumed to be harvested at 28% moisture and dried to 14% moisture for storage at a cost of $0.02 per point of moisture per bushel. Table 4.8 depicts the unit costs for hauling for each crop.

Labor

The budgets are constructed under the assumption that only family labor is employed. Family living expenses were estimated at about $14,000 per year which is approximately equivalent to median household income in Michigan once allowance is made for differences in income tax treatment of family farms. That results in $35.00 per acre and $23.33 per acre labor charges on 400 and 600 acre farms, respectively. The purpose here is to rank rotations within size configurations and no comparisons are made between the two size configurations.

Table 4.7 Machinery Cost and Fuel Consumption per Acre[a]

	Rotation	400 Acres Machinery Cost ($)	400 Acres Fuel (gal)	600 Acres Machinery Cost ($)	600 Acres Fuel (gal)
1	C-NB	68.71	8.63	66.95	8.78
2	C-SB	74.57	7.94	75.12	8.07
3	C-C-SB	83.84	8.15	84.64[a]	8.26
4	C-NB-B	82.83	9.44	76.32	9.98
5	C-SB-B	99.15	9.44	97.62	9.71
6	C-NB-W-B	82.56	8.22	80.45	8.88
7	C-SB-W-B	132.62	8.03	99.84[a]	8.25
8	C-NB-NB-B	79.40	9.26	68.05	9.49
9	O/A-A-A-A-C-C-SB-C	91.68	8.29	81.87	8.47
10	O/A-A-A-A-A-C-C-C	97.50	8.62	102.00	7.24
11	C-C-NB-W	77.36	7.46	79.12	7.63
12	NB-C-SB	65.41	8.20	58.38	8.20
13	C-C-NB-B	100.08	9.37	96.09	9.59
14	O/A-A-NB-B	117.51	10.09	98.24	9.77
15	O-NB-B	122.91	10.09	105.14	9.38
16	O/A-A-A-A-C-C-NB-C	96.69	8.51	85.27	8.69

[a]For rotations 10, 14, and 15, the fuel consumption per acre is higher on a 400 acre farm than on a 600 acre farm. This is due to the size of the machinery selected by the machinery model. Machinery size is selected with sufficient capacity to accomplish the most constraining field task. This implies that the machinery is relatively inefficiently used for other field operations. Fuel efficiency varies by type of fuel and by percent load.

Table 4.8 Estimated Unit Hauling Costs for Each Crop

Crop	Unit Cost
Navy beans	0.12/cwt
Sugarbeets	2.75/ton
Alfalfa	4.50/ton
Small grains (corn, soybeans, wheat, and oats)	0.07/bu

Source: Nott et al., 1979.

The philosophy of pricing family labor adopted is to treat it as a fixed cost rather than valuing it on an opportunity cost basis. An advantage of this approach is that it is not necessary to estimate what is the actual opportunity cost of labor. A major drawback is that a given rotation with a high net return to land, relative to another rotation, may require more hours of labor than the less profitable rotation. The disutility of the additional work is not expressly accounted for.

Estimating Relative Prices

In modeling the prices received component, the purpose is distinctly different from that of short range forecasting. The purpose in designing a design model is to determine long term price relationships in the market.

Neoclassical economic theory (Henderson and Quandt, 1971) describes the conditions for a long-run multi-market equilibrium in a perfectly competitive industry. A firm is considered to be operating in a perfectly competitive environment if:

1. The price of each good is defined and is exogeneous to the firm and therefore independent of firm production decisions.
2. At the market price, a firm may acquire any quantity of an input it requires or dispose of any quantity of a good it has produced without impacting the market place.

In a competitive environment, if general equilibrium exists, it is defined in terms of relative prices (see Appendix B). The issue then is whether the Neoclassical general equilibrium model approximates an adequate description of the economics of cash crop markets in the Saginaw Valley.

The assumption that producers are generally price takers is probably satisfied in the context under study. However, this economic model also implicitly assumes the following.

1. Perfect knowledge of prices and quantities, both present and future, on the part of all buyers and sellers.
2. The system is closed. The possibility of introducing exogeneous demand on production from outside the system does not exist.
3. Production functions and utility functions are static over time.

This implies static technology and constant consumer preferences. All of the above assumptions must be relaxed to obtain an adequate description of Saginaw Valley agriculture.

The production of agricultural commodities is the result of a biological process. Production of cash crops requires that the decision as to the quantity to produce must be made at one point, and the harvest is completed at a later time. Producers make decisions as to what and how much to produce based on expectations about market conditions which may or may not be fulfilled. Knowledge about future quantities and prices is incomplete.

With regard to the second assumption, there are many reasons that the "Saginaw Valley" cannot be regarded as a "closed system." First, the production process itself is subject to the vagarities of weather, disease, and pestilence. Also, there are numerous goods in the market place and inputs used in production that are assumed to be exogeneous simply to keep any resulting model of manageable size.

The fundamental assumption made here is that although the above assumptions necessary for a purely deterministic general equilibrium model do not exist, there may be an underlying long-term equilibrium ratio of relative prices. A great deal of the short-term variation in prices follows no distinct pattern and is thus transitory in nature. Such random variation is a source of price risk to farmers and may be described within the modeling context by an estimated value for variance of a probability distribution.

Some changes cannot be regarded as transitory from period to period. Development and adoption of new technology represents a change that is defined over time and once accomplished represents a permanent change. The non-transitory but gradual changes over time represent trend.

The implications of trend may be illustrated as follows. In a two product, one input world, PPF_1 represents the production possibility frontier. I_1 represents consumers' indifference curve between the two goods. General equilibrium theory suggests that utility maximizing consumers and profit maximizing producers obtain a unique equilibrium in which the rate of exchange between goods determines relative prices.

Technical change, which may alter not only the locus but the shape of the production possibility frontier, will alter the relative price ratio at which goods exchange in the market. In Figure 4.1, this is illustrated by the shift from PPF_1 to PPF_2 and the corresponding change in the price line (and slope of the price line) from P_1 to P_2. A similar price occurs if changing consumer preference patterns alter the shape of consumer indifference curves, consequently altering the relative prices at which goods exchange.

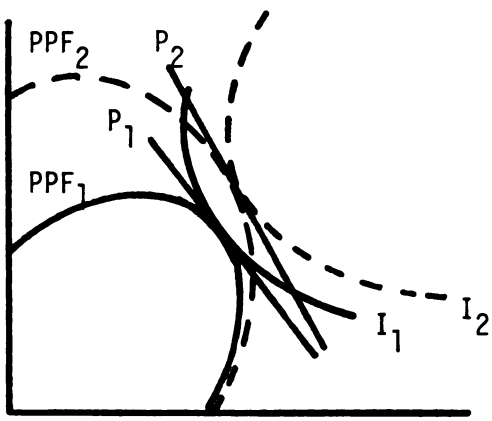

Figure 4.1 Changes in Relative Prices, Illustrated.

As stated at the outset, the purpose here is to identify the longer term trends in the relative price relationship while filtering out transient disequilibra. In order to derive relative price ratios, the price of one commodity must be selected as numeraire. The numeraire should have the following characteristics: the Saginaw Vally should comprise a small portion of overall market production. The "market price" should be based on a relatively large volume as distinguished from "thin" markets for specialty crops. The crop selected as numeraire is corn.

Prices received by Michigan farmers were obtained for the seven crops in the study for the years 1950 through 1978. Price ratios for the six crops relative to the price of corn were calculated for each of the 28 years of data, prices are from Michigan Agricultural Statistics, various years. The gradual, non-transitory change in relative prices such as represented by a change in the price line in Figure 4.1 is the basis of trend. This must be removed to obtain a more accurate estimate of the transitory change. To remove trend from the numbers, a least squares regression was estimated with time as the independent variable. The estimated equations are presented below:

1. $$\frac{\text{Navy bean price}}{\text{Corn price}} = \underset{(-1.33)}{-2.64} + \underset{(4.74)}{0.146}\ \text{time} \qquad R^2 = 0.46$$

2. $$\frac{\text{Soybean price}}{\text{Corn price}} = \underset{(-0.91)}{-0.35} + \underset{(6.53)}{0.0395}\ \text{time} \qquad R^2 = 0.62$$

3. $$\frac{\text{Sugarbeet price}}{\text{Corn price}} = \underset{(0.726)}{1.99} + \underset{(3.02)}{0.129}\ \text{time} \qquad R^2 = 0.26$$

4. $\frac{\text{Oat price}}{\text{Corn price}} = \underset{(2.45)}{0.240} + \underset{(3.48)}{0.0053}\ \text{time}$ R = 0.32

*5. $\frac{\text{Alfalfa price}}{\text{Corn price}} = \underset{(0.277)}{2.36} + \underset{(1.93)}{0.253}\ \text{time}$ R = 0.33 p = 0.390

*6. $\frac{\text{Wheat price}}{\text{Corn price}} = \underset{(3.32)}{2.75} + \underset{(-1.65)}{0.020}\ \text{time}$ R = 0.57 p = 0.677

These equations preceded by an asterisk exhibited auto correlation and and were re-estimated using the Cochrane-Orcutt technique. Examination of the residuals offers no evidence of a non-linear relationship to time.

Forecasting with a simple linear regression equation can give spurious results particularly when forecasting substantially beyond the range of the original data set. This approach, despite its shortcomings, was employed here. The expected price employed in the analysis are presented in Table 4.9

Table 4.9 Expected Cash Prices

Crop	Price
Corn	$ 2.50/bu
Navy beans	22.60/cwt
Soybeans	6.53/bu
Sugarbeets	30.94/ton
Oats	1.44/bu
Alfalfa	60.73/ton
Wheat	3.30/bu

At this point all expected value elements of the model have been defined. It is now possible to rank the sixteen cropping systems according to net returns to land, and such results are presented in Chapter VI.

CHAPTER V

METHODOLOGY: SIMULATION OF CUMULATIVE DENSITY FUNCTIONS OF NET RETURN TO LAND

Introduction

The data and methodology necessary to rank the cropping systems in an expected value sense were set forth in Chapter IV. One of the primary objectives of this research is to evaluate the economic performance of alternative crop rotations in a risky environment. The objective of this chapter is to present the necessary methodology for evaluating the riskiness associated with each of the sixteen crop rotations. Included are:

1. modeling risk using stochastic dominance;
2. an explanation of the "tools" used and the data required; and
3. the method used to obtain the data used in the model.

Methodological Approach

The basic form of the model outline used was presented in the last chapter as follows: Gross Income - Costs = Return to Land. A net return to land is developed for each rotation, not for each crop, due to the "complementarities" among crops. This was illustrated in the last chapter with development of the budgets for each crop in each rotation and the machinery simulation model used to develop machinery costs for each crop rotation. Costs are not deterministic since prices and application levels for inputs are not known with certainty before planting; but their variability is of a much lower order of magnitude than variability of gross income. In this analysis, costs are to be regarded as deterministic while gross income is a random variable.

The approach adopted is to define the probability distributions of the components of gross income and then simulate 100 "draws" representing 100 alternative states of nature. Upon arranging the net returns to land (NRTL) in ascending order of size, the i^{th} observation can be taken as a reasonable estimate of the $i^{th}/(100+1)$ fractile. This approximation works irrespective of the form of the underlying probability distribution (Anderson, 1974).

Gross income is defined as: The yield of crop i per acre times the price of crop i per unit, times the number of acres planted to crop i. Acreage alloted to each crop in the rotation is equiproportional. For example, on a 600 acre farm planted to a corn-Navy bean-Navy bean-sugarbeet rotation (C-NB-NB-B), there would be 150 acres in corn following sugarbeets, 150 acres in Navy beans following corn, 150 acres in Navy beans after Navy beans, and 150 acres of sugarbeets after Navy beans.

Costs are presented on a per acre basis; gross income and net returns to land are on a per acre basis. Gross income is:

$$\frac{1}{N} \sum_{i=1}^{N} (\text{yield/acre})_i \times (\text{price/unit})_i \qquad i = 1 \text{ to } N \text{ number of crops.}$$

The variability of yields and prices give gross income its stochastic nature. Therefore, for any rotation, the probability density function for gross income is determined by the probability density functions for price and yield. The determination of a distribution involving several random variables is considerably more difficult than assessment of a distribution of a single random variable. However, there is a plausible simplifying assumption that makes the simulation of the gross income distribution tractable.

The assumption is made that each farm is a price taker; each operator may vary output as much as he wishes and have no impact on market price. This assumption assures the statistical independence of the price and yield variables and insures that their relationship is multiplicative; there is then no need to attempt to define conditional probabilities. Thus, gross revenue for the i^{th} crop is E(P) x E(Y), where E is the expectation operator.

The relationship between income distributions for each crop within a rotation is additive. It can be shown that for X_i random variables that

$$E(X_1 + X_2 + \ldots + X_i) = E(X_1) + E(X_2) + \ldots + E(X_i).$$

For the present case,

$$E\text{ (gross income)} = \sum_{i=1}^{n} E\text{ (income for crop i)} \quad i = 1, \ldots, n \text{ crops in a rotation.}$$

For cropping systems as they are defined for this study,

$$E(\text{gross income}) = \frac{1}{N} E(P_1 \times Y_1) + \frac{1}{N} E(P_2 \times Y_2) + \ldots + \frac{1}{N} E(P_n \times Y_n)$$

where

N = the number of crops in the rotation;

P_n = price of crop n; and

Y_n = yield of crop n.

The next step is to determine the parameters of the probability density functions. Expected yields of each crop in each rotation were presented in Chapter II and procedures for determining expected prices were developed in Chapter IV.

Random Variables--Prices and Yields

Evidence suggests that yields are not normally distributed in many instances; Day (1965) found that yield distributions may be somewhat negatively skewed. One hypothesis is that as management techniques improve, expected yields will approach the biological limit of the system; thus, the preponderance of yields observed will be closer to the upper bound of possible yields. However, in a year of adverse weather or unusual pest or disease problems, yields could be quite low despite best management practice. This suggests a long left tail for yield probability density functions. Also the effect of government price support mechanisms is to truncate the left tail of the price distribution while the upper bound is not similarly limited (see Appendix I). This introduces skewness in the distribution of prices.

In light of these facts, probability density functions should be flexible enough to accommodate the possibility of normality as well as varying degrees of skewness and kurtosis in sample distributions. Beta distributions were considered to be an adequate approximation. The Beta distribution has the probability density function of the form:

$$f_B(Y) = \begin{cases} \dfrac{Y^{R-1}(1-Y)^{S-1}}{B(R, S)} & \text{if } 0 \leq Y \leq 1 \\ 0 & \text{elsewhere} \end{cases}$$

R and S are positive real numbers. B(R, S) is given by:

$$B(R, S) = \frac{\Gamma(R)\,\Gamma(S)}{\Gamma(R + S)} \qquad \text{where } \Gamma(\lambda) \text{ is } (\lambda-1)!$$

The Beta distribution has the desirable property that the density function may adopt a wide variety of shapes, depending on the values of R and S (Derman et al., 1973). The Beta function has the less desirable property that it exists only on the closed interval [0, 1] interval unlike the standard normal which is defined on the open interval $-\infty, +\infty$.

Estimates of the Beta parameters are derived from estimates of the mean and variance from the following formula (Derman et al., 1973):

$$\hat{R} = \hat{\mu}_y \left[\frac{\hat{\mu}_y (1-\hat{\mu}_y) - 1}{\hat{\sigma}_y^2} \right] \qquad (1)$$

$$\hat{S} = (1-\hat{\mu}_y) \left[\frac{(\hat{\mu}_y)(1-\hat{\mu}_y) - 1}{\hat{\sigma}_y^2} \right] \qquad (2)$$

Since the Beta distribution exists only on a [0, 1] interval, it is necessary to transform estimates for the mean and variance to a 0, 1 scale. This implies that upper and lower bounds must be defined for each distribution; then the random variable, in this case yield or price, can be transformed to a value on the proper interval scale.

Measurement of Variability

The total variation in prices and income can be partitioned into two parts, that which is systematic and reflects long run biological, technological, and economic trends and a second random portion which may be regarded as unpredictable. The assumption is that farmers do recognize long term trends in yields and relative prices and, therefore, view deviations from trend as a "random" element.

There are several methods used to determine the current level of the time series. A simple approach is to assume that the current level is identical with the value for the previous year, hence the random element would be represented by first differences. Another approach is to employ some form of moving average as an estimate for the current value and then differences between observed values and estimated values represent the random elements. A third approach is to employ some general index to represent "real" values and deviations from the long run deflated series represents the random element. There are arguments for and against each alternative procedure. The approach adopted here assumes that the systematic component of the time series can be approximated by a polynomial function. This assumption appears substantiated by the sample yield and price data. Once the systematic component of total variability is estimated, it can be removed. The remainder represents an estimated random variability.

Estimating Variability of Yields

Yield probability density functions were estimated from a time series of yield observations from a sample of six farms (see Appendix B for raw data). Each of the time series for each crop was detrended using linear regression of yield on time. As pointed out earlier, some of the yield probability density functions may be non-normal. The residuals of each regression were tested using the Wilks-Shapiro test (see Appendix D).

Variance was estimated from the pooled regressions; the least-squares-with-dummy-variables (LSDV) method is a commonly used method of pooling time series with cross-section data (Madalla, 1977). The set of six detrending equations for sample yields are of the form:

$$\text{Yield}_i = \alpha_i + \beta_i \text{ time} \quad \text{where } i = 1, \ldots , G \text{ sample time-series.}$$

In order to determine the desirability of LSDV as a pooling technique, Madalla (1977) suggests testing a set of three hypotheses concerning equation parameters.

1. H_0: $\alpha_1 = \alpha_2 = \ldots = \alpha_n$; $\beta_1 = \beta_2 = \ldots = \beta_n$

   H_A: $\alpha_1 \neq \alpha_2 \neq \ldots \neq \alpha_n$; $\beta_1 \neq \beta_2 \neq \ldots \neq \beta_n$

Rejection of the null hypothesis implies that there are differences among the coefficients of the sample detrending equations and the data should not be directly pooled. The null hypothesis was rejected in all cases using a 5% test.

The second step tests the hypothesis that the slope coefficients are equivalent; that is:

2. H_0: $\beta_1 = \beta_2 = \ldots = \beta_n$

H_A: $\beta_1 \neq \beta_2 \neq \ldots \neq \beta_n$

The F ratio obtained for each of the seven crops indicated that the null hypothesis could not be rejected at the 5% level.

The third set of hypotheses represents a conditional test:

3. H_0: $\alpha_1 = \alpha_2 \ldots = \alpha_n$ given $\beta_1 = \beta_2 = \ldots = \beta_n$

H_A: $\alpha_1 \neq \alpha_2 \ldots \neq \alpha_n$ given $\beta_1 = \beta_2 = \ldots = \beta_n$.

The null hypothesis was rejected for all seven cases at the 5% level.

The results of these tests indicate that a LSDV approach is appropriate for pooling the data. LSDV equations were estimated for each crop. The mean-squared error of the estimates represents an estimate of yield variation.

The estimated standard error represents an estimate based on an expected value of the field sample yields. Since the expected value of yields employed in this model are obtained from a different source than the field data used in estimating variability, the coefficient of variation is employed to determine the variance of yields with different expected values than those of the same in the field sample. Furthermore, this approach provides differing values for estimated variance depending on the expected yield of a crop in a specific rotation. For example, the coefficient of variability for corn is 24.9%; therefore, the standard deviation used for corn with 115 bushels per acre expected value is 28.6 bushels per acre, while the value used for 110 bushels corn is 27.4 bushels per acre. Presented in Table 5.1 is the estimate of variance obtained for each crop and the coefficient of variation.

Table 5.1 Estimates of Yield Variation[a]

Crop	Unit	Standard Deviation	Coefficient of Variation (%)
Corn	bu	20.0	24.9
Navy beans	cwt	4.6	31.5
Soybeans	bu	7.9	26.9
Sugarbeets	ton	3.2	17.9
Oats	bu	20.2	31.1
Alfalfa	ton	0.9	25.5
Wheat	bu	10.8	25.6

[a]See Appendix E for a more detailed discussion of the procedure used and the parameter values obtained for the estimated equation.

Variability of Prices

The approach in this study for the estimation of price variability is similar to that employed in estimating yield variabiltiy. A time series of prices received by Michigan farmers is detrended by regression and the mean square error is used as an estimate of price variance. The approach adopted is controversial when applied to prices.

The difficulty encountered by employing the simple detrending scheme used here is the assumption that estimates of price variability based on historical data are necessarily good predictors of future price variability. In the 1950s and 1960s, grain surpluses coupled with government price support programs became minimized price variability. In the 1970s, U.S. grain markets became much more interdependent with the rest of the world and more volitile. These changes may have a differential impact on different crops. A case can be made for the alternative that the 1980s may see a return to more stable farm prices as price stability is a direct objective of government policy. At any rate, the model is flexible enough to accommodate changes in price variability scenarios and the assumption is set forth here that historical price variability is a reasonably good predictor of future price variability.

For all price series a quadratic function represented a superior fit to the data over a linear fit or a 3rd degree polynomial. This suggests falling nominal (and real) farm prices through the 1950s and 1960s and increasing nominal prices through the 1970s. Farm prices (at least in Michigan) have not followed the trend suggested by indices, such as the C.P.I.

The approach adopted for this analysis is to estimate price variability as the mean square error of a regression of prices received on time (see Appendix F. As suggested above, a quadratic equation was appropriate for all seven crops and the price variances estimated are presented in Table 5.2.

Table 5.2 Standard Deviation and Coefficient of Variation of Prices Received by Michigan Farmers

Crop	Unit	Standard Deviation	Coefficient of Variation (%)
Corn	$/bu	0.45	18
Navy beans	$/cwt	2.65	31
Soybeans	$/bu	1.08	18
Sugarbeets	$/ton	3.56	41
Oats	$/bu	0.45	14
Alfalfa	$/ton	2.34	9
Wheat	$/bu	0.95	25

The coefficient of variation is computed from mean square error and is used to compete a variance based on expected prices. For example, the coefficient of variation estimate of the price of corn is 18%. This translates to a variance of 0.20 based on a $2.50 expected corn price.[1]

Correlation Coefficients

It can be shown that the variance of a linear combination of random variables is:

$$\sigma^2\ (Y_1 + Y_2 + \ldots + Y_n) = \sigma^2_{y_1} + \sigma^2_{y_2} + \ldots + \sigma^2_{y_n} + \sum_{i=1}^{n} \sum_{j=1}^{n} \sigma_{y_i y_j} \qquad i \neq j.$$

For the present case,

$$\sigma^2\ (\text{gross income}) = \sigma^2\ (\text{income crop}_1) + \sigma^2\ (\text{income crop}_2) + \ldots$$
$$+ \sigma^2\ (\text{income crop}_n) + \sum_{i=1}^{n} \sum_{j=1}^{n} \text{cov}\ (\text{income crop}_i, \text{income crop}_j)$$
$$i \neq j.$$

In determining gross income variance, covariance between crops must be determined. It was previously assumed that covariance between yields and prices is zero. This is based on the assumption that individual farm units are perfect competitors and is appropriate only at the firm level. The covariance between crop incomes is due to covariance between prices and yields of different crops in a rotation.

Correlation coefficients were computed using the random disturbances of the least squares dummy variables (LSDV) pooled regression equations. Since all crops (except soybeans) were grown in close geographical proximity, weather stresses and soil types would be similar among all samples. It is realized that some inaccuracy may be introduced since management practices vary from sample to sample. The correlation coefficient between soybeans and other crops is least accurate since the sample soybean yields were obtained from Monroe County farms which are about 60 miles south of the Saginaw Valley region.

Correlations between prices were computed between the residuals of the price detrending equations. The coefficient estimates used in this study are presented in Tables 5.3 and 5.4. Appendix F presents a more detailed discussion of the method employed in estimating correlation coefficients.

Table 5.3 Correlation Coefficients for Yields

Crop	Corn	Navy Beans	Soybeans	Sugarbeets	Oats	Alfalfa
Corn	1.00					
Navy beans	0.07	1.00				
Soybeans	0.11	-0.03	1.00			
Sugarbeets	0.05	-0.15	0.07	1.00		
Oats	0.10	0.21	0.05	-0.15	1.00	
Alfalfa	0.08	0.13	0.16	-0.13	0.00	1.00
Wheat	-0.01	0.02	-0.05	-0.05	-0.14	-0.27

Table 5.4 Correlation Coefficients Estimated for Prices Received by Michigan Farmers

Crop	Corn	Navy Beans	Soybeans	Sugarbeets	Oats	Alfalfa
Corn	1.00					
Navy beans	-0.07	1.00				
Soybeans	0.94	-0.08	1.00			
Sugarbeets	0.81	0.18	0.75	1.00		
Oats	0.97	-0.15	-0.14	0.74	1.00	
Alfalfa	0.95	-0.27	0.96	0.62	0.98	1.00
Wheat	0.25	0.51	0.13	0.61	0.13	-0.04

Upper and Lower Bounds on Distributions

The Beta distribution is defined on the closed interval [0, 1]. It is, therefore, necessary to estimate an upper and lower bound for each yield and price distribution. All information regarding the effect of moments higher than the second is embodied in the values of the bounds of each distribution.

The procedure used to estimate upper and lower bounds involved selecting the extreme observations from the detrending equations for yield and prices. The value of the extreme observation was computed as a percentage of the trend value at that point in time. The value that represented the greatest percentage increase over trend was selected as the upper bound of the distribution. Conversely, the value that fell below its respective trend values by the greatest percentage was selected as the lower bound of the distribution. The only exception to this procedure was that the lower bound of prices was set at the government support or loan rate for those crops where a support program exists. Presented in Table 5.5 are the percentages used in computing upper and lower bound values for the distributions.

With information on expected values, variances, and bound values, it is possible to describe an univariate probability distribution for the yield and price of each crop. These distributions become the "marginal" distributions of a multivariate gross income distribution. The remainder of this chapter will be devoted to a description of the program that simulates net returns to land.

Table 5.5 Percentage Rates Used in Calculating Upper and Lower Bound Values

Crop	Upper Bound[a]	Lower Bound
Prices:		
Corn	1.52	2.10[b]
Navy beans	1.89	0.60
Soybeans	1.51	5.25[c]
Sugarbeets	1.89	6.40
Oats	1.34	7.60
Alfalfa and oat straw	1.12	8.90
Wheat	1.76	2.35[c]
Yield:		
Corn	1.56	0.37
Navy beans	2.05	0.32
Soybeans	1.56	0.37
Sugarbeets	1.46	0.53
Oats	1.66	0.13
Alfalfa and oat straw	1.70	0.30
Wheat	1.51	0.44

[a]Expected value times all upper bound and lower bound figures except those indicated by other footnotes.

[b]Loan rate.

[c]Support price.

Simulation of Gross Income

It is common in attempting to derive the behavior of probabilistic systems to turn to Monte Carlo solution procedures (e.g., Wagner, 1975). Exogeneous variables can be described as random variables and sample states of nature obtained. System output levels may then be derived for each state of nature. The initial step is to describe the exogeneous variables as probability density functions (PDF). Numerical procedures exist which enable PDF's to be simulated on a computer (Naylor et al., 1966). Such procedures have been developed for a wide variety of probability distributions. Process generators exist for many univariate distributions. These methods may be employed to simulate any number of stochastic variables in a system assuming all underlying processes are statistically independent. If this assumption is not satisfied, as is the case here, a multivariate generator is required. Multivariate process generators have been developed for some distributions, notably the multivariate normal and Wishart distributions (Naylor et al., 1966). A generalized, multivariate process generator has been developed to approximate the situation in which the marginal distributions are not normal (King, 1979) and is used here.

Experience with the process generator in this study indicates an error of about 10% between the correlation coefficients among the generated sample vectors and the correlation values entered as data.[1]

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[1]For a complete discussion of the theoretical justification of this approach and presentation of a Monte Carlo experiment with 1,000 draws to examine behavior of correlation, see Appendix A (King, 1979).

As used in the present situation, a vector of 100 "draws" is selected from a distribution describing yield and a distribution describing price for each crop in each rotation. The distribution of gross farm income is then defined as:

$$\text{Gross Income}_i = \left(\sum_{j=1}^{m} \text{Yield}_{ij} \times \text{Price}_{ij}\right)/M \qquad \begin{array}{l} i = 1, 2, \ldots, n \text{ "draws"} \\ j = 1, 2, \ldots, M \text{ crops.} \end{array}$$

The non-stochastic elements comrpising the costs associated with a particular rotation are then subtracted from each of the i gross income samples leaving "i" net returns to land.

The 100 net return to land values are then rank ordered from lowest to highest. The i^{th} return to land is then an estimate of the i^{th} fractile of the cumulative probability distribution of returns to land. These discrete estimates of the cumulative probability distributions of net returns are employed to rank rotations according to the rules of first, second, and third degree stochastic dominance. Figure 5.1 represents in block form the decision model as used in this analysis. Appendix G presents the FORTRAN code of the model along with sample output.

Summary

As stated in the research objectives, the goal is to rank sixteen cropping systems as to desirability to the individual farm decision maker operating in an uncertain environment. This chapter described the process by which the probability distributions for crop yield and

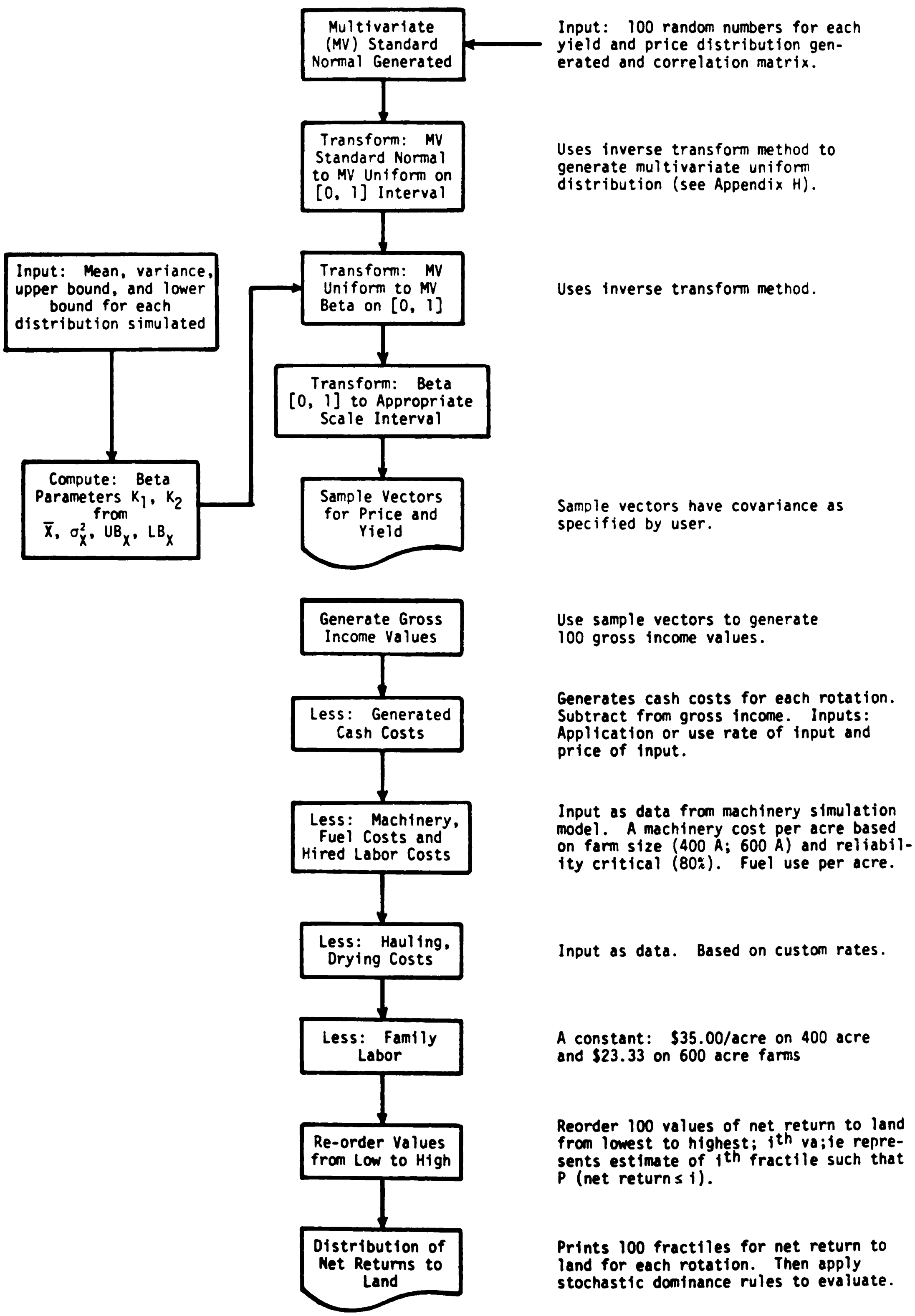

Figure 5.1 Block Representation of Stochastic Generator to Simulate Net Returns to Land.

crop price are obtained and assembled to estimate a distribution for gross farm income and ultimately an estimate for net returns to land.

The next chapter will present the results of ranking sixteen cropping systems using both the deterministic model and a stochastic model for a 400 acre and a 600 acre owner/operator cash crop farm.

CHAPTER VI

RANKING OF SAGINAW VALLEY CROP ROTATIONS

Introduction

The sixteen rotations for 400 and 600 acre operations are ranked using alternative criteria; they are expected value and first, second, and third degree stochastic dominance. The input/output, yield, and price relationships used were presented in Chapter V.

Tables 6.1 and 6.2 present the expected value rankings in order of their net return to land. The C-NB-B rotation has the highest net return to land for 400 and 600 acre configurations. In contrast, the C-C-SB and O/A-A-A-A-A-C-C-C rotations yield the poorest return on the 400 acre and 600 acre farms, respectively. Rotation #14, O/A-A-NB-B, ranked second for both sizes and is considered to be agronomically superior in terms of impact on soil structure and organic matter. Rotation #8, C-NB-NB-B, ranked third. If the agronomists estimates of relative yield differentials are correct, then comparing rotation #8, C-NB-NB-B, with #14, O/A-A-NB-B, O/A-A could be preferable to C-NB in the first two years.

All rotations through the sixth place included sugarbeets; and no rotation that included sugarbeets ranked lower than ninth. The inclusion of successive years of Navy beans on the same field was considered by agronomists to be an instrumental factor in the declining

Table 6.1 *Income*-Expense Summary for 400 Acre Farm ($/Acre)

Rotation No.	Crops Rotated[a]	"Expected"[b] Gross Income	Cash Costs	Machinery Costs	Fuel Cost	Hauling Drying	Family Labor	"Expected"[b] Return to Land
4	C-NB-B	398.65	66.73	82.83	9.44	32.55	35.00	172.10
14	O/A-A-NB-B	389.39	46.95	117.51	10.09	23.33	35.00	156.51
8	C-NB-NB-B	359.05	61.61	79.40	9.26	24.08	35.00	149.70
5	C-SB-B	384.43	58.95	99.15	9.44	32.90	35.00	148.99
6	C-NB-W-B	352.05	63.23	82.56	8.22	24.83	35.00	138.21
13	C-C-NB-B	379.04	67.93	100.08	9.37	34.10	35.00	132.56
1	C-NB	290.65	52.21	68.71	8.63	20.88	35.00	105.22
12	NB-C-SB	262.42	46.90	65.41	8.20	14.70	35.00	92.19
15	O-NB-B	337.13	60.10	122.91	10.09	21.10	35.00	87.93
16	O/A-A-A-C-C-NB-C	281.27	40.62	96.69	8.51	24.88	35.00	75.57
2	C-SB	258.03	43.92	74.57	7.94	21.35	35.00	75.25
9	O/A-A-A-C-C-SB-C	268.72	38.65	91.68	8.29	25.00	35.00	70.10
11	C-C-NB-W	266.10	56.55	77.36	7.46	20.71	35.00	69.02
7	C-SB-W-B	325.96	57.28	132.62	8.03	24.95	35.00	68.08
10	O/A-A-A-A-A-C-C-C	264.21	38.69	97.50	8.62	25.74	35.00	58.66
3	C-C-SB	263.68	52.41	83.84	8.15	27.07	35.00	57.21

[a]C = corn; NB = Navy beans; S = soybeans; B = sugarbeets; O = oats; A = alfalfa; W = wheat.

[b]"Expected" is used in a probabilistic sense; that is, the weighted average of possible outcomes.

Table 6.2 Income-Expense Summary for 600 Acre Farm ($/Acre)

Rotation No.	Crops Rotated [a]	"Expected"[b] Gross Income	Cash Costs	Machinery Costs	Fuel Costs	Hauling Drying	Family Labor	"Expected" Return to Land
4	C-NB-B	398.65	66.73	76.32	9.98	32.55	23.33	189.74
14	O/A-A-NB-B	389.39	46.95	98.24	9.77	23.33	23.33	187.77
8	C-NB-NB-B	359.05	61.61	68.05	9.49	24.08	23.33	172.49
5	C-SB-B	384.43	58.95	97.62	9.71	32.90	23.33	161.92
6	C-NB-W-B	352.05	63.23	80.45	8.88	24.83	23.33	151.33
13	C-C-NB-B	379.04	67.93	96.09	9.59	34.10	23.33	148.00
1	C-NB	290.65	52.21	66.95	8.25	20.88	23.33	119.03
15	O-NB-B	337.13	60.10	105.14	9.38	21.10	23.33	118.08
7	C-SB-W-B	325.96	57.28	99.84	8.25	24.95	23.33	112.31
12	NB-C-SB	262.42	46.90	58.38	8.20	14.70	23.33	110.91
16	O/A-A-A-C-C-NB-C	281.27	40.62	85.27	8.69	24.88	23.33	98.48
9	O/A-A-A-C-C-SB-C	268.72	38.65	81.87	8.47	25.00	23.33	91.40
2	C-SB	258.03	43.92	75.12	8.07	21.35	23.33	86.24
11	C-C-NB-W	266.10	56.55	79.12	7.63	20.71	23.33	78.76
3	C-C-SB	263.68	52.41	84.64	8.26	27.07	23.33	67.97
10	O/A-A-A-A-A-C-C-C	264.21	38.69	102.00	7.24	25.74	23.33	67.21

[a] C = corn; NB = Navy beans; S = soybeans; B = sugarbeets; O = oats; A = alfalfa; W = wheat.

[b] "Expected" is used in a probabilistic sense; that is, the weighted average of possible outcomes.

Navy bean yields experienced in the Saginaw Valley. Most cash crop farms in the Saginaw Valley grow corn, Navy beans, and sugarbeets in some configuration.

Sugarbeets are grown under contract with processors; not all Saginaw Valley crop farmers have such contracts (or the necessary equipment to harvest sugarbeets). The best alternative for growers who do not have sugarbeets is a C-NB rotation.

Several rotations are identical with the exception of the type of bean crop included, soybeans or Navy beans. The directly comparable pairs are: rotations 1 and 2; rotations 4 and 5; rotations 6 and 7; and rotations 9 and 16. In all cases, the rotations with Navy beans were economically superior to soybeans. The "breakeven" point on a 600 acre farm between Navy beans and soybeans varies with the rotation. In comparing rotations 1 and 2, expected soybean prices would have to increase from $6.53/bu. to $8.40/bu. Or, expected yields would have to be 45 bu./acre rather than 35 bu./acre. In comparing rotations 4 and 5, expected soybean prices would have to be $2.38/bu. higher or yields 12.76 bu./acre higher. For rotations 6 and 7, the breakeven increments are: $4.46/acre or 23.9 bu./acre. For rotations 9 and 16 the values are $1.42/acre or 7.61 bu./acre. Comparing rotations 9, 10, and 16 with rotation 1, the "breakeven" alfalfa price increment is $14.32/ton for rotation 9, $20.40/ton for rotation 10, and $14.37/ton for rotation 16.

Comparison by Stochastic Dominance Rules

The differing degrees of risks associated with each crop and rotation make comparison on the basis of expected net returns to land invalid for many producers; it is comparing unlike items. This emphasizes the importance of comparison where risk is expressly accounted for.

In the previous chapter, a process was presented to "simulate" net returns to land when prices and yields are random variables. The result is a discrete cumulative distribution function where the i^{th} element is an estimate of the i^{th} fractile of the distribution. Sixteen alternative cropping systems are ranked according to the rules of stochastic dominance which were discussed in Chapter III. The rules are reproduced here for convenience.

1. First degree stochastic dominance. If rotation A is first degree stochastic efficient over rotation B, it implies that all decision makers who prefer more income to less will select rotation A.
2. Second degree stochastic dominance. If rotation A is second degree stochastic efficient over rotation B, it implies that all decision makers who prefer more income to less and are risk averse will choose rotation A over rotation B.
3. Third degree stochastic dominance. If rotation A is third degree stochastic efficient with respect to rotation B, this implies that all risk averse decision makers prefering more income to less but who are less risk averse as the absolute level of wealth increases will prefer rotation A to rotation B.

Stochastic dominance rules stand in hierarchical relationship to one another with first degree dominance being the most comprehensive; i.e., if rotation A is first degree dominant over B, then it is also second and third degree dominant over B. However, if it is known that A is third degree stochastic dominant over B, A may not be first or second degree dominant over B.

The rule of transitivity also applies but only up to the weakest rule in the relationship. For example, if A dominates B by first degree and B dominates C by second degree, then A dominates C but only by second degree. The first degree relationship between A and C is undefined without a direct comparison of the two.

Results of Analysis on 400 Acres

Using a stochastic dominance criteria, a comparison of all rotations was undertaken for both a 400 acre and 600 acre farm. First, comparison was made among all rotations employing the first degree stochastic dominance rule. Where this was not decisive, comparison was made using the second degree stochastic dominance rule and similarly, comparison by third degree was undertaken where the second degree rule did not give a clear result.

Figure 6.1 presents the cumulative distribution functions of rotations 1 and 14 for illustration. This represents an example of first degree stochastic dominance of rotation 1 by rotation 14. Figure 6.2 presents a comparison of rotations 4 and 14. In this case, first degree stochastic dominance suggests no clear choice between the alternatives. Application of second or third degree dominance criteria may resolve the issue.

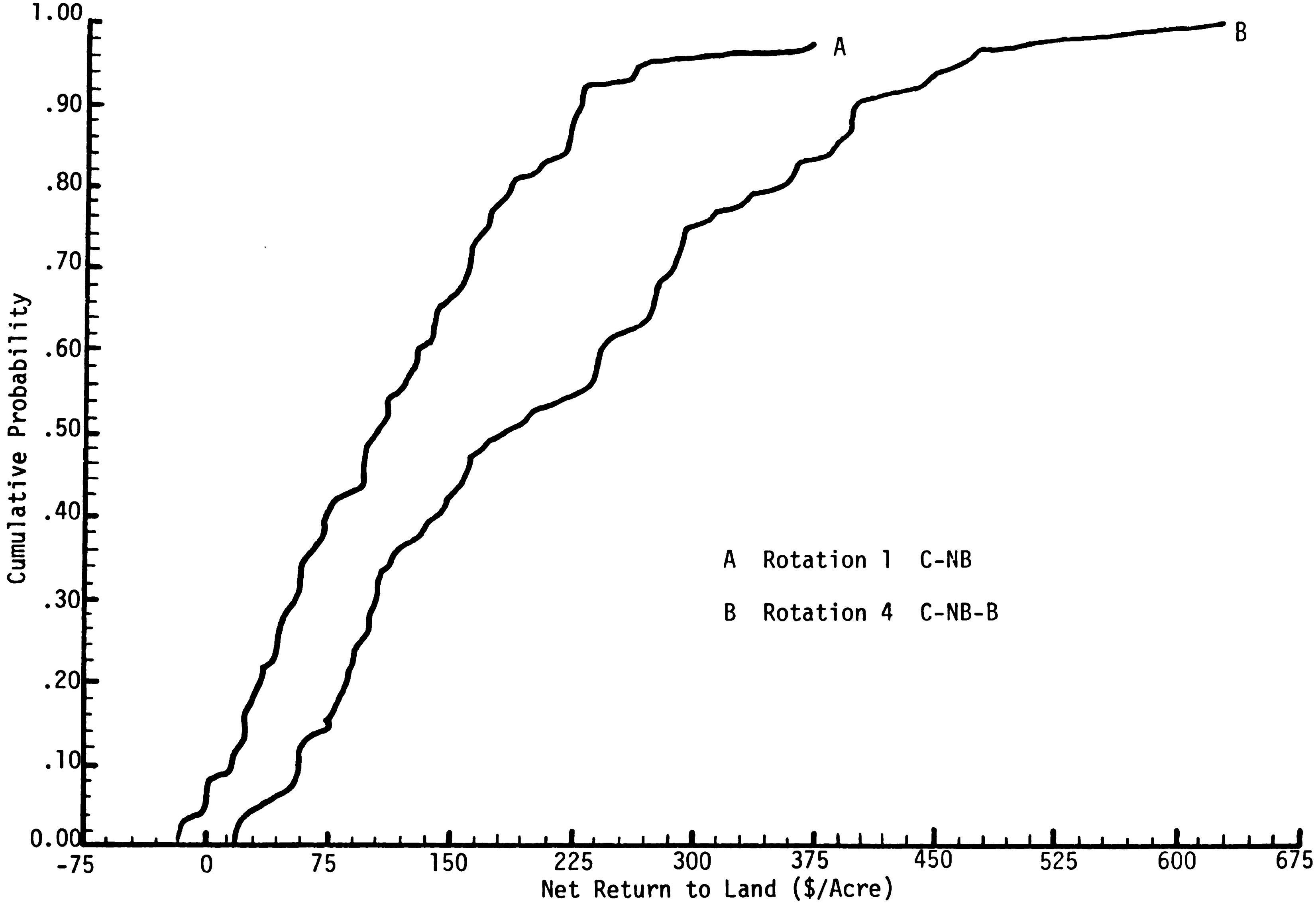

Figure 6.1 Cumulative Density Function--600 Acre Farm.

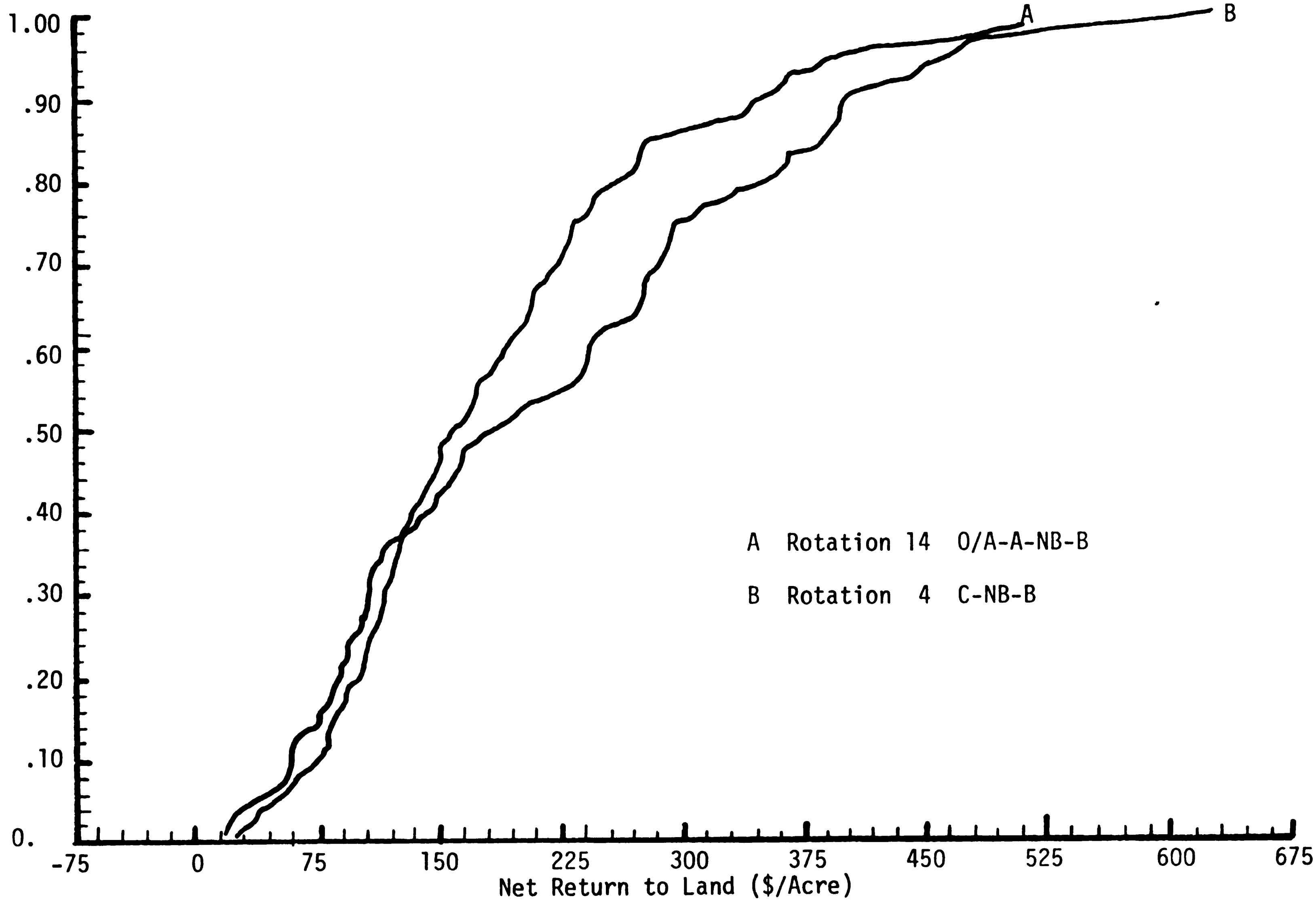

Figure 6.2 Cumulative Density Function--600 Acre Farm

Table 6.3 presents the results of ranking for a 400 acre farm using the first and second degree rules. Table 6.4 presents the result of a 400 acre farm using all three stochastic dominance rules.

Some rotations appear on more than one line, thus their ranking appears ambiguous. This should be interpreted as follows: where a rotation appears at more than one rank level implies that the highest stochastic dominance rule (1st, 2nd, or 3rd) was inadequate to determine a preference between that rotation and others at that level or rank. For example, at rank 3, second degree stochastic dominance rules indicate no preference among rotations 8, 6, and 12. At rank 4, the preference among 5, 6, and 12 is ambiguous; however, the preference between rotations 8 and 5 is clear with 8 being preferred to 5 by all risk averse, income preferring decision makers. In other words, 8 is preferred to 5, and 5 is preferred to 13, but the relationship between any of these three and 6 or 12 cannot be determined on the basis of second degree stochastic dominance.

Table 6.4 presents a ranking which includes third degree stochastic dominance. The use of third degree stochastic dominance reduces some of the ambiguity in the rankings, but not all. Second degree stochastic dominance is presented separately, since the assumptions necessary for first and second degree stochastic dominance are more easily accepted with respect to most farm managers. Third degree dominance requires declining risk aversion as the absolute level of wealth increases. This assumption is more tenuous; it

Table 6.3 Ranking of Sixteen Cropping Systems on a 400 Acre Farm Using First and Second Degree Stochastic Dominance

Rank	Rotation No.	Crops Rotated	Expected Net Return to Land[a]
1	4	C-NB-B	112.10
2	14	O/A-A-NB-B	156.51
3	8	C-NB-NB-B	149.70
	6	C-NB-W-B	138.21
	12	NB-C-SB	92.19
4	5	C-SB-B	148.99
	6	C-NB-W-B	138.21
	12	NB-C-SB	92.19
5	13	C-C-NB-B	132.56
	6	C-NB-W-B	138.21
	12	NB-C-SB	92.19
6	1	C-NB	105.22
	12	NB-C-SB	92.19
7	15	O-NB-B	69.02
	9	O/A-A-A-C-C-SB-C	70.10
	10	O/A-A-A-A-A-C-C-C	58.66
	16	O/A-A-A-C-C-NB-C	75.57
8	15	O-NB-B	69.02
	10	O/A-A-A-A-A-C-C-C	58.66
	16	O/A-A-A-C-C-NB-C	75.57
	11	C-C-NB-W	69.02
	2	C-SB	75.25
9	3	C-C-SB	57.21
	7	C-SB-W-B	68.08

[a]Expected net return to land figures are taken from Table 6.1.

Table 6.4 Ranking of Sixteen Cropping Systems on a 400 Acre Farm Using First, Second, and Third Degree Stochastic Dominance

Rank	Rotation No.	Crops Rotated	Expected Net Return to Land[a]
1	4	C-NB-B	172.10
2	14	O/A-A-NB-B	156.51
3	8	C-NB-NB-B	149.70
	6	C-NB-W-B	138.21
4	5	C-SB-B	148.99
	6	C-NB-W-B	138.21
5	5	C-SB-B	148.99
	12	NB-C-SB	92.19
6	13	C-C-NB-B	132.56
	12	NB-C-SB	92.19
7	1	C-NB	105.22
8	9	O/A-A-A-C-C-SB-C	70.10
9	11	C-C-NB-W	69.02
	10	O/A-A-A-A-A-C-C-C	58.66
	16	O/A-A-A-C-C-NB-C	75.57
10	2	C-SB	75.25
11	15	O-NB-B	69.02
12	3	C-C-SB	57.21
	7	C-SB-W-B	68.08

[a]Expected net return to land figures are taken from Table 6.1.

implies older farmers with a higher equity interest are less risk averse than younger, more highly leveraged farmers. Extension workshop experience in Michigan indicates, at least with respect to forward pricing behavior, that some older farmers are more risk averse than many younger farmers, despite their higher net worth.[1]

Results of Analysis on 600 Acres

On a 600 acre farm moves, rotation 14 becomes competitive with rotation 4. This is true with or without the use of third degree stochastic dominance. Rotations 7 and 15 tend to benefit most in the larger configuration; moving from positions 11 and 12, respectively, on 400 acres to 6 and 7, respectively, on 600 acres. Rotation 8 although clearly inferior to rotations 14 and 4, represents a superior strategy to rotation 6 on 600 acres. Rotation 6 differs from 8 by the substitution of a wheat crop for the second year of Navy beans. Although agronomists caution against successive plantings of Navy beans and experience on the Saginaw Valley Bean and Beat Research Farm indicate that longer periods between successive plantings of Navy beans is desirable, the evidence here suggests that the simple substitution of wheat for Navy beans is a marginally inferior strategy particularly on larger operations. The long rotations, rotations 9, 10, and 16, would not be the rotations of choice on either the 400 or 600 acre farms although they were superior to the standard "corn belt" rotations, C-SB and C-C-SB, which by all measures of this study are unsuitable for Saginaw Valley cash crop farming at prevailing prices and yields.

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[1]Dr. John Ferris, personal communication.

Table 6.5 Ranking of Sixteen Cropping Systems on a 600 Acre Farm Using First and Second Degree Stochastic Dominance

Rank	Rotation No.	Crops Rotated	Expected Net Return to Land[a]
1	4	C-NB-B	189.74
	14	O/A-A-NB-B	187.77
2	8	C-NB-NB-B	172.49
3	12	NB-C-SB	110.91
	6	C-NB-W-B	151.33
	5	C-SB-B	161.92
4	13	C-C-NB-B	148.00
	6	C-NB-W-B	151.33
	12	NB-C-SB	110.91
5	15	O-NB-B	118.08
	12	NB-C-SB	110.91
	1	C-NB	119.03
6	9	O/A-A-A-C-C-SB-C	91.40
	16	O/A-A-A-C-C-NB-S	98.48
7	7	C-SB-W-B	112.31
	15	O-NB-B	118.08
8	2	C-SB	86.24
	15	O-NB-B	118.08
9	11	C-C-NB-W	78.76
	15	O-NB-B	118.08
	2	C-SB	86.24
	10	O/A-A-A-A-A-C-C-C	67.21
10	3	C-C-SB	67.97

[a]Expected net return to land figures are taken from Table 6.1.

Table 6.6 Ranking of Sixteen Cropping Systems on a 600 Acre Farm Using First, Second, and Third Degree Stochastic Dominance

Rank	Rotation No.	Crop Rotated	Expected Net Return to Land[a]
1	4	C-NB-B	189.74
	14	O/A-A-NB-B	187.77
2	8	C-NB-NB-B	172.49
3	6	C-NB-W-B	151.33
	5	C-SB-B	161.92
	12	NB-C-SB	110.91
4	13	C-C-NB-B	148.00
	12	NB-C-SB	110.91
5	1	C-NB	119.03
	9	O/A-A-A-C-C-SB-C	91.40
	16	O/A-A-A-C-C-NB-C	98.48
6	15	O-NB-B	118.08
	7	C-SB-W-B	112.31
7	11	C-C-NB-W	78.76
	15	O-NB-B	118.08
8	10	O/A-A-A-A-A-C-C-C	67.21
	15	O-NB-B	118.08
9	2	C-SB	86.24
	15	O-NB-B	67.21
10	3	C-C-SB	67.97

[a]Expected net return to land figures are taken from Table 6.2.

Since sugarbeets are grown on contract with processors, not all cash crop farmers can produce sugarbeets. The rotations with sugarbeet components were more profitable but this alternative is not feasible for all producers; therefore, Table 6.7 presents a ranking of those rotations without sugarbeet components. Rotation 12 represents the best alternative for those producers who are not sugarbeet producers. NB-C-SB represents a slightly better choice than C-NB which is a common cropping pattern for those farmers not producing sugarbeets.

A comparison can be made between soybeans and Navy beans in different cropping systems. Rotation sets 1 and 2, 4 and 5, 6 and 7, and 9 and 16, are identical except 1, 4, 6, and 9 include Navy beans while 2, 5, 7, and 16 substitute soybeans. For both 400 and 600 acre farm configurations, the system with Navy beans dominated its analogous system with soybeans by first degree stochastic dominance. Only in the case of the long rotations, 9 and 16, was the choice unclear. No dominance was attained between 9 and 16 on a 400 acre farm and 16 dominated 9 by the weakest of the three stochastic dominance rules on a 600 acre farm. Under the circumstances of this study, it appears that Navy beans are the crop of choice as opposed to soybeans.

Despite the greater risk inherent in the production of Navy beans (coefficients of variability of yields of soybeans versus Navy beans is 26.9% < 31%, and similarly, for prices 13% < 31%), the relative prices used in this study ($22.60/cwt for Navy beans as against $6.53/bu. for soybeans) is sufficient compensation for the added risk.

Table 6.7 Ranking of Saginaw Valley Cropping Systems Without Sugarbeets Using First, Second, and Third Degree Stochastic Dominance

Rank	Rotation No.	Crops Rotated	Expected Net Return to Land
400 Acres:			
1	12	NB-C-SB	92.19
2	1	C-NB	105.22
3	9	O/A-A-A-C-C-SB-C	70.10
4	11	C-C-NB-W	69.02
	10	O/A-A-A-A-A-C-C-C	58.66
	16	O/A-A-A-C-C-NB-C	75.57
5	2	C-SB	75.25
6	3	C-C-SB	57.21
600 Acres:			
1	12	NB-C-SB	110.91
2	1	C-NB	119.03
	9	O/A-A-A-C-C-SB-C	
	16	O/A-A-A-C-C-NB-C	
3	11	C-C-NB-W	78.76
4	10	O/A-A-A-A-A-C-C-C	67.21
5	2	C-SB	86.24
6	3	C-C-SB	67.97

Perhaps one reason for this is that the expected yield of soybeans used in this study is 35 bu./acre; this is less than the usual yield attainable in the "corn belt" and would consequently imply that Saginaw Valley farmers are at a comparative disadvantage growing soybeans vis-à-vis farmers in other parts of the mid-west. New varieties of soybeans that would make 40 plus bu./acre yields, the norm in the Saginaw Valley, would be necessary to make the crop competitive with Navy beans. Expected soybean prices in the $9 to $10 per bushel range relative to $22.60/cwt Navy beans could achieve a similar result.

Sensitivity Analysis

Rotations like 4, 8, and 12 are common in the Saginaw Valley; their relatively high ranking is no surprise. However, rotation 14 which includes alfalfa as a soil building legume as well as a cash crop is a high ranking, although not the leading candidate. Alfalfa is the main crop that is unique among the leading set of rotations (rotations 4, 14, 8, and 12). The estimates of yield and price of alfalfa would affect the ranking of this rotation with respect to the other leaders. Therefore, the ranking of rotation 14 with respect to 4, 8, and 12, was analyzed as changes were made in assumed alfalfa yield, price, and price variance. The following scenarios were tested:

1. Expected alfalfa yield raised 10%;
2. Expected alfalfa yield lowered 10%;
3. Expected alfalfa price raised 10% and 20%;
4. Expected alfalfa price lowered 10% and 20%; and
5. Alfalfa price variance raised 50%.

The relative ranking of rotation 14 with respect to rotations 4, 8, and 12 was unchanged for all adjustments except the 20% decline in the expected alfalfa price. In that case, rotation 14 dropped out of a first place tie with rotation 4 and into a second place tie with rotation 8. A decline in the expected cash price of alfalfa from \$60.73/ton to \$48.00/ton reduces the attractiveness of the rotation considerably. Many sensitivity analysis comparisons are possible, examination of this set was undertaken because these 4 rotations had among the highest net returns to land; 14 is considered to be an agronomically "desirable" rotation and ranked well compared with the common systems employed in the Saginaw Valley, which are variants of rotations 4 and 8. Less is known about the cash market for alfalfa as it is very often a market among farmers, hence there is probably a greater chance of error in the alfalfa price data than the other data series.

Machinery Costs

Systems which are agronomically desirable have among the lowest cash costs of all sixteen rotations. In terms of cash costs, rotations 9, 10, 14, and 16 ranked 16th, 15th, 11th, and 14th, respectively. Unfortunately, reduced variable cash costs were offset by higher machinery costs. Rotations 9, 10, 14, and 16 rank 9th, 2nd, 7th, and 4th in per acre machinery costs.

Rotations 4 and 8 have the 2nd and 4th highest cash cost vis-à-vis rotation 14, which ranks 11th. But rotation 14 ranks 4th per acre machinery costs while 4 and 8 rank 12th and 14th, respectively. This implies that rotation 14 has a higher proportion of fixed to variable costs as compared with its two main competitors, rotations 8 and 4. This represents a higher level of operating leverage and represents an inherently "riskier" farm plan than does rotation 4 and 8 regardless of the shape of the gross income distribution. This same observation holds with respect to rotations 9, 10, and 16 and their primary competitors which would be rotation 12 and 2.

Reliability Criteria

Another issue with regard to machinery costs is the impact of machinery cost versus reliability on rotational ranking. The point was made in Chapter IV that the design critique used in this study for developing machinery complements was 80%. This implied that such a machinery set would be able to complete designated field operations in eight out of ten years given historical weather patterns and the number of derived work/no work days. The selection of 80% was somewhat arbitrary, but was based on experience and rule of thumb estimates of losses from not being able to complete field operations within designated time allowances and the cost of excess machinery capacity.

Cost is an increasing function of machinery "reliability." The machinery cost reliability curves as generated by the machinery simulation model are plotted for rotations 4, 8, and 14 in Figure 6.3. The dotted hash-mark represents the 80% design criteria assumed for this study. What is apparent is that although cost is an increasing function of reliability, as expected, the different shapes of each curve imply a different machinery complement cost for each rotation depending on the

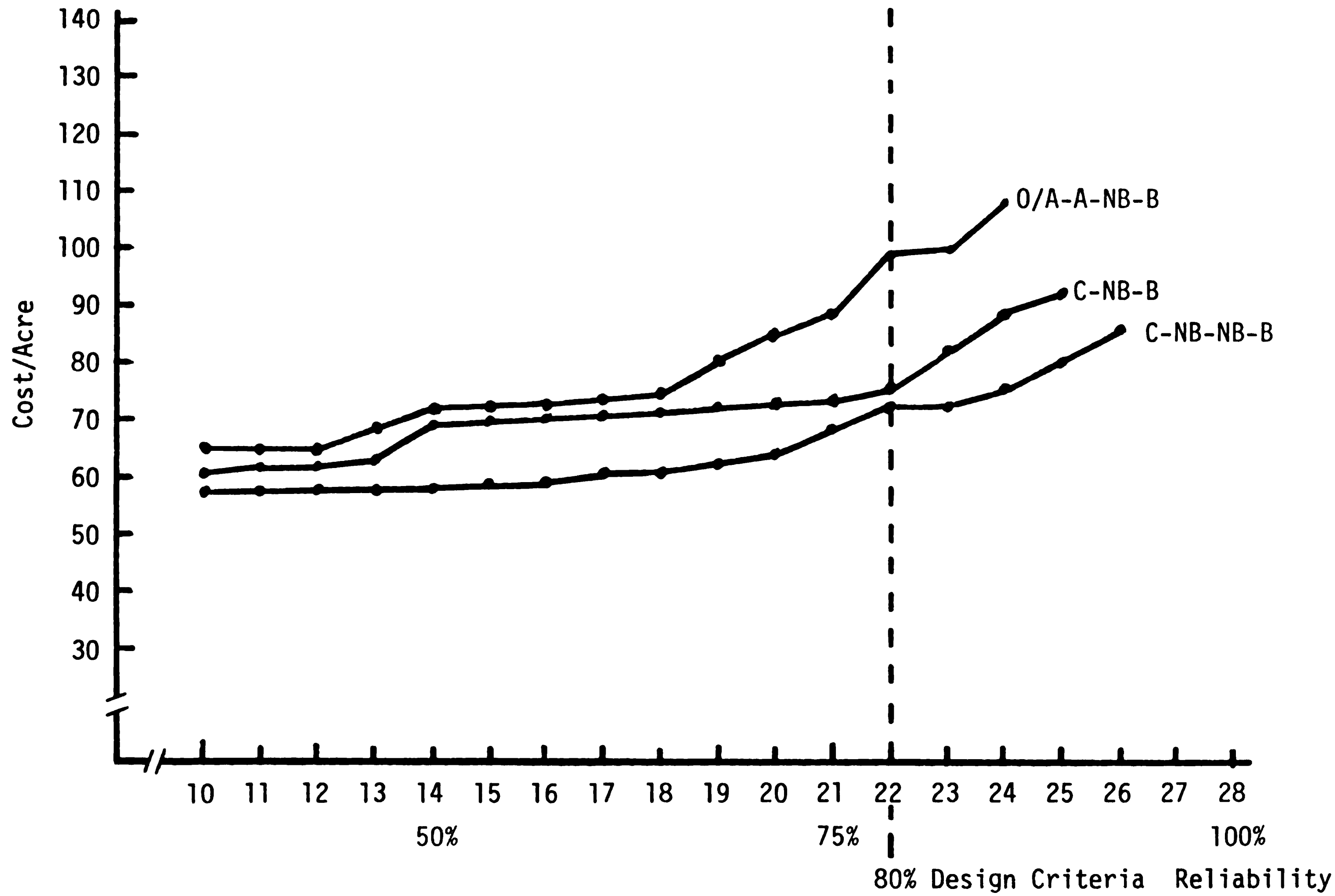

Figure 6.3 Machinery Cost Reliability Curves for Three Saginaw Valley Cropping Systems--600 Acre Farm.

design criteria selected. At 80% the per acre machinery cost is $98.24 for rotation 14 and $76.32 for rotation 4, the difference being $21.92 per acre. At 82% design criteria, the per acre machinery cost is $82.76 for rotation 4 and $99.61/acre for rotation 14 with a difference of $16.85 per acre. At a 75% design criteria, the costs are $88.31 for rotation 14 and $73.61 for rotation 4 with a difference of $14.70. In the ranking analysis, rotations 4 and 14 were deadlocked most of the time. The relative ranking appeared somewhat insensitive to variations in price and yield parameters, yet the machinery cost estimate varies by some $5.00 to $7.00 per acre with slight alternatives in the selected design criteria. It would appear that further study and some greater logical justification would be helpful in assessing cost of machinery which appear to be very important in the relative ranking process.

Summary

Sixteen Saginaw Valley cropping systems were ranked on the basis of net returns to land. The rules of stochastic dominance were employed as the decision criteria. The rotations were ranked for a synthetic 400 and 600 acre cash grain operation. A sensitivity analysis was performed on alfalfa yield, price, and variance parameters for rotation 14 (O/A-A-NB-B) as it appeared that this agronomically desirable rotation appeared competitive with rotation 4 (C-NB-B) which is representative of common cropping practice in the area. Results suggest a 20% drop in the price of alfalfa is sufficient to drop rotation 14 out of the efficient set, yet a 20% increase in the price is not sufficient to drop rotation 4 out of the efficient set.

It was observed that those rotations which are agronomically superior (rotation 9, 10, 14, and 16) entail a higher proportion of fixed to variable costs and consequently represent a higher level of operating leverage. A final observation suggests that the overall ranking of rotations may be sensitive to the design criteria selected for the machinery complement. This is due to the fact that the shape of cost reliability curves for machinery complements are not identical.

CHAPTER VII

SUMMARY AND CONCLUSIONS

Summary of Research Objectives

Increased cash crop farming at the expense of mixed cash crop/livestock farming in the Saginaw Valley has led to increased problems of soil compaction, low levels of soil organic matter, and diseases and pests. Agronomists believe, based upon extensive research, that these problems are responsible for reductions in Navy bean yields.

Sixteen crop rotations were identified; they range from the intense cropping practices currently in use to those emphasizing legumenous crops. The objectives of this study are:

1. to describe the economic environment in which Saginaw Valley cash crop farmers operate;
2. to identify crop rotations which are technically feasible illustrating a wide variety of agronomic properties; and
3. to analyze the economic viability, including explicit considerations of risk, of each of the cropping systems from the farm decision maker's perspective.

Theory

The theoretical basis for choice framework is deduced from the utility theory of a decision maker facing a risky environment. The study was conducted from the micro level system design perspective as opposed to a system management or sector level analysis.

Methodology

Enterprise budgets were developed for each of the sixteen alternative crop rotations; interactions among crops in terms of yield, and fertilizer and chemical requirements were accounted for. Machinery costs were estimated using a simulation model which generates a unique machinery complement for each rotation taking account of optimal field operation date constraints and a predetermined level of reliability to complete required field operations on time. Hauling and drying charges were priced at the custom rate. All labor was assumed to be family labor and renumeration based on family living expense.

Gross income is expected yield times expected price, and rotations are ranked according to the size of the residual remaining after costs are subtracted; the residual is labled as net return to land. Rotations are ranked according to two general criteria: net return to land and stochastic efficiency.

Risk is introduced by treating gross income as a random variable since it is the product of two random variables, yield and price. Variances and correlations among yields were derived from detrended farm data. Variances of and correlation among prices were derived from detrended average annual Michigan prices. Prices and yields were assumed distributed as multivariate beta random variables. A multivariate generator was used to generate 100 states of nature; the cumulative probability density functions for net farm income were made estimated by ranking the "states of nature" from lowest to highest and using the i^{th} values as an estimate of the i^{th} fractile of the gross income cumulative distribution function. The sixteen alternative cropping systems were ranked applying the rules of first, second, and third degree stochastic dominance.

Empirical Results

Major findings. Ranking the sixteen crop rotations for 400 acre and 600 acre farms on the basis of expected net returns to land suggests:

1. The C-NB-B system presented the highest returns to land. This corresponds to one of the commonly used rotations in the Saginaw Valley.
2. An O/A-A-NB-B rotation finishes second with $15.49/acre less income. This is one of the systems considered to be agronomically more desirable, as the inclusion of alfalfa improves soil structure.
3. A C-NB-NB-B rotation, probably the most common rotation in the early and mid-1970s, ranked third, $17.25/acre less than C-NB-B on a 600 acre farm. This rotation illustrates the common, but undesirable practice, of successive Navy bean crops. If the relative yield relationship suggested by agronomists are accurate, continuous years of Navy beans in a rotation is economically undesirable. Cash, machinery, fuel, and hauling costs are higher with C-NB-B than with C-NB-NB-B; however, gross income for C-NB-B system is estimated to be almost $40.00 higher than for C-NB-NB-B.
4. Rotations which inlude sugarbeets are typically more profitable than those that do not. Rankings 1 and 6 and 8 and 9 were

rotations with beets for the 400 acre farm; rankings 1 through 8 were beet rotations on the 600 acre farm.

5. Rotations with Navy beans were economically superior to analogous rotations where soybeans were substituted for Navy beans.
6. C-NB was the best rotation for the non-sugarbeet producer. The soil building rotations 9, 10, and 16, which included several years of alfalfa were not nearly as profitable.

The fact that rotations containing sugarbeets and/or Navy beans are more profitable than systems without them is no surprise. Since these crops are "riskier" to produce. This was one of the prime motivations for ranking the systems in a manner where risk is adequately accounted for. Findings based on stochastic dominance included:

1. The C-NB-B, O/A-A-NB-B and C-NB-NB-B rotations were ranked one, two, and three under both expected value and stochastic dominance criteria on the 400 acre farm.
2. Rotations with beets gradually ranked ahead of those without beets. For only one rotation, O-NB-B, three rotations without beets ranked ahead of a rotation with beets.
3. In the deterministic model, the C-NB rotation was superior to NB-C-SB when expected value was the criteria; the ranking was reversed under stochastic dominance.
4. There was no clear preference between C-NB-B and O/A-A-NB-B for the 600 acre farm.

5. The long rotations, O/A-A-A-C-C-NB-B, O/A-A-A-C-C-SB-C, and O/A-A-A-A-A-C-C-C, were not highly ranked.
6. Rotations with Navy beans were preferred to analogous rotations with soybeans. This suggests that, given prevailing relative prices, that the premium on Navy beans is more than adequate compensation for the increased risk involved.

A sensitivity analysis was conducted on the alfalfa yield, price, and price variance parameters for O/A-A-NB-B rotation. Since this rotation was a relatively strong performer in all rankings, the sensitivity of this ranking to alfalfa yield and price parameters is deemed important; particularly in comparison with the rotation's primary competition: rotations 4, C-NB-B; 8, C-NB-NB-B; and 12, NB-C-SB. The alfalfa parameters only were tested as alfalfa was the major difference between rotation 14 and 4, 8, and 12. Results of the sensitivity analysis suggest the following:

1. Raising and lowering expected yield values by 10% had no effect on the relative ranking of rotation 14.
2. Raising and lowering expected price by 10% had no effect on relative ranking.
3. Raising the expected alfalfa price by 20% had no affect on relative ranking. Lowering the expected price by 20% dropped rotation 14 out of first place with rotation 4 and into second place with rotation 8.
4. Increasing alfalfa price variance by 50% had no effect on relative ranking.

Scope of the study. If the results of this study are to be placed in their proper perspective, recognition of the scope of this study are necessary.

1. The use of a "design parameter" which abstracts from some problems in order to highlight underlying relative relationships makes direct application of the absolute values generated to a particular farm unrealistic. Issues of taxes, debt equity structure of the farm were not addressed.
2. The labor market assumptions employed in this study are probably unrealistic. The machinery complements were designed such that one full time operator was available on the 400 acre operation and one full time family operator was available on the 600 acre configuration with additional help available from other family members; e.g., spouse or adolescent children at peak labor demand periods. This assumption was made in lieu of good knowledge of the operation of the hired labor market.
3. These rankings are based on the assumption that each system is operating in "steady state." Thus, if a producer wished to change from a C-NB-B system to O/A-A-NB-B, no investigation was made of the time-path of expected yields differential changes. In other words, in shifting from one rotation to another, how many years would it take before the yield benefits expected under the new rotation would accrue? This question was not addressed.

4. The expected alfalfa price is based on invesitgations of historical relative price relationships. If many farmers were to shift to growing alfalfa as a soil building cash crop, the assumption of price insensitivity to increased crop production by an individual producer is unwarranted at the aggregate level. This is particularly true of alfalfa. Since the crop is bulky, its market tends to be localized.
5. The estimates of price variance and yield variance are based on historical data. This presumes the future is adequately predicted by past behavior. This assumption is probably more realistic for yield data than for price data. The probability density functions graphed in Appendix J, are probably too exponential in appearance. This is true because the information used to generate them encompassed two eras of substantially different agricultural commodity price behaviors. The 1950s and 1960s was a period of stable prices and large surpluses, whereas the 1970s was a period of great volatility. If it is believed that the future will be similar to the recent past, then the price PDF's should be estimated using only the more recent data.

Conclusion

Based on the economic analysis conducted, the introduction of alfalfa as a soil builder into cash crop farming is not immediately a likely proposition. However, the possibility of introducing alfalfa is not as hopeless as some critics would believe. The strong ranking of the O/A-A-NB-B indicates that the economic benefits of good soil structure are real in terms of decreased variable costs and improved yields.

Successive crops of Navy beans are to be avoided. This is established since C-NB-B dominated C-NB-NB-B by first degree stochastic dominance in all ranking tests. Another point is that farmers are not employing "intense" cropping systems in a cash crop environment out of tradition or habit. They do it because it is profitable, at least in the short run; and any effort to modify or change agricultural practice must be attuned to the profitability test of decision makers.

In this study, the level and variability of net returns on land were used as the basis for decision making. It is realized that other factors such as labor availability and requirements, the present financial position of the operator; current farm organization, investment requirement, and the age of the operator are all important in selection of a cropping system strategy.

Recommendations for Further Research

One of the objectives accomplished with this study is to establish a methodology for analysis of many alternative crop rotations, cultural practices, and tillage systems. Given the methodology presented, it would be possible to analyze alternatives in light of generalized decision maker preferences. Possibilities include:

1. Application of conservation and no-till tillage practice.
2. Return to the practice of green manure winter cover crops which would offer some of the soil building benefits of alfalfa without tying-up productive farm land in a relatively unprofitable crop for an entire growing season.

Further research is needed in the development of machinery complements. Some incongruities appear with machinery costs. For example, on a 400 acre farm the machinery costs are $82.83 with a C-NB-B rotation and $117.51 with a O/A-A-NB-B rotation. This appears implausible since with O/A-A-NB-B, the farmer fall plows only 200 acres. But the model sizes machinery to meet peek conditions which with O/A-A-NB-B is in the spring cutting alfalfa and planting Navy beans. Considerable work needs to be done to permit scheduling work and making more economically sound decisions as to acquiring machinery capacity.

Further research should be carried out in evaluating stochastic sets where no clear choice is apparent. For example, on a 600 acre farm, stochastic dominance criteria are inconclusive between rotations 6, C-NB-W-B; 5, C-SB-B; and 12, NB-C-SB with expected returns of $151.53, $161.92, and $110.91, respectively. The difference between the expected returns of rotations 6 and 12 is $41.24 per acre. Despite this difference, stochastic dominance suggests that for some decision makers, rotation 12 would be preferred. The methodology of Meyer and King and Robison on estimation of rich aversion coefficients and their implantation in the determination of stochastically efficient sets should be implemented.

APPENDIX A

VARIABLE CASH COST BUDGETS

APPENDIX A

VARIABLE CASH COST BUDGETS

Variable cash cost per acre of each crop in each of the sixteen crop rotations is presented in this appendix. The cash cost per acre of a particular rotation is obtained by summing cash costs over all crops in the rotation and dividing by the number of crops in the rotation. Rotation number 8 (C-CB-NB-B), for example, has variable costs per acre of: corn, $50.70; 1st Navy beans $46.50, 2nd Navy beans, $44.63; and sugarbeets, $90.60. The average variable cost os this system is $58.11 per acre. This is obtained by summing $50.70, $46.50, $44.63, and $90.60 and dividing by four.

An interest charge of 13 percent for six months on variable cost is included to cover financing of working capital in the economic analysis. The finance charge is omitted in the following tables.

PAGE 1

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED ON SAGINAW VALLEY FARMS

ROTATION: C-NB — CROP: CORN — APPEARANCE: FIRST — YIELD: 115.0 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	13.5 LBS/ACRE	1.00	13.50
FERTILIZER			
NITROGEN 82-0-0	130.00 LBS/ACRE	.14	18.20
PHOSPHATE 0-46-0	40.30 LBS/ACRE	.20	8.06
POTASH 0-0-60	31.10 LBS/ACRE	.11	3.42
HERBICIDES			
ATRAZINE	.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
LASSO	2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
BLADEX	1.00 LB/ACRE ACTIVE INGREDIENT	3.34	3.34
TOTAL VARIABLE COST PER ACRE			52.02

ROTATION: C-NB — CROP: NAVYBEANS — APPEARANCE: FIRST — YIELD: 13.0 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	40.0 LBS/ACRE	.30	12.00
FERTILIZER			
NITROGEN 46-0-0	40.00 LBS/ACRE	.24	9.60
PHOSPHATE 0-46-0	10.80 LBS/ACRE	.20	2.16
POTASH 0-0-60	10.80 LBS/ACRE	.11	1.19
HERBICIDES			
EPTAM	2.25 LB/ACRE ACTIVE INGREDIENT	2.67	6.01
AMIBEN	2.00 LB/ACRE ACTIVE INGREDIENT	6.02	12.04
TREFLAN	.50 LB/ACRE ACTIVE INGREDIENT	7.01	3.51
TOTAL VARIABLE COST PER ACRE			46.50

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED ON SAGINAW VALLEY FARMS

ROTATION: C-SB   CROP: CORN   APPEARANCE: FIRST   YIELD: 115.0   BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	13.5 LRS/ACRE	1.00	13.50
FERTILIZER			
NITROGEN 82-0-0	100.00 LBS/ACRE	.14	14.00
PHOSPHATE 0-46-0	40.30 LBS/ACRE	.20	8.06
POTASH 0-0-60	31.10 LBS/ACRE	.11	3.42
HERBICIDES			
ATRAZINE	.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
LASSO	2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
BLADEX	1.00 LB/ACRE ACTIVE INGREDIENT	3.34	3.34
TOTAL VARIABLE COST PER ACRE			47.82

ROTATION: C-SB   CROP: SOYBEANS   APPEARANCE: FIRST   YIELD: 35.0   BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	50.0 LBS/ACRE	.28	14.00
FERTILIZER			
PHOSPHATE 0-46-0	31.50 LBS/ACRE	.20	6.30
POTASH 0-0-60	49.00 LBS/ACRE	.11	5.39
HERBICIDES			
LASSO	2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
LOROX	.75 LB/ACRE ACTIVE INGREDIENT	2.21	1.66
TOTAL VARIABLE COST PER ACRE			35.05

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED ON SAGINAW VALLEY FARMS

ROTATION: C-C-SB | CROP: CORN | APPEARANCE: FIRST | YIELD: 115.0 BU., TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	13.5 LBS/ACRE	1.00	13.50
FERTILIZER			
NITROGEN 82-0-0	100.00 LBS/ACRE	.14	14.00
PHOSPHATE 0-46-0	40.30 LBS/ACRE	.20	8.06
POTASH 0-0-60	31.10 LBS/ACRE	.11	3.42
HERBICIDES			
ATRAZINE	.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
SUTAN	.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
LASSO	2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
TOTAL VARIABLE COST PER ACRE			57.04

ROTATION: C-C-SB | CROP: CORN | APPEARANCE: SECOND | YIELD: 110.0 BU., TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	13.5 LBS/ACRE	1.00	13.50
FERTILIZER			
NITROGEN 82-0-0	124.30 LBS/ACRE	.14	17.40
PHOSPHATE 0-46-0	38.50 LBS/ACRE	.20	7.70
POTASH 0-0-60	29.70 LBS/ACRE	.11	3.27
HERBICIDES			
ATRAZINE	.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
LASSO	2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
BLADEX	1.00 LB/ACRE ACTIVE INGREDIENT	3.34	3.34
INSECTICIDES			
FURADAN	.75 LB/ACRE ACTIVE INGREDIENT	7.40	5.55
TOTAL VARIABLE COST PER ACRE			56.25

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED
ON SAGINAW VALLEY FARMS

ROTATION: C-C-SB

CROP: SOYBEANS APPEARANCE: FIRST YIELD: 35.0 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	50.0 LBS/ACRE	.28	14.00
FERTILIZER			
PHOSPHATE 0-46-0	31.50 LBS/ACRE	.20	6.30
POTASH 0-0-60	49.00 LBS/ACRE	.11	5.39
HERBICIDES			
LASSO	2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
LOROX	.75 LB/ACRE ACTIVE INGREDIENT	2.21	1.66
TOTAL VARIABLE COST PER ACRE			35.05

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED ON SAGINAW VALLEY FARMS

ROTATION: C-NB-B CROP: CORN APPEARANCE: FIRST YIELD: 110.0 BU.,TON, OR CWT/ACRE

ITEM		EXPLANATION	PRICE PER UNIT	COST
SEED		13.5 LBS/ACRE	1.00	13.50
FERTILIZER				
NITROGEN	82-0-0	124.30 LBS/ACRE	.14	17.40
PHOSPHATE	0-46-0	38.50 LBS/ACRE	.20	7.70
POTASH	0-0-60	29.70 LBS/ACRE	.11	3.27
HERBICIDES				
ATRAZINE		.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
LASSO		2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
BLADEX		1.00 LB/ACRE ACTIVE INGREDIENT	3.34	3.34
TOTAL VARIABLE COST PER ACRE				50.70

ROTATION: C-NB-B CROP: NAVYBEANS APPEARANCE: FIRST YIELD: 12.0 BU.,TON, OR CWT/ACRE

ITEM		EXPLANATION	PRICE PER UNIT	COST
SEED		40.0 LBS/ACRE	.30	12.00
FERTILIZER				
NITROGEN	46-0-0	37.60 LBS/ACRE	.24	9.02
PHOSPHATE	0-46-0	10.00 LBS/ACRE	.20	2.00
POTASH	0-0-60	10.00 LBS/ACRE	.11	1.10
HERBICIDES				
EPTAM		2.25 LB/ACRE ACTIVE INGREDIENT	2.67	6.01
AMIBEN		2.00 LB/ACRE ACTIVE INGREDIENT	6.02	12.04
TREFLAN		.50 LB/ACRE ACTIVE INGREDIENT	7.01	3.51
TOTAL VARIABLE COST PER ACRE				45.68

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED ON SAGINAW VALLEY FARMS

ROTATION: C-NB-B   CROP: SUGARBEETS   APPEARANCE: FIRST   YIELD: 21.0 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	1.0 LBS/ACRE	5.00	5.00
FERTILIZER			
NITROGEN 46-0-0	105.00 LBS/ACRE	.24	25.20
PHOSPHATE 0-46-0	27.30 LBS/ACRE	.20	5.46
POTASH 0-0-60	69.30 LBS/ACRE	.11	7.62
HERBICIDES			
PYRAMIN	3.00 LB/ACRE ACTIVE INGREDIENT	13.50	40.50
TCA	6.00 LB/ACRE ACTIVE INGREDIENT	1.45	8.70
TOTAL VARIABLE COST PER ACRE			92.48

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED
ON SAGINAW VALLEY FARMS

ROTATION: C-NB-B　　CROP: SUGARBEETS　　APPEARANCE: FIRST　　YIELD: 21.0　BU.,TON, OR CWT/ACRE

ITEM		EXPLANATION	PRICE PER UNIT	COST
SEED		1.0 LBS/ACRE	5.00	5.00
FERTILIZER				
NITROGEN	46-0-0	105.00 LBS/ACRE	.24	25.20
PHOSPHATE	0-46-0	27.30 LBS/ACRE	.20	5.46
POTASH	0-0-60	69.30 LBS/ACRE	.11	7.62
HERBICIDES				
PYRAMIN		3.00 LB/ACRE ACTIVE INGREDIENT	13.50	40.50
TCA		6.00 LB/ACRE ACTIVE INGREDIENT	1.45	8.70
TOTAL VARIABLE COST PER ACRE				92.48

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED ON SAGINAW VALLEY FARMS

ROTATION: C-SB-B CROP: CORN APPEARANCE: FIRST YIELD: 110.0 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	13.5 LBS/ACRE	1.00	13.50
FERTILIZER			
NITROGEN 82-0-0	124.30 LBS/ACRE	.14	17.40
PHOSPHATE 0-46-0	38.50 LBS/ACRE	.20	7.70
POTASH 0-0-60	29.70 LBS/ACRE	.11	3.27
HERBICIDES			
ATRAZINE	.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
LASSO	2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
BLADEX	1.00 LB/ACRE ACTIVE INGREDIENT	3.34	3.34
TOTAL VARIABLE COST PER ACRE			50.70

ROTATION: C-SB-B CROP: SOYBEANS APPEARANCE: FIRST YIELD: 35.0 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	35.0 LBS/ACRE	.28	9.80
FERTILIZER			
PHOSPHATE 0-46-0	31.50 LBS/ACRE	.20	6.30
POTASH 0-0-60	49.00 LBS/ACRE	.11	5.39
HERBICIDES			
LASSO	2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
LOROX	.75 LB/ACRE ACTIVE INGREDIENT	2.21	1.66
TOTAL VARIABLE COST PER ACRE			30.85

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED
ON SAGINAW VALLEY FARMS

ROTATION: C-SB-B   CROP: SUGARBEETS   APPEARANCE: FIRST   YIELD: 21.0   BU.,TON, OR CWT/ACRE

ITEM		EXPLANATION	PRICE PER UNIT	COST
SEED		1.0 LBS/ACRE	5.00	5.00
FERTILIZER				
NITROGEN	46-0-0	75.00 LBS/ACRE	.24	18.00
PHOSPHATE	0-46-0	27.30 LBS/ACRE	.20	5.46
POTASH	0-0-60	69.30 LBS/ACRE	.11	7.62
HERBICIDES				
PYRAMIN		3.00 LB/ACRE ACTIVE INGREDIENT	13.50	40.50
TCA		6.00 LB/ACRE ACTIVE INGREDIENT	1.45	8.70
TOTAL VARIABLE COST PER ACRE				85.28

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED ON SAGINAW VALLEY FARMS

ROTATION: C-NB-W-B   CROP: CORN   APPEARANCE: FIRST   YIELD: 110.0   BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	13.5 LBS/ACRE	1.00	13.50
FERTILIZER			
NITROGEN 82-0-0	124.30 LBS/ACRE	.14	17.40
PHOSPHATE 0-46-0	38.50 LBS/ACRE	.20	7.70
POTASH 0-0-60	29.70 LBS/ACRE	.11	3.27
HERBICIDES			
ATRAZINE	.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
LASSO	2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
BLADEX	1.00 LB/ACRE ACTIVE INGREDIENT	3.34	3.34
TOTAL VARIABLE COST PER ACRE			50.70

ROTATION: C-NB-W-B   CROP: NAVYBEANS   APPEARANCE: FIRST   YIELD: 14.0   BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	40.0 LBS/ACRE	.30	12.00
FERTILIZER			
NITROGEN 46-0-0	43.80 LBS/ACRE	.24	10.51
PHOSPHATE 0-46-0	11.60 LBS/ACRE	.20	2.32
POTASH 0-0-60	11.60 LBS/ACRE	.11	1.28
HERBICIDES			
EPTAM	2.25 LB/ACRE ACTIVE INGREDIENT	2.67	6.01
AMIBEN	2.00 LB/ACRE ACTIVE INGREDIENT	6.02	12.04
TREFLAN	.50 LB/ACRE ACTIVE INGREDIENT	7.01	3.51
TOTAL VARIABLE COST PER ACRE			47.66

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED
ON SAGINAW VALLEY FARMS

ROTATION: C-NB-W-B — CROP: WHEAT — APPEARANCE: FIRST — YIELD: 60.0 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	120.0 LBS/ACRE	.14	16.80
FERTILIZER			
NITROGEN 46-0-0	90.00 LBS/ACRE	.24	21.60
PHOSPHATE 0-46-0	37.20 LBS/ACRE	.20	7.44
POTASH 0-0-60	22.80 LBS/ACRE	.11	2.51
HERBICIDES			
2 4D	.50 LB/ACRE ACTIVE INGREDIENT	2.44	1.22
TOTAL VARIABLE COST PER ACRE			49.57

ROTATION: C-NB-W-B — CROP: SUGARBEETS — APPEARANCE: FIRST — YIELD: 20.0 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	1.0 LBS/ACRE	5.00	5.00
FERTILIZER			
NITROGEN 46-0-0	100.00 LBS/ACRE	.24	24.00
PHOSPHATE 0-46-0	26.00 LBS/ACRE	.20	5.20
POTASH 0-0-60	66.00 LBS/ACRE	.11	7.26
HERBICIDES			
PYRAMIN	3.00 LB/ACRE ACTIVE INGREDIENT	13.50	40.50
TCA	6.00 LB/ACRE ACTIVE INGREDIENT	1.45	8.70
TOTAL VARIABLE COST PER ACRE			90.66

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED
ON SAGINAW VALLEY FARMS

ROTATION: C-SB-W-B — CROP: CORN — APPEARANCE: FIRST — YIELD: 110.0 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	13.5 LBS/ACRE	1.00	13.50
FERTILIZER			
NITROGEN 82-0-0	124.30 LBS/ACRE	.14	17.40
PHOSPHATE 0-46-0	38.50 LBS/ACRE	.20	7.70
POTASH 0-0-60	29.70 LBS/ACRE	.11	3.27
HERBICIDES			
ATRAZINE	.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
LASSO	2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
BLADEX	1.00 LB/ACRE ACTIVE INGREDIENT	3.34	3.34
TOTAL VARIABLE COST PER ACRE			50.70

ROTATION: C-SB-W-B — CROP: SOYBEANS — APPEARANCE: FIRST — YIELD: 35.0 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	50.0 LBS/ACRE	.28	14.00
FERTILIZER			
PHOSPHATE 0-46-0	31.50 LBS/ACRE	.20	6.30
POTASH 0-0-60	49.00 LBS/ACRE	.11	5.39
HERBICIDES			
LASSO	2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
LOROX	.75 LB/ACRE ACTIVE INGREDIENT	2.21	1.66
TOTAL VARIABLE COST PER ACRE			35.05

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED ON SAGINAW VALLEY FARMS

ROTATION: C-SB-W-B   CROP: WHEAT   APPEARANCE: FIRST   YIELD: 55.0   BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	120.0 LBS/ACRE	.14	16.80
FERTILIZER			
NITROGEN 46-0-0	52.50 LBS/ACRE	.24	12.60
PHOSPHATE 0-46-0	34.10 LBS/ACRE	.20	6.82
POTASH 0-0-60	20.90 LBS/ACRE	.11	2.30
HERBICIDES			
2 4D	.50 LB/ACRE ACTIVE INGREDIENT	2.44	1.22
TOTAL VARIABLE COST PER ACRE			39.74

ROTATION: C-SB-W-B   CROP: SUGARBEETS   APPEARANCE: FIRST   YIELD: 20.0   BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	1.0 LBS/ACRE	5.00	5.00
FERTILIZER			
NITROGEN 46-0-0	100.00 LBS/ACRE	.24	24.00
PHOSPHATE 0-46-0	26.00 LBS/ACRE	.20	5.20
POTASH 0-0-60	66.00 LBS/ACRE	.11	7.26
HERBICIDES			
PYRAMIN	3.00 LB/ACRE ACTIVE INGREDIENT	13.50	40.50
TCA	6.00 LB/ACRE ACTIVE INGREDIENT	1.45	8.70
TOTAL VARIABLE COST PER ACRE			90.66

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED
ON SAGINAW VALLEY FARMS

ROTATION: C-NB-NB-B　CROP: CORN　APPEARANCE: FIRST　YIELD: 110.0　BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	13.5 LBS/ACRE	1.00	13.50
FERTILIZER			
NITROGEN 82-0-0	124.30 LBS/ACRE	.14	17.40
PHOSPHATE 0-46-0	38.50 LBS/ACRE	.20	7.70
POTASH 0-0-60	29.70 LBS/ACRE	.11	3.27
HERBICIDES			
ATRAZINE	.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
LASSO	2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
BLADEX	1.00 LB/ACRE ACTIVE INGREDIENT	3.34	3.34
TOTAL VARIABLE COST PER ACRE			50.70

ROTATION: C-NB-NB-B　CROP: NAVYBEANS　APPEARANCE: FIRST　YIELD: 13.0　BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	40.0 LBS/ACRE	.30	12.00
FERTILIZER			
NITROGEN 46-0-0	40.00 LBS/ACRE	.24	9.60
PHOSPHATE 0-46-0	10.80 LBS/ACRE	.20	2.16
POTASH 0-0-60	10.80 LBS/ACRE	.11	1.19
HERBICIDES			
EPTAM	2.25 LB/ACRE ACTIVE INGREDIENT	2.67	6.01
AMIBEN	2.00 LB/ACRE ACTIVE INGREDIENT	6.02	12.04
TREFLAN	.50 LB/ACRE ACTIVE INGREDIENT	7.01	3.51
TOTAL VARIABLE COST PER ACRE			46.50

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED
ON SAGINAW VALLEY FARMS

ROTATION: C-NB-NB-B CROP: NAVYBEANS APPEARANCE: SECOND YIELD: 11.0 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	40.0 LBS/ACRE	.30	12.00
FERTILIZER			
NITROGEN 46-0-0	34.40 LBS/ACRE	.24	8.26
PHOSPHATE 0-46-0	9.10 LBS/ACRE	.20	1.82
POTASH 0-0-60	9.10 LBS/ACRE	.11	1.00
HERBICIDES			
EPTAM	2.25 LB/ACRE ACTIVE INGREDIENT	2.67	6.01
AMIBEN	2.00 LB/ACRE ACTIVE INGREDIENT	6.02	12.04
TREFLAN	.50 LB/ACRE ACTIVE INGREDIENT	7.01	3.51
TOTAL VARIABLE COST PER ACRE			44.63

ROTATION: C-NB-NB-B CROP: SUGARBEETS APPEARANCE: FIRST YIELD: 20.0 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	1.0 LBS/ACRE	5.00	5.00
FERTILIZER			
NITROGEN 46-0-0	100.00 LBS/ACRE	.24	24.00
PHOSPHATE 0-46-0	26.00 LBS/ACRE	.20	5.20
POTASH 0-0-60	66.00 LBS/ACRE	.11	7.26
HERBICIDES			
PYRAMIN	3.00 LB/ACRE ACTIVE INGREDIENT	13.50	40.50
TCA	6.00 LB/ACRE ACTIVE INGREDIENT	1.45	8.70
TOTAL VARIABLE COST PER ACRE			90.66

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED ON SAGINAW VALLEY FARMS

ROTATION: O/A-A-A-C-C-SB-C CROP: OATS APPEARANCE: FIRST YIELD: 80.0 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	55.0 LBS/ACRE	.13	6.88
FERTILIZER			
NITROGEN 46-0-0	30.00 LBS/ACRE	.24	7.20
PHOSPHATE 0-46-0	41.90 LBS/ACRE	.20	8.38
POTASH 0-0-60	132.00 LBS/ACRE	.11	14.52
HERBICIDES			
MCPA	.19 LB/ACRE ACTIVE INGREDIENT	.68	.13
TOTAL VARIABLE COST PER ACRE			37.10

ROTATION: O/A-A-A-C-C-SB-C CROP: ALFALFA APPEARANCE: FIRST YIELD: 1.0 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	12.0 LBS/ACRE	2.40	28.80
FERTILIZER			
PHOSPHATE 0-46-0	10.00 LBS/ACRE	.20	2.00
POTASH 0-0-60	45.00 LBS/ACRE	.11	4.95
HERBICIDES			
MCPA	.19 LB/ACRE ACTIVE INGREDIENT	.68	.13
TOTAL VARIABLE COST PER ACRE			35.88

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED ON SAGINAW VALLEY FARMS

ROTATION: O/A-A-A-C-C-SB-C   CROP: ALFALFA   APPEARANCE: SECOND   YIELD: 4.6 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
FERTILIZER			
PHOSPHATE 0-46-0	46.00 LBS/ACRE	.20	9.20
POTASH 0-0-60	207.00 LBS/ACRE	.11	22.77
TOTAL VARIABLE COST PER ACRE			31.97

ROTATION: O/A-A-A-C-C-SB-C   CROP: ALFALFA   APPEARANCE: THIRD   YIELD: 4.4 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
FERTILIZER			
PHOSPHATE 0-46-0	44.00 LBS/ACRE	.20	8.80
POTASH 0-0-60	198.00 LBS/ACRE	.11	21.78
TOTAL VARIABLE COST PER ACRE			30.58

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED ON SAGINAW VALLEY FARMS

ROTATION: O/A-A-A-C-C-SB-C CROP: CORN APPEARANCE: FIRST YIELD: 118.0 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	13.5 LBS/ACRE	1.00	13.50
FERTILIZER			
NITROGEN 82-0-0	63.30 LBS/ACRE	.14	8.86
PHOSPHATE 0-46-0	41.30 LBS/ACRE	.20	8.26
POTASH 0-0-60	31.90 LBS/ACRE	.11	3.51
HERBICIDES			
ATRAZINE	.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
SUTAN	.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
LASSO	2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
TOTAL VARIABLE COST PER ACRE			52.19

ROTATION: O/A-A-A-C-C-SB-C CROP: CORN APPEARANCE: SECOND YIELD: 115.0 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	13.5 LBS/ACRE	1.00	13.50
FERTILIZER			
NITROGEN 82-0-0	130.00 LBS/ACRE	.14	18.20
PHOSPHATE 0-46-0	40.30 LBS/ACRE	.20	8.06
POTASH 0-0-60	31.10 LBS/ACRE	.11	3.42
HERBICIDES			
ATRAZINE	.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
LASSO	2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
BLADEX	1.00 LB/ACRE ACTIVE INGREDIENT	3.34	3.34
INSECTICIDES			
FURADAN	.75 LB/ACRE ACTIVE INGREDIENT	7.40	5.55
TOTAL VARIABLE COST PER ACRE			57.57

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED
ON SAGINAW VALLEY FARMS

ROTATION: O/A-A-A-C-C-SB-C   CROP: SOYBEANS   APPEARANCE: FIRST   YIELD: 35.0   BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	50.0 LBS/ACRE	.28	14.00
FERTILIZER			
PHOSPHATE 0-46-0	31.50 LBS/ACRE	.20	6.30
POTASH 0-0-60	49.00 LBS/ACRE	.11	5.39
HERBICIDES			
LASSO	2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
LOROX	.75 LB/ACRE ACTIVE INGREDIENT	2.21	1.66
BLADEX	9.00 LB/ACRE ACTIVE INGREDIENT	3.34	30.06
TOTAL VARIABLE COST PER ACRE			35.05

ROTATION: O/A-A-A-C-C-SB-C   CROP: CORN   APPEARANCE: THIRD   YIELD: 115.0   BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	13.5 LBS/ACRE	1.00	13.50
FERTILIZER			
NITROGEN 82-0-0	100.00 LBS/ACRE	.14	14.00
PHOSPHATE 0-46-0	40.30 LBS/ACRE	.20	8.06
POTASH 0-0-60	31.10 LBS/ACRE	.11	3.42
HERBICIDES			
ATRAZINE	.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
LASSO	2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
BLADEX	1.00 LB/ACRE ACTIVE INGREDIENT	3.34	3.34
TOTAL VARIABLE COST PER ACRE			47.82

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED ON SAGINAW VALLEY FARMS

ROTATION: O/A-A-A-A-A-C-C-C   CROP: OATS   APPEARANCE: FIRST   YIELD: 80.0 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	55.0 LBS/ACRE	.13	6.88
FERTILIZER			
NITROGEN 46-0-0	30.00 LBS/ACRE	.24	7.20
PHOSPHATE 0-46-0	41.90 LBS/ACRE	.20	8.38
POTASH 0-0-60	132.00 LBS/ACRE	.11	14.52
HERBICIDES			
MCPA	.19 LB/ACRE ACTIVE INGREDIENT	.68	.13
TOTAL VARIABLE COST PER ACRE			37.10

ROTATION: O/A-A-A-A-A-C-C-C   CROP: ALFALFA   APPEARANCE: FIRST   YIELD: 1.0 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	12.0 LBS/ACRE	2.40	28.80
FERTILIZER			
PHOSPHATE 0-46-0	10.00 LBS/ACRE	.20	2.00
POTASH 0-0-60	45.00 LBS/ACRE	.11	4.95
HERBICIDES			
MCPA	.19 LB/ACRE ACTIVE INGREDIENT	.68	.13
TOTAL VARIABLE COST PER ACRE			35.88

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED
ON SAGINAW VALLEY FARMS

ROTATION: O/A-A-A-A-A-C-C-C   CROP: ALFALFA   APPEARANCE: SECOND   YIELD: 4.6 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
FERTILIZER			
PHOSPHATE 0-46-0	46.00 LBS/ACRE	.20	9.20
POTASH 0-0-60	207.00 LBS/ACRE	.11	22.77
TOTAL VARIABLE COST PER ACRE			31.97

ROTATION: O/A-A-A-A-A-C-C-C   CROP: ALFALFA   APPEARANCE: THIRD   YIELD: 4.4 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
FERTILIZER			
PHOSPHATE 0-46-0	44.00 LBS/ACRE	.20	8.80
POTASH 0-0-60	198.00 LBS/ACRE	.11	21.78
TOTAL VARIABLE COST PER ACRE			30.58

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED ON SAGINAW VALLEY FARMS

ROTATION: O/A-A-A-A-A-C-C-C CROP: ALFALFA APPEARANCE: FOURTH YIELD: 4.0 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
FERTILIZER			
PHOSPHATE 0-46-0	40.00 LBS/ACRE	.20	8.00
POTASH 0-0-60	180.00 LBS/ACRE	.11	19.80
TOTAL VARIABLE COST PER ACRE			27.80

ROTATION: O/A-A-A-A-A-C-C-C CROP: ALFALFA APPEARANCE: FIFTH YIELD: 3.8 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
FERTILIZER			
PHOSPHATE 0-46-0	38.00 LBS/ACRE	.20	7.60
POTASH 0-0-60	171.00 LBS/ACRE	.11	18.81
TOTAL VARIABLE COST PER ACRE			26.41

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED
ON SAGINAW VALLEY FARMS

ROTATION: O/A-A-A-A-A-C-C-C   CROP: CORN   APPEARANCE: FIRST   YIELD: 118.0   BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	13.5 LBS/ACRE	1.00	13.50
FERTILIZER			
NITROGEN 82-0-0	63.30 LBS/ACRE	.14	8.86
PHOSPHATE 0-46-0	41.30 LBS/ACRE	.20	8.26
POTASH 0-0-60	31.90 LBS/ACRE	.11	3.51
HERBICIDES			
ATRAZINE	.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
SUTAN	.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
LASSO	2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
TOTAL VARIABLE COST PER ACRE			52.19

ROTATION: O/A-A-A-A-A-C-C-C   CROP: CORN   APPEARANCE: SECOND   YIELD: 115.0   BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	13.5 LBS/ACRE	1.00	13.50
FERTILIZER			
NITROGEN 82-0-0	130.00 LBS/ACRE	.14	18.20
PHOSPHATE 0-46-0	40.30 LBS/ACRE	.20	8.06
POTASH 0-0-60	31.10 LBS/ACRE	.11	3.42
HERBICIDES			
ATRAZINE	.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
SUTAN	.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
LASSO	2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
INSECTICIDES			
FURADAN	.75 LB/ACRE ACTIVE INGREDIENT	7.40	5.55
TOTAL VARIABLE COST PER ACRE			66.79

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED
ON SAGINAW VALLEY FARMS

ROTATION: O/A-A-A-A-A-C-C-C   CROP: CORN   APPEARANCE: THIRD   YIELD: 110.0   BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	13.5 LBS/ACRE	1.00	13.50
FERTILIZER			
NITROGEN 82-0-0	124.30 LBS/ACRE	.14	17.40
PHOSPHATE 0-46-0	38.50 LBS/ACRE	.20	7.70
POTASH 0-0-60	29.70 LBS/ACRE	.11	3.27
HERBICIDES			
ATRAZINE	.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
LASSO	2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
BLADEX	1.00 LB/ACRE ACTIVE INGREDIENT	3.34	3.34
INSECTICIDES			
FURADAN	.75 LB/ACRE ACTIVE INGREDIENT	7.40	5.55
TOTAL VARIABLE COST PER ACRE			56.25

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED ON SAGINAW VALLEY FARMS

ROTATION: C-C-NB-W   CROP: CORN   APPEARANCE: FIRST   YIELD: 110.0   BU.,TON, OR CWT/ACRE

ITEM		EXPLANATION	PRICE PER UNIT	COST
SEED		13.5 LBS/ACRE	1.00	13.50
FERTILIZER				
NITROGEN	82-0-0	124.30 LBS/ACRE	.14	17.40
PHOSPHATE	0-46-0	38.50 LBS/ACRE	.20	7.70
POTASH	0-0-60	29.70 LBS/ACRE	.11	3.27
HERBICIDES				
ATRAZINE		.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
SUTAN		.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
LASSO		2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
TOTAL VARIABLE COST PER ACRE				59.93

ROTATION: C-C-NB-W   CROP: CORN   APPEARANCE: SECOND   YIELD: 110.0   BU.,TON, OR CWT/ACRE

ITEM		EXPLANATION	PRICE PER UNIT	COST
SEED		13.5 LBS/ACRE	1.00	13.50
FERTILIZER				
NITROGEN	82-0-0	124.30 LBS/ACRE	.14	17.40
PHOSPHATE	0-46-0	38.50 LBS/ACRE	.20	7.70
POTASH	0-0-60	29.70 LBS/ACRE	.11	3.27
HERBICIDES				
ATRAZINE		.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
LASSO		2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
BLADEX		1.00 LB/ACRE ACTIVE INGREDIENT	3.34	3.34
INSECTICIDES				
FURADAN		.75 LB/ACRE ACTIVE INGREDIENT	7.40	5.55
TOTAL VARIABLE COST PER ACRE				56.25

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED
ON SAGINAW VALLEY FARMS

ROTATION: C-C-NB-W CROP: NAVYBEANS APPEARANCE: FIRST YIELD: 14.0 BU.,TON, OR CWT/ACRE

ITEM		EXPLANATION	PRICE PER UNIT	COST
SEED		40.0 LBS/ACRE	.30	12.00
FERTILIZER				
NITROGEN	46-0-0	43.80 LBS/ACRE	.24	10.51
PHOSPHATE	0-46-0	11.60 LBS/ACRE	.20	2.32
POTASH	0-0-60	11.60 LBS/ACRE	.11	1.28
HERBICIDES				
EPTAM		2.25 LB/ACRE ACTIVE INGREDIENT	2.67	6.01
AMIBEN		2.00 LB/ACRE ACTIVE INGREDIENT	6.02	12.04
TREFLAN		.50 LB/ACRE ACTIVE INGREDIENT	7.01	3.51
TOTAL VARIABLE COST PER ACRE				47.66

ROTATION: C-C-NB-W CROP: WHEAT APPEARANCE: FIRST YIELD: 60.0 BU.,TON, OR CWT/ACRE

ITEM		EXPLANATION	PRICE PER UNIT	COST
SEED		120.0 LBS/ACRE	.14	16.80
FERTILIZER				
NITROGEN	46-0-0	90.00 LBS/ACRE	.24	21.60
PHOSPHATE	0-46-0	37.20 LBS/ACRE	.20	7.44
POTASH	0-0-60	22.80 LBS/ACRE	.11	2.51
HERBICIDES				
2 4D		.50 LB/ACRE ACTIVE INGREDIENT	2.44	1.22
TOTAL VARIABLE COST PER ACRE				49.57

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED
ON SAGINAW VALLEY FARMS

ROTATION: NB-C-SB   CROP: NAVYBEANS   APPEARANCE: FIRST   YIELD: 12.0   BU.,TON, OR CWT/ACRE

ITEM		EXPLANATION	PRICE PER UNIT	COST
SEED		40.0 LBS/ACRE	.30	12.00
FERTILIZER				
NITROGEN	46-0-0	37.60 LBS/ACRE	.24	9.02
PHOSPHATE	0-46-0	10.00 LBS/ACRE	.20	2.00
POTASH	0-0-60	10.00 LBS/ACRE	.11	1.10
HERBICIDES				
EPTAM		2.25 LB/ACRE ACTIVE INGREDIENT	2.67	6.01
AMIBEN		2.00 LB/ACRE ACTIVE INGREDIENT	6.02	12.04
TREFLAN		.50 LB/ACRE ACTIVE INGREDIENT	7.01	3.51
TOTAL VARIABLE COST PER ACRE				45.68

ROTATION: NB-C-SB   CROP: CORN   APPEARANCE: FIRST   YIELD: 115.0   BU.,TON, OR CWT/ACRE

ITEM		EXPLANATION	PRICE PER UNIT	COST
SEED		13.5 LBS/ACRE	1.00	13.50
FERTILIZER				
NITROGEN	82-0-0	130.00 LBS/ACRE	.14	18.20
PHOSPHATE	0-46-0	40.30 LBS/ACRE	.20	8.06
POTASH	0-0-60	31.10 LBS/ACRE	.11	3.42
HERBICIDES				
ATRAZINE		.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
LASSO		2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
BLADEX		1.00 LB/ACRE ACTIVE INGREDIENT	3.34	3.34
TOTAL VARIABLE COST PER ACRE				52.02

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED
ON SAGINAW VALLEY FARMS

ROTATION: NB-C-SB CROP: SOYBEANS APPEARANCE: FIRST YIELD: 35.0 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	50.0 LBS/ACRE	.28	14.00
FERTILIZER			
PHOSPHATE 0-46-0	31.50 LBS/ACRE	.20	6.30
POTASH 0-0-60	49.00 LBS/ACRE	.11	5.39
HERBICIDES			
LASSO	2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
LOROX	.75 LB/ACRE ACTIVE INGREDIENT	2.21	1.66
TOTAL VARIABLE COST PER ACRE			35.05

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED
ON SAGINAW VALLEY FARMS

ROTATION: C-C-NB-B   CROP: CORN   APPEARANCE: FIRST   YIELD: 110.0   BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	13.5 LBS/ACRE	1.00	13.50
FERTILIZER			
NITROGEN 82-0-0	124.30 LBS/ACRE	.14	17.40
PHOSPHATE 0-46-0	38.50 LBS/ACRE	.20	7.70
POTASH 0-0-60	29.70 LBS/ACRE	.11	3.27
HERBICIDES			
ATRAZINE	.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
SUTAN	.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
LASSO	2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
TOTAL VARIABLE COST PER ACRE			59.93

ROTATION: C-C-NB-B   CROP: CORN   APPEARANCE: SECOND   YIELD: 110.0   BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	13.5 LBS/ACRE	1.00	13.50
FERTILIZER			
NITROGEN 82-0-0	124.30 LBS/ACRE	.14	17.40
PHOSPHATE 0-46-0	38.50 LBS/ACRE	.20	7.70
POTASH 0-0-60	29.70 LBS/ACRE	.11	3.27
HERBICIDES			
ATRAZINE	.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
LASSO	2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
BLADEX	1.00 LB/ACRE ACTIVE INGREDIENT	3.34	3.34
INSECTICIDES			
FURADAN	.75 LB/ACRE ACTIVE INGREDIENT	7.40	5.55
TOTAL VARIABLE COST PER ACRE			56.25

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED ON SAGINAW VALLEY FARMS

ROTATION: C-C-NB-B   CROP: NAVYBEANS   APPEARANCE: FIRST   YIELD: 14.0 BU.,TON, OR CWT/ACRE

ITEM		EXPLANATION	PRICE PER UNIT	COST
SEED		40.0 LBS/ACRE	.30	12.00
FERTILIZER				
NITROGEN	46-0-0	43.80 LBS/ACRE	.24	10.51
PHOSPHATE	0-46-0	11.60 LBS/ACRE	.20	2.32
POTASH	0-0-60	11.60 LBS/ACRE	.11	1.28
HERBICIDES				
EPTAM		2.25 LB/ACRE ACTIVE INGREDIENT	2.67	6.01
AMIBEN		2.00 LB/ACRE ACTIVE INGREDIENT	6.02	12.04
TREFLAN		.50 LB/ACRE ACTIVE INGREDIENT	7.01	3.51
TOTAL VARIABLE COST PER ACRE				47.66

ROTATION: C-C-NB-B   CROP: SUGARBEETS   APPEARANCE: FIRST   YIELD: 21.0 BU.,TON, OR CWT/ACRE

ITEM		EXPLANATION	PRICE PER UNIT	COST
SEED		1.0 LBS/ACRE	5.00	5.00
FERTILIZER				
NITROGEN	46-0-0	105.00 LBS/ACRE	.24	25.20
PHOSPHATE	0-46-0	27.30 LBS/ACRE	.20	5.46
POTASH	0-0-60	69.30 LBS/ACRE	.11	7.62
HERBICIDES				
PYRAMIN		3.00 LB/ACRE ACTIVE INGREDIENT	13.50	40.50
TCA		6.00 LB/ACRE ACTIVE INGREDIENT	1.45	8.70
TOTAL VARIABLE COST PER ACRE				92.48

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED
ON SAGINAW VALLEY FARMS

ROTATION: O/A-A-NB-B — CROP: OATS — APPEARANCE: FIRST — YIELD: 80.0 BU.,TON, OR CWT/ACRE

ITEM		EXPLANATION	PRICE PER UNIT	COST
SEED		55.0 LBS/ACRE	.13	6.88
FERTILIZER				
NITROGEN	46-0-0	30.00 LBS/ACRE	.24	7.20
PHOSPHATE	0-46-0	41.90 LBS/ACRE	.20	8.38
POTASH	0-0-60	132.00 LBS/ACRE	.11	14.52
HERBICIDES				
MCPA		.19 LB/ACRE ACTIVE INGREDIENT	.68	.13
TOTAL VARIABLE COST PER ACRE				37.10

ROTATION: O/A-A-NB-B — CROP: ALFALFA — APPEARANCE: FIRST — YIELD: 1.0 BU.,TON, OR CWT/ACRE

ITEM		EXPLANATION	PRICE PER UNIT	COST
SEED		12.0 LBS/ACRE	2.40	28.80
FERTILIZER				
PHOSPHATE	0-46-0	10.00 LBS/ACRE	.20	2.00
POTASH	0-0-60	45.00 LBS/ACRE	.11	4.95
HERBICIDES				
MCPA		.19 LB/ACRE ACTIVE INGREDIENT	.68	.13
TOTAL VARIABLE COST PER ACRE				35.88

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED
ON SAGINAW VALLEY FARMS

ROTATION: O/A-A-NB-B CROP: ALFALFA APPEARANCE: SECOND YIELD: 4.6 BU.,TON, OR CWT/ACRE

ITEM		EXPLANATION	PRICE PER UNIT	COST
SEED		12.0 LBS/ACRE	2.40	28.80
FERTILIZER				
PHOSPHATE	0-46-0	46.00 LBS/ACRE	.20	9.20
POTASH	0-0-60	207.00 LBS/ACRE	.11	22.77
TOTAL VARIABLE COST PER ACRE				60.77

ROTATION: O/A-A-NB-B CROP: NAVYBEANS APPEARANCE: FIRST YIELD: 16.0 BU.,TON, OR CWT/ACRE

ITEM		EXPLANATION	PRICE PER UNIT	COST
SEED		40.0 LBS/ACRE	.30	12.00
FERTILIZER				
PHOSPHATE	0-46-0	13.30 LBS/ACRE	.20	2.66
POTASH	0-0-60	13.30 LBS/ACRE	.11	1.46
HERBICIDES				
EPTAM		2.25 LB/ACRE ACTIVE INGREDIENT	2.67	6.01
AMIBEN		2.00 LB/ACRE ACTIVE INGREDIENT	6.02	12.04
TREFLAN		.50 LB/ACRE ACTIVE INGREDIENT	7.01	3.51
TOTAL VARIABLE COST PER ACRE				37.68

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED
ON SAGINAW VALLEY FARMS

ROTATION: O/A-A-NB-B CROP: SUGARBEETS APPEARANCE: FIRST YIELD: 22.0 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	1.0 LBS/ACRE	5.00	5.00
FERTILIZER			
NITROGEN 46-0-0	110.00 LBS/ACRE	.24	26.40
PHOSPHATE 0-46-0	28.60 LBS/ACRE	.20	5.72
POTASH 0-0-60	72.60 LBS/ACRE	.11	7.99
HERBICIDES			
PYRAMIN	3.00 LB/ACRE ACTIVE INGREDIENT	13.50	40.50
TCA	6.00 LB/ACRE ACTIVE INGREDIENT	1.45	8.70
TOTAL VARIABLE COST PER ACRE			94.31

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED
ON SAGINAW VALLEY FARMS

ROTATION: O-NB-B CROP: OATS APPEARANCE: FIRST YIELD: 100.0 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	70.0 LBS/ACRE	.13	8.75
FERTILIZER			
NITROGEN 46-0-0	78.00 LBS/ACRE	.24	18.72
PHOSPHATE 0-46-0	25.00 LBS/ACRE	.20	5.00
POTASH 0-0-60	19.00 LBS/ACRE	.11	2.09
HERBICIDES			
MCPA	.38 LB/ACRE ACTIVE INGREDIENT	.68	.26
TOTAL VARIABLE COST PER ACRE			34.82

ROTATION: O-NB-B CROP: NAVYBEANS APPEARANCE: FIRST YIELD: 11.0 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	40.0 LBS/ACRE	.30	12.00
FERTILIZER			
NITROGEN 46-0-0	34.40 LBS/ACRE	.24	8.26
PHOSPHATE 0-46-0	9.10 LBS/ACRE	.20	1.82
POTASH 0-0-60	9.10 LBS/ACRE	.11	1.00
HERBICIDES			
EPTAM	2.25 LB/ACRE ACTIVE INGREDIENT	2.67	6.01
AMIBEN	2.00 LB/ACRE ACTIVE INGREDIENT	6.02	12.04
TREFLAN	.50 LB/ACRE ACTIVE INGREDIENT	7.01	3.51
TOTAL VARIABLE COST PER ACRE			44.63

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED
ON SAGINAW VALLEY FARMS

ROTATION: O-NB-B　CROP: SUGARBEETS　APPEARANCE: FIRST　YIELD: 20.0 BU.,TON, OR CWT/ACRE

ITEM		EXPLANATION	PRICE PER UNIT	COST
SEED		1.0 LBS/ACRE	5.00	5.00
FERTILIZER				
NITROGEN	46-0-0	100.00 LBS/ACRE	.24	24.00
PHOSPHATE	0-46-0	26.00 LBS/ACRE	.20	5.20
POTASH	0-0-60	66.00 LBS/ACRE	.11	7.26
HERBICIDES				
PYRAMIN		3.00 LB/ACRE ACTIVE INGREDIENT	13.50	40.50
TCA		6.00 LB/ACRE ACTIVE INGREDIENT	1.45	8.70
TOTAL VARIABLE COST PER ACRE				90.66

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED ON SAGINAW VALLEY FARMS

ROTATION: O/A-A-A-C-C-NB-C   CROP: OATS   APPEARANCE: FIRST   YIELD: 80.0 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	55.0 LBS/ACRE	.13	6.88
FERTILIZER			
NITROGEN 46-0-0	30.00 LBS/ACRE	.24	7.20
PHOSPHATE 0-46-0	41.90 LBS/ACRE	.20	8.38
POTASH 0-0-60	132.00 LBS/ACRE	.11	14.52
HERBICIDES			
MCPA	.19 LB/ACRE ACTIVE INGREDIENT	.68	.13
TOTAL VARIABLE COST PER ACRE			37.10

ROTATION: O/A-A-A-C-C-NB-C   CROP: ALFALFA   APPEARANCE: FIRST   YIELD: 1.0 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	12.0 LBS/ACRE	2.40	28.80
FERTILIZER			
PHOSPHATE 0-46-0	10.00 LBS/ACRE	.20	2.00
POTASH 0-0-60	45.00 LBS/ACRE	.11	4.95
HERBICIDES			
MCPA	.19 LB/ACRE ACTIVE INGREDIENT	.68	.13
TOTAL VARIABLE COST PER ACRE			35.88

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED
ON SAGINAW VALLEY FARMS

ROTATION: O/A-A-A-C-C-NB-C CROP: ALFALFA APPEARANCE: SECOND YIELD: 4.6 BU.,TON, OR CWT/ACRE

ITFM	EXPLANATION	PRICE PER UNIT	COST
FERTILIZER			
PHOSPHATE 0-46-0	46.00 LBS/ACRE	.20	9.20
POTASH 0-0-60	207.00 LBS/ACRE	.11	22.77
TOTAL VARIABLE COST PER ACRE			31.97

ROTATION: O/A-A-A-C-C-NB-C CROP: ALFALFA APPEARANCE: THIRD YIELD: 4.4 BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
FERTILIZER			
PHOSPHATE 0-46-0	44.00 LBS/ACRE	.20	8.80
POTASH 0-0-60	198.00 LBS/ACRE	.11	21.78
TOTAL VARIABLE COST PER ACRE			30.58

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED
ON SAGINAW VALLEY FARMS

ROTATION: O/A-A-A-C-C-NB-C   CROP: CORN   APPEARANCE: FIRST   YIELD: 118.0   BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	13.5 LBS/ACRE	1.00	13.50
FERTILIZER			
NITROGEN 82-0-0	63.50 LBS/ACRE	.14	8.89
PHOSPHATE 0-46-0	41.30 LBS/ACRE	.20	8.26
POTASH 0-0-60	31.90 LBS/ACRE	.11	3.51
HERBICIDES			
ATRAZINE	.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
SUTAN	.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
LASSO	2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
TOTAL VARIABLE COST PER ACRE			52.13

ROTATION: O/A-A-A-C-C-NB-C   CROP: CORN   APPEARANCE: SECOND   YIELD: 115.0   BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	13.5 LBS/ACRE	1.00	13.50
FERTILIZER			
NITROGEN 82-0-0	130.00 LBS/ACRE	.14	18.20
PHOSPHATE 0-46-0	40.30 LBS/ACRE	.20	8.06
POTASH 0-0-60	31.10 LBS/ACRE	.11	3.42
HERBICIDES			
ATRAZINE	.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
LASSO	2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
BLADEX	1.00 LB/ACRE ACTIVE INGREDIENT	3.34	3.34
INSECTICIDES			
FURADAN	.75 LB/ACRE ACTIVE INGREDIENT	7.40	5.55
TOTAL VARIABLE COST PER ACRE			57.57

ENTERPRISE BUDGETS FOR ROTATIONS EMPLOYED
ON SAGINAW VALLEY FARMS

ROTATION: O/A-A-A-C-C-NB-C   CROP: NAVYBEANS   APPEARANCE: FIRST   YIELD: 13.0   BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	40.0 LBS/ACRE	.30	12.00
FERTILIZER			
NITROGEN 46-0-0	43.80 LBS/ACRE	.24	10.51
PHOSPHATE 0-46-0	11.60 LBS/ACRE	.20	2.32
POTASH 0-0-60	11.60 LBS/ACRE	.11	1.28
HERBICIDES			
EPTAM	2.25 LB/ACRE ACTIVE INGREDIENT	2.67	6.01
AMIBEN	2.00 LB/ACRE ACTIVE INGREDIENT	6.02	12.04
TREFLAN	.50 LB/ACRE ACTIVE INGREDIENT	7.01	3.51
TOTAL VARIABLE COST PER ACRE			47.66

ROTATION: O/A-A-A-C-C-NB-C   CROP: CORN   APPEARANCE: THIRD   YIELD: 115.0   BU.,TON, OR CWT/ACRE

ITEM	EXPLANATION	PRICE PER UNIT	COST
SEED	13.5 LBS/ACRE	1.00	13.50
FERTILIZER			
NITROGEN 82-0-0	130.00 LBS/ACRE	.14	18.20
PHOSPHATE 0-46-0	40.30 LBS/ACRE	.20	8.06
POTASH 0-0-60	31.10 LBS/ACRE	.11	3.42
HERBICIDES			
ATRAZINE	.50 LB/ACRE ACTIVE INGREDIENT	2.27	1.14
LASSO	2.00 LB/ACRE ACTIVE INGREDIENT	3.85	7.70
BLADEX	1.00 LB/ACRE ACTIVE INGREDIENT	3.34	3.34
TOTAL VARIABLE COST PER ACRE			52.02

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APPENDIX B

CONCEPTUAL BASIS FOR ESTIMATING EXPECTED RELATIVE PRICES

APPENDIX B

CONCEPTUAL BASIS FOR ESTIMATING EXPECTED RELATIVE PRICES[1]

In a Waliasian world a firm is assumed to maximize profits through the production of a set of outputs using a specified set of inputs. This may be expressed by an implicit production function.

$$H_f(x_i, \ldots , x_n, \ldots , y_m) = 0 \quad (1)$$

where x_i are outputs and y_i are inputs used by firm f. The profits of the firm are given as:

$$\Pi_f = P_i X_i - W_i Y_i \quad (2)$$

where P_i is the price received from the sale of a unit of X_i and W_i is the payment for one unit of Y_i.

Firms are assumed to maximize profits subject to the technical constraint of the production function, H_f. The constrained objective function can be represented by the Lagrangian:

$$\max L^f = P_i X_i{}^f - W_i Y_i{}^f - \lambda^f[H(X^f Y^f)] \quad (3)$$

---

[1]The analysis presented is available in most intermediate microeconomic texts. For example, see J. M. Henderson and R. E. Quandt, Microeconomic Theory: A Mathematical Approach (New York: McGraw-Hill, 1971); or see J. Quirk and R. Saposnik, Introduction to General Equilibrium and Welfare Theory (New York: McGraw-Hill, 1968).

First order conditions are:

$$\frac{\partial L^f}{\partial X_i^f} = P_i - \lambda^f \frac{\partial H^f}{\partial X_i} = 0 \qquad i = 1 \text{ to } n \text{ inputs}$$

$$\frac{\partial L^f}{\partial Y_j} = W_j - \lambda^f \frac{\partial H^f}{\partial Y_j} = 0 \qquad j = 1 \text{ to } m \text{ outputs} \tag{4}$$

$$\frac{\partial L^f}{\partial \lambda^f} = H(X_i Y_j) = 0$$

This yield n + m + 1 equations in n + m +1 unknowns X_i^f, Y_i^f, λ^f. Since there are F firms in the system, there are then (n + m + 1) x F unknowns.

An analogous presentation can be made for G utility maximizing household which supply inputs and ownership to the producing sector. The utility function is given by:

$$U^G = U(X_i, \ldots, X_m, Y_i, \ldots, Y_n) \tag{5}$$

where X_i represents the goods consumed by the household and Y_j represents the inputs supplied by the household. The budget constraint for the household is:

$$\sum_{j=1}^{n} Y_j R_j^h + \sum_{h=1}^{F} S^h \Pi^f - \sum_{1=1}^{m} P_i X_i = 0 \tag{6}$$

where R_i is the wage rate.

$$S^h = (S^1 \ldots S^f) \tag{7}$$

S^h is the share of profits from firm F accruing to household h. Profits of the firm are represented as:

$$\Pi = (\Pi^1 \ldots \Pi^f) \tag{8}$$

And P_i is the proce of good X_i. The housenold maximizes utility subject to budget constraints:

$$\max L^h = U(X_1, \ldots, X_m Y_i, \ldots, Y_n) - \lambda^h \tag{9}$$

subject to:

$$[\sum_{j=1}^{n} Y_j R_j^h + \sum_{i=1}^{F} S^{hf} \Pi^f - \sum_{i=1}^{m} P_i X_i] = 0$$

First order conditions are:

$$\frac{\partial L^h}{\partial X_i} = \frac{\partial U^h}{\partial X_i} - \lambda^h P_i = 0 \tag{10}$$

$$\frac{\partial L^h}{\partial \lambda^h} = \frac{\partial U^h}{\partial Y_j} - \lambda^h R_j = 0$$

$$\frac{\partial L^h}{\partial \lambda^h} = Y_j R_j^h + S^h \Pi - P_i X_i = 0$$

The first order conditions yield n + m + 1 equations. Since these equations hold in equilibrium for all households, there are (M + n + 1) x G equations in the household sector.

Walras's law states that in equilibrium, aggregate demand must equal aggregate supply. This identity condition implies that the system of equations is not linearly independent. This can be demonstrated by examining the budget constraint for households. The budget constraint represent identities satisfied for all sets of prices. Substitute, into equation 7, the definition of Π^f (equation 2), and sum over all households.

$$\sum_{n=1}^{H} \sum_{i=1}^{M} Y_j R_j^h + \sum_{i=1}^{F} \left(\sum_{i=1}^{N} P_i X_i^f - \sum_{i=1}^{M} R_j Y_j^f \right) = \sum_{i=1}^{N} \sum_{i=1}^{N} P_i X_i^f \qquad (11)$$

Collect terms:

$$\sum_{i=1}^{M} R_i \left(\sum_{h=1}^{H} Y_i^h - \sum_{f=1}^{F} Y_i^f \right) = \sum_{i=1}^{N} P_i \left(\sum_{h=1}^{H} X_i^h - \sum_{f=1}^{F} X_i^f \right) \qquad (12)$$

If all factor markets are in equilibrium, the left side of 12 is equal to zero. If $i = 1, n - 1$ goods market are in equilibrium, then for the identity to hold the nth market must be in equilibrium. Thus, the system is not linearly independent.

As a result, in equilibrium there are $(m + n + 1)$ $(F + H)$ + $(m + n)$ unknowns in goods, factors, prices, and lagrangian multipliers, but $(m + n + 1)$ $F + H)$ + $(m + n - 1)$ independent equations.

Since there are P_i $(i = 1, \ldots, m)$ prices of goods and R_j $(j = 1, \ldots, n)$ prices of factors, the total number of $n + m$ unknowns can be reduced by dividing through by P_i or R_j. The result is that prices of both goods and factors are expressed as relative prices.

$$\left(1, \frac{P_2}{P_1} \cdots \frac{P_i}{P_1} \frac{R_j}{P_1} \cdots \frac{R_j}{P_1}\right)$$

There are then (m + n - 1) relative prices in the system and a unique solution may exist.

This exercise illustrates the theoretical rationale for estimating the long run equilibrium prices as relative price ratios.

APPENDIX C

RAW DATA USED TO ESTIMATE YIELD PROBABILITY DENSITY FUNCTIONS

APPENDIX C

RAW DATA USED TO ESTIMATE YIELD PROBABILITY DENSITY FUNCTIONS

Presented in this appendix are the raw data used to estimate the probability density functions for yields for the seven crops studied. The data were obtained from Telfarm (Kelsey and Johnson, 1979) records of yields on selected farms in the Saginaw Valley area. (The Saginaw Valley area is comprised of six Michigan counties: Bay, Saginaw, Tuscola, Arenac, Huron, and Sanilac). Telfarm is the computerized farm record keeping and management service offered to Michigan farmers by Michigan State University. The samples selected were chosen on the basis of completeness and length of the data series and are not random. Since the Telfarm system represents a management service provided for a fee, producers on the Telfarm system are self-selected and represent a higher proportion of better-than-average managers. As a complete soybean series of adequate length was unobtainable for the Saginaw Valley area, yields used to generate soybean variability were obtained from three farms in Monroe County, Michigan.

Sample Data for Corn

Year	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
1976	100	90	120	136	100	115
1975	100	80	131	133	117	116
1974	70	84	82	85	80	65
1973	85	94	75	115	60	110
1972	90	67	100	121	100	115
1971	90	85	90	106	80	72
1970	100	105	100	128	110	105
1969	90	80	110	89	74	117
1968	80	110	113	101	98	101
1967	70	90	100	81	29	149
1966	80	71	95	97	79	74
1965	80	101	63	37	90	105
1964	64	83	67	106	69	103
1963	75	70	100	--	94	110
1962	73	50	100	105	104	94
1961	61	75	100	91	90	80
1960	60	50	80	85	50	--
1959	68	40	100	76	75	80
1958	69	62	100	75	--	60
1957	60	40	59	80	40	40
1956	44	50	40	110	50	--
1955	41	75	57	91	50	60
1954	64	75	42	75	38	50
1953	85	--	35	72	--	--
1952	125	75	33	80	50	15
1951	70	53	37	75	75	--
1950	100	45	38	34	--	31
	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6

Sample Data for Navy Beans

Year	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
1976	11.1	25.0	12.6	11.1	12.0	15.0
1975	12.6	25.0	16.3	11.0	20.0	4.5
1974	14.7	18.5	19.2	15.6	18.0	15.0
1973	10.4	22.7	12.0	13.0	10.0	12.0
1972	14.0	19.3	14.0	12.6	12.0	12.0
1971	11.7	21.6	12.6	9.0	12.0	17.1
1970	9.0	18.5	11.8	18.7	18.0	15.0
1969	20.2	21.6	18.0	16.3	16.3	15.0
1968	8.9	28.7	13.0	10.2	10.2	29.6
1967	5.8	21.8	21.0	13.7	13.7	8.9
1966	25.0	31.8	17.2	12.1	12.1	18.4
1965	10.1	16.9	14.9	10.6	10.6	13.3
1964	9.4	15.0	18.6	13.3	13.3	19.6
1963	15.0	--	21.0	18.9	18.9	18.0
1962	13.8	17.4	18.0	15.0	19.8	--
1961	11.4	14.4	18.6	15.6	18.0	--
1960	10.8	7.6	19.2	7.2	16.8	--
1959	15.6	9.0	13.2	18.0	19.8	--
1958	7.8	11.5	13.8	10.2	12.6	15.0
1957	9.0	12.0	19.8	5.4	10.8	13.0
1956	9.0	7.8	--	--	--	12.0
1955	9.0	11.4	--	--	--	15.0
1954	--	--	--	--	--	--
1953	--	8.7	--	--	--	13.9
1952	12.0	10.7	--	--	--	15.0
1951	18.0	6.9	--	--	--	17.9
1950	6.8	10.6	--	--	--	16.5
	Farm 5	Farm 4	Farm 7	Farm 8	Farm 9	Farm 10

Sample Data for Soybeans

Year	Sample 1	Sample 2	Sample 3
1977	42.0	40.0	54.0
1976	20.5	30.0	31.0
1975	23.7	35.0	40.0
1974	20.7	23.7	24.3
1973	17.0	20.5	45.0
1972	20.0	35.0	48.7
1971	16.5	20.0	31.0
1970	26.7	40.0	44.2
1969	30.0	20.0	41.8
1968	33.5	30.0	39.4
1967	24.0	30.0	29.0
1966	26.0	30.0	19.5
1965	21.8	31.7	42.0
1964	18.6	38.0	24.7
1963	19.7	--	25.6
1962	18.0	44.0	31.0
1961	32.0	25.0	38.0
1960	11.0	20.0	33.0
1959	15.0	30.0	--
	Farm 14	Farm 15	Farm 16

Sample Data for Sugar Beets

Year	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
1976	21.0	15.0	18.7	15.0	24.2	17.2
1975	23.7	20.4	22.2	16.9	21.5	18.9
1974	20.7	15.0	20.0	16.6	20.0	19.6
1973	19.8	13.0	19.0	21.3	26.9	--
1972	14.5	17.0	20.0	16.7	25.3	--
1971	22.2	14.0	17.0	17.4	21.0	--
1970	25.5	22.3	25.5	26.9	27.8	--
1969	16.0	15.0	15.0	14.1	15.6	--
1968	20.0	17.1	17.1	17.0	20.3	20.4
1967	21.3	17.0	17.0	21.2	19.3	22.0
1966	19.7	9.2	9.2	18.4	16.8	14.6
1965	21.3	13.1	13.1	18.4	22.1	19.9
1964	24.3	14.1	14.1	20.9	17.8	17.5
1963	17.1	14.2	14.2	18.2	--	16.3
1962	21.7	13.3	--	--	20.6	16.0
1961	23.3	16.7	13.4	--	15.6	21.1
1960	18.6	12.5	14.0	--	12.7	13.5
1959	18.0	17.9	16.6	--	15.1	20.8
1958	16.2	13.1	11.8	20.2	19.2	20.7
1957	16.0	--	20.0	14.2	20.0	16.2
1956	--	--	--	13.0	13.0	15.0
1955	--	--	--	21.0	19.0	19.0
1954	--	--	--	--	--	--
1953	--	--	--	19.8	14.5	13.4
1952	--	--	--	13.6	17.8	12.4
1951	--	--	--	13.5	11.4	14.6
1950	--	--	--	13.6	17.7	19.2
	Farm 7	Farm 8	Farm 9	Farm 10	Farm 4	Farm 11

Sample Data for Oats

Year	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
1976	100.0	80.0	70.0	75.0	27.8	95.0
1975	100.0	85.0	67.3	90.0	55.6	68.3
1974	70.0	100.0	63.3	80.0	--	88.3
1973	90.0	60.0	60.0	60.0	75.0	45.8
1972	40.0	60.0	60.0	50.0	57.1	65.0
1971	90.0	76.5	60.2	55.0	70.0	71.1
1970	100.0	105.0	90.0	90.0	90.0	92.1
1969	100.0	98.3	87.7	90.0	40.0	85.0
1968	100.0	100.0	60.0	80.0	98.1	80.0
1967	10.0	75.0	50.0	70.0	39.5	46.5
1966	90.0	70.0	59.0	87.0	80.0	69.2
1965	126.0	85.4	60.0	100.0	72.4	26.6
1964	87.0	88.6	46.8	100.0	91.3	87.8
1963	95.0	100.0	--	60.0	98.5	--
1962	88.0	79.0	--	42.0	102.0	--
1961	70.0	60.0	--	57.0	93.0	--
1960	50.0	40.0	50.0	--	50.0	78.0
1959	75.0	70.0	70.0	60.0	61.0	90.0
1958	85.0	13.0	60.0	78.0	56.0	67.0
1957	50.0	60.0	35.0	43.0	36.0	62.0
1956	50.0	90.0	34.0	50.0	35.0	45.0
1955	67.0	70.0	60.0	60.0	35.0	68.0
1954	60.0	62.0	45.0	31.0	48.0	43.0
1953	40.0	23.0	20.0	6.0	41.0	50.0
1952	30.0	60.0	40.0	36.6	22.9	35.0
1951	65.0	45.0	8.6	45.0	44.8	63.0
1950	50.0	106.5	40.0	42.0	51.4	75.0
	Farm 12	Farm 6	Farm 11	Farm 13	Farm 2	Farm 3

Sample Data for Alfalfa

Year	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
1976	--	5.7	5.0	4.5	3.0	6.5
1975	--	4.3	5.0	5.1	3.5	5.7
1974	2.5	4.0	5.0	4.4	3.5	4.7
1973	--	5.1	--	4.7	4.0	5.0
1972	--	3.3	--	4.4	3.0	3.3
1971	--	4.7	--	3.8	3.5	3.0
1970	--	5.6	--	4.7	4.0	3.0
1969	2.6	5.3	--	4.8	3.5	4.0
1968	--	3.8	5.0	4.6	3.5	4.9
1967	2.0	5.0	5.3	5.5	4.0	2.7
1966	3.3	6.1	4.0	4.0	4.3	3.6
1965	3.0	6.8	2.9	4.0	3.5	4.8
1964	2.4	4.1	3.5	--	2.9	2.4
1963	1.8	2.3	5.9	--	3.8	3.1
1962	--	1.5	3.0	--	2.4	3.5
1961	--	3.1	2.4	--	2.0	1.8
1960	4.0	4.0	4.2	4.9	4.0	2.2
1959	4.0	4.1	5.2	3.8	4.6	3.6
1958	3.0	3.0	5.6	4.1	3.4	2.1
1957	3.0	--	3.3	4.1	3.0	--
1956	3.0	3.0	4.3	3.9	2.0	2.7
1955	2.5	--	3.0	3.0	1.8	1.9
1954	2.5	--	2.5	3.0	2.6	2.7
1953	2.5	0.8	4.0	2.5	4.4	--
1952	--	2.6	3.6	3.2	2.0	1.5
1951	1.9	2.2	4.5	3.5	1.0	--
1950	2.5	2.9	4.1	3.0	2.0	--
	Farm 12	Farm 6	Farm 11	Farm 13	Farm 2	Farm 3

Sample Data for Wheat

Year	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
1976	50.0	50.0	59.0	58.0	76.0	51.0
1975	45.1	54.5	40.0	60.0	66.0	81.0
1974	50.0	60.0	40.0	75.0	60.0	57.5
1973	40.0	39.0	40.0	28.0	43.0	--
1972	46.5	53.8	30.0	25.0	61.3	--
1971	60.0	30.0	35.0	42.8	49.6	--
1970	60.0	49.1	17.0	55.0	50.0	--
1969	55.6	46.4	40.0	48.3	56.7	--
1968	35.5	36.0	40.0	46.7	50.0	50.0
1967	66.8	40.0	40.0	36.5	62.1	55.4
1966	50.0	43.3	--	53.7	40.0	66.3
1965	20.4	20.0	--	16.3	--	--
1964	56.1	50.0	41.3	--	50.0	61.4
1963	45.0	--	39.3	25.3	--	62.4
1962	26.0	--	37.0	34.0	--	38.0
1961	26.0	--	49.0	19.0	--	61.0
1960	30.0	48.0	--	15.0	39.0	54.0
1959	35.0	30.0	30.0	29.0	46.0	55.0
1958	--	50.0	49.0	35.0	70.0	65.0
1957	15.0	32.0	--	12.0	40.0	40.0
1956	35.0	32.0	38.0	21.0	60.0	46.0
1955	20.0	36.0	20.0	40.0	55.0	40.0
1954	24.0	36.0	35.0	33.0	44.0	47.0
1953	23.0	37.0	33.0	--	43.0	25.0
1952	27.3	26.0	35.0	--	40.0	--
1951	30.0	11.0	33.9	--	37.8	32.7
1950	25.0	40.0	29.3	--	30.0	45.0
	Farm 5	Farm 12	Farm 1	Farm 2	Farm 13	Farm 11

APPENDIX D

TEST FOR NORMALITY

APPENDIX D

TEST FOR NORMALITY

The Wilks-Shapiro test is a test used to determine whether a sample of observations was drawn from a normal distribution. The Wilks test is origin and scale invariant and a composite test of normality against alternatives (Shapiro and Wilk, 1965; Bikel and Doksum, 1977). The Wilks statistic may take on values from 0 to 1 and the distribution is a function of the sample size being tested. The authors present the percentage points on the W distribution to be used for hypothesis testing.

Presented below are the Wilks statistics for each sample for each crop. In the second column is the critical value of a 5 percent test of:

1. H_{NULL}: Underlying Distribution is Normal;
   H_{ALT}: Underlying Distribution is Non-Normal.

Conclusions from any test depend on the form of the statement of hypothesis. The formulation of hypotheses in "1" suggests that the expectation is that the tested distributions are normal. An alternative formulation of hypotheses is possible under the expectation that the distributions are not normal. Previous evidence (Day, 1965) suggests that this might be a reasonable expectation. The formulation of hypothesis under this expectation would be:

2. H_{NULL}: Underlying Distribution is Non-Normal;

   H_{ALT}: Underlying Distribution is Normal.

The third column presents the critical value of a 5 percent test of formulation 2. The fourth column is the 50th percentile point on the W distribution for the appropriate sample size for reference.

It is impossible to reject the null hypothesis at the 5 percent level, regardless of the specification of hypothesis for most of the samples. Those where rejection of the null hypothesis is possible are labeled with an "R." Navy beans has the highest number of rejections where the null hypothesis of normality is rejected four out of six times, and five out of six samples are below the 50th percentile point on the distribution. The null hypothesis of non-normality (formulation 1) could not be rejected once for corn; using the reformulated set of hypotheses (formaltion 2) a null hypothesis of normality could be rejected in one of six samples. The Wilks' statistic for three of six samples is below the 50th percentile mark. Five of the six sugarbeet samples had Wilks statistics below the 50th percentile level. The null hypotheses of formulation 1 was rejected only once in six times, but using formulation 2, the null hypothesis could not be rejected in any of the six samples.

The Wilks statistics for all three soybean samples was below the 50th percentile mark. The null hypothesis could not be rejected for any of the three samples, regardless of the set of hypotheses used.

Crop Sample Farm Number	Sample Size	Wilks Statistic	5 Percent Value (1)	5 Percent Value (2)	50 Percent Value
Corn					
1	27	.9371	.9230	.9850	.9660
2	26	.9735	.9200	.9850	.9650
3	27	.9695	.9230	.9850	.9660
4	26	.9151	.9200 R	.9850	.9650
5	24	.9633	.9160	.9840	.9640
6	23	.9699	.9140	.9840	.9630
Navy beans					
5	25	.8903	.9180 R	.9850	.9650
4	25	.8672	.9180 R	.9850	.9650
7	20	.9120	.9050	.9830	.9600
8	20	.9707	.9050	.9830	.9600
9	20	.8848	.9050 R	.9830	.9600
10	22	.8783	.9110 R	.9840	.9620
Soybeans					
14	19	.9181	.9010	.9820	.9590
15	18	.9403	.8970	.9820	.9570
16	18	.9380	.8970	.9820	.9570
Sugarbeets					
7	20	.9825	.9050	.9830	.9600
8	19	.9361	.9010	.9820	.9590
9	19	.9569	.9010	.9820	.9590
10	22	.9102	.9110 R	.9840	.9620
4	25	.9598	.9180	.9850	.9650
11	21	.9120	.9080	.9610	.9830
Oats					
12	27	.9147	.9230 R	.9850	.9660
6	27	.9825	.9230	.9850	.9660
11	24	.9352	.9160	.9840	.9640
13	26	.9875	.9200	.9850 R	.9650
2	26	.9619	.9200	.9850	.9650
3	24	.9571	.9160	.9840	.9640
Alfalfa					
12	17	.9130	.8920	.9810	.9560
6	24	.9721	.9160	.9840	.9640
11	22	.9696	.9110	.9840	.9620
13	23	.9591	.9140	.9840	.9630
2	27	.9759	.9230	.9850	.9660
3	23	.9519	.9140	.9840	.9630
Wheat					
5	26	.9857	.9200	.9850 R	.9650
12	24	.9489	.9160	.9840	.9640
1	23	.9090	.9140 R	.9840	.9630
2	22	.9585	.9110	.9840	.9620
13	23	.9642	.9140	.9840	.9630
11	20	.9660	.9050	.9830	.9600

R indicates null hypothesis is rejected.

The Wilks statistics generated for oat and wheat samples had one sample each where null hypotheses were rejected using hypothesis 1 and one rejection using hypothesis 2.

The six Wilks statistics generated for alfalfa samples showed no null hypotheses rejection regardless of hypotheses formulation. Three of the six samples had Wilks statistics below the 50th percentile point on the W distribution.

The conclusion of this analysis is that although there is some evidence of non-normality in the samples (measured by the number of samples where the Wilks statistic is less than the 50 percent value). The evidence is not overwhelming. The evidence of non-normality is strongest for Navy beans, sugarbeets, corn, and soybeans. For oats, alfalfa, and wheat the issue is one of open conjecture.

APPENDIX E

POOLING TIME SERIES AND CROSS-SECTION DATA

APPENDIX E

POOLING TIME SERIES AND CROSS-SECTION DATA

For each crop, six farm level time series of yields were obtained (three for soybeans). Each time series was detrended by a linear regression of yield per acre on time.

$$\text{Yield} + \alpha_i + \beta_i \text{ Time} + \varepsilon_i \qquad \text{where } i = 1, \ldots , 6 \text{ farms}$$

Pooling of sample time series across farms, if possible, was desired. Three hypotheses were tested to determine appropriate procedures for pooling. This appendix presents the results of those tests and the final least-squares-dummy-variables (LSDV) equations estimated.[1]

The first hypothesis tested was:

1. H_{null} $\alpha_i = \alpha_2 = \ldots = \alpha_i$ $\qquad \beta_1 = \beta_2 = \ldots = \beta_n$

   $H_{alt.}$ $\alpha_1 \neq \alpha_2 \neq \ldots \neq \alpha_{ai}$ $\qquad \beta_1 \neq \beta_2 \neq \ldots \neq \beta_n$

This is accomplished by estimating a common equation for each crop across all samples. To test the hypothesis, an F test is employed where S_1 is the unrestructured residual sum of squares.

$S_1 = \Sigma \text{ RSS}_i$ $\qquad$ $i = 1, 6$ samples;

and $\qquad$ T_i = Number of observations in Sample 1;

$df = (\Sigma T_i) - 2N$ $\qquad$ N = Number of Samples.

[1]The approach used here is essentially one presented in Madalla, 1977, pp. 323-326.

S_2 is the restructured residual sum of squares:

S_2 = RSS of the common regression

dt = $(\Sigma Ti) - 2$

The F ratio is:

$$F = \frac{(S_2 - S_1) / (2N - 2)}{S_1 / (\Sigma Tk - 2N)}$$

Hypothesis 1 was tested for each of the seven crops using the above test. The results are presented below.

Table E.1 "F" Ratios Testing Hypothesis 1

Crop	F Ratio	Critical F (.05)
Corn	7.07	> 1.91
Navy beans	29.68	> 1.91
Soybeans	7.65	> 2.53
Sugarbeets	12.36	> 1.91
Oats	4.12	> 1.83
Alfalfa	21.63	> 1.81
Wheat	15.81	> 1.91

The null hypothesis was rejected for all seven crops. Therefore, direct pooling of the data would be inappropriate. Hypothesis 2 tests the assumption.

2. H_n: $\beta_1 = \beta_2 = \ldots = \beta_n$

   H_A: $\beta_1 \neq \beta_2 \neq \ldots \neq \beta_n$

It is necessary to determine S_3 a second restructed residual sum of squares with df = $(\Sigma Ti) - (N+1)$ to test this hypothesis. The F test is then:

$$F = \frac{(S_3 - S_1) / (N-1)}{S_1 / (\Sigma Ti - 2N)}$$

This ratio was generated for the set of seven crops and the results are summarized below.

Table E.2 "F" Ratios Testing Hypothesis 2

Crop	F Ratio	Critical F (.05)
Corn	0.60	> 2.29
Navy beans	0.58	> 2.29
Soybeans	0.73	> 3.23
Sugarbeets	0.46	> 2.45
Oats	0.62	> 2.29
Alfalfa	0.00	> 2.29
Wheat	0.60	> 2.29

The third set of hypotheses tested is:

3. H_n: $\alpha_1 = \alpha_2 = \ldots = \alpha_n$ given $\beta_1 = \beta_2 \ldots = \beta_n$

   H_A: $\alpha_1 \neq \alpha_2 \neq \quad \neq \alpha_n$ $\beta_1 = \beta_2 \ldots = \beta_n$

For this test the unrestructed residual sum of squares is S_3 with af = $\Sigma_i T_i - (N+1)$. The restructed residual sum of squares S_2 with df = $\Sigma_i - T_i - 2$. The F test is:

$$F = \frac{(S_2 - S_3) / (N-1)}{S_3/(\Sigma T_i - (N+1))}$$

The results of this test on yield data are presented in Table E.3.

Table E.3 "F" Ratios Testing Hypothesis 3

Crop	F-Ratio	Critical F (.05)
Corn	13.75	> 2.21
Navy beans	16.70	> 2.29
Soybeans	13.84	> 3.19
Sugarbeets	24.81	> 2.29
Oats	7.71	> 2.21
Alfalfa	25.80	> 2.29
Wheat	31.02	> 2.29

The LSDV approach to pooling data is based on the assumption that the β_i's for each farm sample detrended equation are not significantly different but that the intercept coefficients, the α_i's, do differ. The three hypotheses tested indicate that these assumptions are fulfilled for the sample yield data for the seven crops studied here. The LSDV approach to pooling time series and cross-section data is appropriate in this case. The equations estimated are presented below:

Corn:

$$Y = -47.32 + 1.98T - 5.24D_1 + 2.70D_2 + 14.14D_3 - 4.78D_4 + 5.21D_5$$
$$(3.43)\quad(9.42)\quad(.95)\quad(.50)\quad(2.57)\quad(-.85)\quad(.92)$$
$R^2 = .35.$

Navy beans:

$$Y = 2.85 + 14T + 4.59D_1 + 3.81D_2 + .44D_3 + 2.31D_4 + 4.59D_5$$
$$(-.31)\quad(.05)\quad(1.30)\quad(1.39)\quad(1.39)\quad(1.39)\quad(1.39)$$
$R^2 = .04.$

Soybeans:

$$Y = -4.17 + .40T + 7.07D_1 + 12.49D_2$$
$$\quad (-.31)\ (2.01)\ (2.71)\quad (4.78)$$
$R^2 = .06.$

Sugarbeets:

$$Y = 5.94 + .21T - 4.84D_1 - 3.36D_2 - 1.850_3 - .37D_4 - 1.45D_5$$
$$\quad (2.12)\ (.04)\ (1.02)\ (1.02)\ (.99)\ (.96)\ (1.02)$$
$R^2 = .12.$

Oats:

$$Y = -12.32 + 1.36T - 1.31D_1 - 19.41D_2 - 10.45D_3 - 12.48D_4 - 6.91D_5$$
$$\quad (-.91)(6.61)\ (.24)\ (-3.42)\ (-1.88\ \ (-2.25)\ (-1.22)$$
$R^2 = .21.$

Alfalfa:

$$Y = -1.80 + .07T + .89D_1 + 1.36D_2 + 1.13D_3 + .23D_4 + .36D_5$$
$$\quad (-2.72)(7.28)\ (3.05)\ (4.60)\ (3.86)\ (.81)\ (1.23)$$
$R^2 = .24.$

Wheat:

$$Y = 19.1 + .91T + 1.30D_1 - 1.35D_2 - 3.29D_3 + 12.63D_4 + 14.91D_5$$
$$\quad (-2.50)(7.84)\ (.43)\ (-.44)\ (-1.05)\ (4.10)\ (4.65)$$
$R^2 = .21.$

where:

Y = Yield;

T = Time in years; and

D_i = Dummy variable.

APPENDIX F

COMPUTATION OF CORRELATION COEFFICIENTS USING AGGREGATED VERSUS DISAGGREGATED DATA

APPENDIX F

COMPUTATION OF CORRELATION COEFFICIENTS USING AGGREGATED VERSUS DISAGGREGATED DATA

The estimated correlation coefficients among yields computed and employed in this study are considerably lower than those computed from state or county data and used in other studies.

Most other studies, e.g., Halter and Dean, 1960; Heady, 1952, used correlation coefficients derived from aggregated data. Such yield figures represent a weighted average for a particular geographic area. In order to obtain an aggregate figure, reported farm yields are combined by an averaging or weighting scheme.

$$X = \sum_{i=1}^{n} W_i x_i$$

where:

W_i = weight; and

x_i = observation.

The above expression is a generalized formulation for such an aggregation scheme. The literature on aggregation of linear models (Theil, 1971) suggests that if there are N economic phenomena, each characterized by an equation of the type,

$$Y_i = X_i B_i + \varepsilon_i$$

where Y_i and ε_i are n (i = 1, ... , n) element column vectors and X_i is by, and if the parameter vector (β_i, ... , β_n) are all equal, then the macro relation can be expressed as:

$$\overline{Y} = \frac{1}{N} \sum_{i=1}^{N} X_i B_i + \frac{1}{N} \sum_{i=1}^{N} \varepsilon_i = \overline{X}B + \frac{1}{N} \sum_{i=1}^{N} E_1$$

The estimated coefficient vector for the macro relation is the same as for the micro relation and, more importantly, the disturbance term for the macro relation is equal to the average of the disturbance terms of the micro relations. These assumptions are met in the present situation regarding yields. As presented in a previous appendix, it was shown that the hypothesis $\beta_1 = \beta_2 = \ldots = \beta_n$ could not be rejected for any of the form sample detrended equations for any of the seven crops. The difficulty is that although the ε_i of the aggregate equation represents an unbiased estimate of the average ε_i for the micro relations, it has been shown that the variance of an aggregated ε_i is inversely proportional to the number of micro units in the aggregation. The proof from Carter and Dean, 1960, is presented here for convenience.

The yield per acre on the i^{th} farm may be written as:

$$Y_{it} = \alpha_i \; Y_i t = \alpha_i + \beta_i t + \varepsilon_i t$$

where t is time, α and β are parameters, ε is the residual and i = 1, ... , N farms.

It is also assumed that $E(\varepsilon_{it}) = 0$ and $E(\varepsilon_{it})^2 = \sigma_j^2$. Aggregating overall farm units results in

$$\overline{Y}_t = \overline{\alpha} + \overline{\beta}_y + \overline{\varepsilon}_{it}.$$

Since $E(\varepsilon_{it}) = 0$, the variance of $\overline{\varepsilon}_i$ is:

$$\sigma^2_{\varepsilon_t} = \frac{1}{N} 2 \, (\Sigma \, \sigma^2_i + 2 \sum_{\substack{j=1 \\ i>j}}^{N} pij \, \sigma_i \sigma_j)$$

Assuming $\sigma^2_i = \sigma^2_\varepsilon$, $\overline{\sigma}^2_{\varepsilon t}$ may be written:

$$\sigma^2_{\overline{\varepsilon}_t} = \frac{\sigma^2}{N} + 2\sigma^2 \sum_{i>j} P_{ij}{}^2$$

where P_{ij} is the correlation among random yield components for crops i and j. Simplifying gives:

$$\sigma^2_{\overline{\varepsilon}} = \sigma^2/N[1 + (N - 1) \, \rho)$$

This equation illustrates that the variance of $\overline{\varepsilon}$ in the macro relation is inversely related to the number of micro agents comprising the macro relation. If $\sigma^2_{\overline{\varepsilon}_t}$ and $\sigma^2_{\overline{\varepsilon}_i}$ are greater than 1, then $\sigma_{\varepsilon_i} > \sigma^2_{\overline{\varepsilon}_t}$. In computing a correlation coefficient among the random elements of farm level yields, use of an aggregated series will overestimate the correlation coefficient if covariance remains unchanged.

The effect of aggregation on covariance cannot be determined analytically. Thus, a Monte Carlo experiment was conducted to examine the impact of aggregation on covariance. The data used were the original data on value of the firm used by Grunfeld's and Griliches' study on the relationship between Micro and Macro variables (reprinted in Madalla, 1977). Twenty years of investment data for four firms in two different industries were used. The data for the four firms, Westinghouse and General Electric in the electrical equipment industry and Atlantic Richfield and Union Oil in the petroleum industry were aggregated by averaging, creating two data series, one for electrical industry and one for the petroleum industry. The two series were detrended and a correlation coefficient was computed between the two sets of residuals. This computation is analogous to using aggregated county or regional yield data in computing correlation coefficients.

The second correlation coefficient was computed by pooling the firm data for each industry using a least-squares-dummy-variable model. Correlation coefficients were computed between the residuals of the two regressions. Presented in the table below is a summary of the results of the computations.

Table F.1 Correlation Coefficients Between Aggregated and Pooled Data

	Aggregated		Pooled by LSDV	
	Petroleum	Electrical Equipment	Petroleum	Electrical Equipment
Variance	1017.89	70684.3	2051.52	93189.1
Covariance	5747.32		3740.52	
Correlation coefficient	.6775		.2705	

The variances behave as predicted--the covariance of the aggregated series was higher than the pooled data resulting in a higher correlation coefficient. This exercise should not be regarded as proof that covariances of aggregated data are necessarily higher than disaggregated series. What is indicated, however, is that by aggregating, one measures a different phenomena than if data are combined in a different fashion.

What has been demonstrated is, use of disaggregated data could have a profound impact on correlation coefficients among random disturbances of yield. The random disturbances, at least at the micro level, may indeed be relatively uncorrelated. Such a result could have an impact on farm planning in that diversification of crop production may be less important from an income maximization risk minimization point of view than previously believed. It is an area worthy of future research.

APPENDIX G

STOCHASTIC ANALYSIS OF ENTERPRISE BUDGETS PROGRAM

APPENDIX G

STOCHASTIC ANALYSIS OF ENTERPRISE BUDGETS PROGRAM

The Monte Carlo model used to estimate the net return to land cumulative distribution functions (CDF's) for each crop rotation, and a brief explanation of what is computed in each portion of the program, are presented.

Program SAEB. This is the executive procedure. Data for each crop in the rotation to be simulated is read in by this module. Figure G.1 presents a sample input data for rotation 14 (O/A-A-NB-B). Rotation 14 is illustrative since the oat-alfalfa companion seeding represents joint production of three products on one field; namely, one ton of alfalfa, 80 bushels of oats, and two tons of oat straw. The values entered on the first card are:

1. The Rotation Number
2. Number of Crops--In this case six: oats, oats straw, first year alfalfa, second year alfalfa, Navy beans, and sugarbeets.
3. The Divisor--A value used internally in computation. This is the number of crop-enterprises grown. In Rotation 14, the divisor is 4 since the crop-enterprises are: oats/alfalfa, alfalfa, Navy beans, and sugarbeets. For rotation 3, C-C-SB, the divisor is 3 because first corn and second corn are considered distinct.
4. Number of Different Crops--This value is used internally in setting up the correlation matrix. In rotation 14, the value is 4 since first and second year alfalfa have perfectly correlated prices and yields. For rotation 3, C-C-SB, the value would be 2, the number of different crops.

The information on each crop in the rotation is on the second and sixth cards. The first value is the crop number followed by expected yield, yield variance, expected price, and price variance. The last number represents a user input "key" to link all identical crops in the generation of covariances; in this case all alfalfa crops are given the value 3. Numbering is to be consecutive odd numbers. Even numbers are generated internally to link price values of "like" crops.

The values on the seventh and subsequent cards represent all non-zero correlation coefficients. The integers in columns two and four, respectively, represent the row and column values in the matrix. The third value is the correlation coefficient; the last, an integer, is a switch used internally to indicate end of data. A zero value will cause the program to read an additional card. A non-zero value will terminate the reading of correlation coefficients.

The "executive" module computes the upper and lower bounds for each distribution to be generated. The mean, variance, and upper and lower bound information is then used to compute the Beta parameters K_1 and K_2. The routine then calls the beta generator which returns a vector of 100 sample states of nature for each distribution. One hundred values for gross income are then computed. Calls to CASH, MACHINE, and HAULDRY return, respectively, variable cash costs, machinery and fuel cost, and finally, hauling and drying costs. Family labor is subtracted and the resultant 100 "net return to land" values are ranked lowest to highest as an estimate of distribution fractiles (see Figure G.2, Anderson, 1977).

The remainder of the "executive" procedure is output formating routines. Sample output for rotation 14 is presented in Figure G.2.

Subroutine MVBETA. This routine (see Appendix A, King 1979) generates a vector of 100 draws for each probability distribution, two for each crop--a price distribution and a yield distribution. Two IMSL (IMSL, 1977) subroutines, MDNRIS and MDBETI are used to generate the normal and beta marginal distribution used in the table, look up functions, TABLIE and TABLI (Manetch and Park, Part II, 1974).

Subroutine MVNOR. Generates normally distributed random numbers (Naylor).

Subroutine COREL. Computes correlation coefficients among sample generated vectors. This information is printed with output as a diagnostic aid.

Subroutine COEF. Generates the lower triangular matrix necessary for generating multivariate normal distribution (Naylor, Chapter V).

Subroutine RORDER. A sort routine used in reordering Net Returns to Land in rank order from lowest to highest.

Subroutine Cash. Generates cash costs including seed, fertilizer, herbicides, and cost of capital. This routine performs the multiplication of the coefficient matrix of application rates per acre for each crop in the rotation acre with the vector of input prices; determines cost of working capital. This is essentially the as generated the budgets presented in Appendix A, but without output formating routines.

Subroutine MACHINE. Attaches as data machinery cost and fuel usage rates for all rotations. The routine then selects the appropriate numbers for the rotation being simulated, computes fuel cost from fuel use rates and returns the figures to the main procedure.

Subroutine HAULDRY. Computes hauling and drying costs (drying corn only) based on custom rates and expected yield of each crop in the rotation.

FORTRAN CODING FORM

PROGRAM: SAMPLE INPUT DATA FOR SAGINAW VALLEY CROPPING NAME

ROUTINE: SYSTEMS MODEL DATE PAGE OF

FORTRAN STATEMENT — 0: ZERO, Ø: ALPHA O; 1: ONE, I: ALPHA I; 2: TWO, Ƶ: ALPHA Z — SERIAL NUMBER

TYPE	STATEMENT NO.	CONT	7–10	11–20	21–30	31–40	41–50	51–60
1	4. 6	.	4.	4.				
			5.	80.0	619.	1.44	.04	1.
			8.	2.	.84	30.00	4.24	1.
			6.	1.0	.07	60.73	28.87	3.
			6.	4.6	1.38	60.73	28.87	3.
			2.	16.0	2.54	22.60	49.00	5.
			4.	22.0	15.50	30.94	160.92	7.
	3 1			0.00 0				
	5 1			0.21 0				
	7 1			0.15 0				
	4 2			0.93 0				
	6 2			-.15 0				
	8 2			0.74 0				
	5 3			0.13 0				
	7 3			-.27 0				
	6 4			-.62 0				
	8 4			0.13 0				
	7 5			-.15 0				
	8 6			0.18 1				

Figure G.1 Sample Input for Rotation #14.

SAGINAW VALLEY CROPPING SYSTEMS MODEL

ROTATION NUMBER 14.

CROPS IN THIS ROTATION ARE:

OATS	EXPECTED YIELD	80.	BU/ACRE	EXPECTED PRICE	$ 1.44/BU
OAT STRAW	EXPECTED YIELD	2.	TON/ACRE	EXPECTED PRICE	$ 30.00/TON
ALFALFA	EXPECTED YIELD	1.0	TON/ACRE	EXPECTED PRICE	$ 60.73/TON
ALFALFA	EXPECTED YIELD	4.6	TON/ACRE	EXPECTED PRICE	$ 60.73/TON
NAVYBEANS	EXPECTED YIELD	16.	CWT/ACRE	EXPECTED PRICE	$ 22.60/CWT
SUGARBEETS	EXPECTED YIELD	22.	TON/ACRE	EXPECTED PRICE	$ 30.94/TON

GROSS INCOME	CASH COSTS	MACHINERY COST	FUEL COST	HIRED LABOR	HAULING DRYING	FAMILY LABOR	RETURN TO LAND
222.14	46.95	98.24	9.77	0.00	23.33	23.33	20.52
233.00							31.39
235.45							33.84
235.99							34.38
246.84							45.23
249.41							47.80
255.25							53.64
257.23							55.62
266.75							65.14
272.31							70.70
274.03							72.42
278.97							77.36
279.21							77.59
279.85							78.23
280.53							78.92
284.19							82.58
288.10							86.48
289.91							88.30
290.49							88.88
296.03							94.41
298.05							96.43
300.27							98.66
301.25							99.64
301.43							99.82
302.64							101.02
306.24							104.63
307.99							106.37
310.21							108.60
312.20							110.59
313.04							111.43
313.93							112.32
314.33							112.71
317.54							115.93
317.88							116.26
321.16							119.54
322.77							121.15
323.01							121.39
323.65							122.04
327.52							125.90
328.78							127.16
329.35							127.74
335.86							134.25
336.59							134.98
340.14							138.53
341.58							139.97
343.91							142.29
345.85							144.24
346.66							145.04
346.98							145.36
353.51							151.90
353.85							152.23
364.12							162.51
364.80							163.18
367.31							165.70
369.44							167.82
370.41							168.80
376.30							174.68
378.62							177.00
380.24							178.63
385.02							183.41
385.61							183.99
389.40							187.79
393.55							191.94
396.01							194.40
399.56							197.94
402.17							200.56

Figure G.2 Sample Output Generated for Rotation #14.

402.61	201.00
404.10	202.49
410.92	209.30
412.15	210.54
418.81	217.20
420.59	218.97
422.85	221.24
423.71	222.10
426.86	225.24
426.93	225.32
434.73	233.11
437.69	236.07
439.71	238.10
446.51	244.90
450.17	248.55
461.61	260.00
466.44	264.83
467.72	266.10
468.36	266.75
468.74	267.13
482.95	281.34
503.96	302.35
518.88	317.27
533.54	331.93
533.61	331.99
544.38	342.76
554.48	352.87
556.50	354.88
571.06	369.44
576.16	374.54
596.40	394.78
642.33	440.72
664.89	463.28
700.86	499.25

22:37:33 10/13/80 TF39057 1609 LINES PRINT. 29 PAGES PRINT. COST AT RG1 IS $ 0.90

Figure G.2--Continued

123456789.123456789.123456789.123456789.123456789.123456789.123456789.123456789.123456789.123456789.123456789.123456789.123456789.123456

```
      PROGRAM SAEB(OUTPUT,TAPE65,TAPE2=OUTPUT,TAPE1,TAPE5,TAPE6,TAPE7,
     +TAPE8,TAPE9,TAPE10,TAPE13,DEBUG=OUTPUT)
      REAL K1,K2
      COMMON /BLOCK2/   K1(20),K2(20),BL(20),BU(20),FACT(20)
      COMMON /BLOCK3/   C(20,20),COR(20,20),PAR(20,20),V(20),MN,ISYS
      COMMON /BLOCK4/   Y(20,110),RHO(20,20),ND
      COMMON /BLOCK5/ ICROPS,DIVISOR,YIELD(20),CROPNO(20)
      DIMENSION VARY(10),PRICE(10),VARP(10)
      DIMENSION GROSINC(110),AMEAN(20),RETLND(110),VAR(20),SYS(20)
      DATA ND/100/
      REWIND 5
      REWIND 6
      REWIND 8
      REWIND 9
      READ(1,10)ROTNO,CROPS,DIVISOR,SCROP
0     FORMAT(4F3.0)
      ISYS=SCROP*2
      ICROPS=CROPS
      DO 12 I=1,ICROPS
2     READ(1,14)CROPNO(I),YIELD(I),VARY(I),PRICE(I),VARP(I),SYS(I)
4     FORMAT(6F10.0)
  CONSTRUCT CORRELATION MATRIX
      CROPS2=CROPS*2.
      MN=CROPS2
      DO 16 I=1,ISYS
      DO 18 J=1,ISYS
      COR(I,J)=0.0
8     IF(I.EQ.J)COR(I,J)=1.0
6     CONTINUE
0     READ(1,22)I,J,COR(I,J),IND
2     FORMAT(2I2,F10.2,I2)
      COR(J,I)=COR(I,J)
      IF(IND.EQ.0)GO TO 20
  COMPUTE UPPER AND LOWER BOUNDS
      JY=-1
      JP=0
      DO 24 I=1,ICROPS
      JY=JY+2
      JP=JP+2
      FACT(JY)=SYS(I)
      FACT(JP)=SYS(I)+1
      AMEAN(JY)=YIELD(I)
      AMEAN(JP)=PRICE(I)
      VAR(JY)=VARY(I)
      VAR(JP)=VARP(I)
      IF(CROPNO(I).NE.1.) GO TO 302
      BU(JY)=YIELD(I)*1.56
      BL(JY)=YIELD(I)*.37
      BU(JP)=PRICE(I)*1.4
      BL(JP)=PRICE(I)*.78
      GO TO 24
02    IF(CROPNO(I).NE.2.) GO TO 304
      BU(JY)=YIELD(I)*2.05
      BL(JY)=YIELD(I)*.32
      BU(JP)=PRICE(I)*1.89
      BL(JP)=PRICE(I)*.60
      GO TO 24
04    IF(CROPNO(I).NE.3.) GO TO 306
      BU(JY)=YIELD(I)*1.56
      BL(JY)=YIELD(I)*.37
      BU(JP)=PRICE(I)*1.51
      BL(JP)=5.75
      GO TO 24
06    IF(CROPNO(I).NE.4.) GO TO 308
      BU(JY)=YIELD(I)*1.46
      BL(JY)=YIELD(I)*.53
      BU(JP)=PRICE(I)*1.89
      BL(JP)=PRICE(I)*.64
      GO TO 24
08    IF(CROPNO(I).NE.5.) GO TO 310
      BU(JY)=YIELD(I)*1.66
      BL(JY)=YIELD(I)*.53
      BU(JP)=PRICE(I)*1.34
      BL(JP)=PRICE(I)*.13
      GO TO 24
10    IF(CROPNO(I).NE.6.) GO TO 312
      BU(JY)=YIELD(I)*1.7
```

```
      BL(JY)=YIELD(I)*.3
      BU(JP)=PRICE(I)*1.12
      BL(JP)=PRICE(I)*.89
      GO TO 24
12    IF(CROPNO(I).NE.7.) GO TO 314
      BU(JY)=YIELD(I)*1.51
      BL(JY)=YIELD(I)*.44
      BU(JP)=PRICE(I)*1.76
      BL(JP)=2.35
      GO TO 24
14    IF(CROPNO(I).NE.8.) GO TO 316
      BU(JY)=YIELD(I)*1.7
      BL(JY)=YIELD(I)*.3
      BU(JP)=PRICE(I)*1.12
      BL(JP)=PRICE(I)*.89
      GO TO 24
16    STOP
   24 CONTINUE
  COMPUTE SHAPE PARAMETERS
      DO 26 I=1,MN
      EMU=(AMEAN(I)-BL(I))/(BU(I)-BL(I))
      SIG=VAR(I)/(BU(I)-BL(I))**2
      K1(I)=EMU*(((EMU*(1.-EMU))/SIG)-1.)
      K2(I)=(1.-EMU)*(((EMU*(1.-EMU))/SIG)-1.)
   26 CONTINUE
      CALL MVBETA
  COMPUTE NET RETURN TO LAND
      DO 28 M=1,ND
   28 GROSINC(M)=0.0
      DO 30 M=1,ND
      LA=-1
      LB=0
      DO 32 N=1,ICROPS
      LA=LA+2
      LB=LB+2
   32 GROSINC(M)=GROSINC(M)+(Y(LA,M)*Y(LB,M))/DIVISOR
   30 CONTINUE
      CALL RORDER(GROSINC,ND)
      CALL CASH(CROPS,ROTNO,CSHCST)
      CALL MACHINE(ROTNO,EQUPCST,FUELCST,HRDLBR)
      CALL HAULDRY(HDCST)
      FMLYLBR=23.33
      DO 35 M=1,ND
5     RETLND(M)=GROSINC(M)-CSHCST-EQUPCST-FUELCST-HRDLBR-FMLYLBR-HDCST
  OUTPOUT FORMAT ROUTINES
  PAGE HEADER ROUTINE
      WRITE(2,42)
   42 FORMAT(*1*,47X,*SAGINAW  VALLEY  CROPPING  SYSTEMS  MODEL*)
      WRITE(2,44)ROTNO
   44 FORMAT(*0*,4X,*ROTATION  NUMBER  *,F3.0)
      WRITE(2,46)
   46 FORMAT(*0*,4X,*CROPS  IN  THIS  ROTATION  ARE:*)
      JJ=1
   47 IF(JJ.GT.ICROPS)GO TO 78
      IF(CROPNO(JJ).NE.1.)GO TO 52
      WRITE(2,50)YIELD(JJ),PRICE(JJ)
   50 FORMAT(8X,*CORN*,8X,*EXPECTED  YIELD  *,F5.0,*  BU/ACRE  EXPECTE
     *D  PRICE  $*,F6.2,*/BU*)
      GO TO 76
   52 IF(CROPNO(JJ).NE.2.)GO TO 56
      WRITE(2,54)YIELD(JJ),PRICE(JJ)
   54 FORMAT(8X,*NAVYBEANS *,2X,*EXPECTED  YIELD  *,F5.0,*  CWT/ACRE  E
     *XPECTED  PRICE  $*,F6.2,*/CWT*)
      GO TO 76
   56 IF(CROPNO(JJ).NE.3.)GO TO 60
      WRITE(2,58)YIELD(JJ),PRICE(JJ)
   58 FORMAT(8X,*SOYBEANS*,4X,*EXPECTED  YIELD  *,F5.0,*  BU/ACRE  EXP
     *ECTED  PRICE  $*,F6.2,*/BU*)
      GO TO 76
   60 IF(CROPNO(JJ).NE.4.)GO TO 64
      WRITE(2,62)YIELD(JJ),PRICE(JJ)
 2    FORMAT(8X,*SUGARBEETS  EXPECTED  YIELD  *,F5.0,*  TON/ACRE  EXPEC
     *TED  PRICE  $*,F6.2,*/TON*)
      GO TO 76
   64 IF(CROPNO(JJ).NE.5.)GO TO 68
      WRITE(2,66)YIELD(JJ),PRICE(JJ)
   66 FORMAT(8X,*OATS*,8X,*EXPECTED  YIELD  *,F5.0,*  BU/ACRE  EXPECTE
```

```
      BL(JY)=YIELD(I)*.3
      BU(JP)=PRICE(I)*1.12
      BL(JP)=PRICE(I)*.89
      GO TO 24
12    IF(CROPNO(I).NE.7.) GO TO 314
      BU(JY)=YIELD(I)*1.51
      BL(JY)=YIELD(I)*.44
      BU(JP)=PRICE(I)*1.76
      BL(JP)=2.35
      GO TO 24
14    IF(CROPNO(I).NE.8.) GO TO 316
      BU(JY)=YIELD(I)*1.7
      BL(JY)=YIELD(I)*.3
      BU(JP)=PRICE(I)*1.12
      BL(JP)=PRICE(I)*.89
      GO TO 24
16    STOP
   24 CONTINUE
C  COMPUTE SHAPE PARAMETERS
      DO 26 I=1,MN
      EMU=(AMEAN(I)-BL(I))/(BU(I)-BL(I))
      SIG=VAR(I)/(BU(I)-BL(I))**2
      K1(I)=EMU*(((EMU*(1.-EMU))/SIG)-1.)
      K2(I)=(1.-EMU)*(((EMU*(1.-EMU))/SIG)-1.)
   26 CONTINUE
      CALL MVBETA
C  COMPUTE NET RETURN TO LAND
      DO 28 M=1,ND
   28 GROSINC(M)=0.0
      DO 30 M=1,ND
      LA=-1
      LB=0
      DO 32 N=1,ICROPS
      LA=LA+2
      LB=LB+2
   32 GROSINC(M)=GROSINC(M)+(Y(LA,M)*Y(LB,M))/DIVISOR
   30 CONTINUE
      CALL RORDER(GROSINC,ND)
      CALL CASH(CROPS,ROTNO,CSHCST)
      CALL MACHINE(ROTNO,EQUPCST,FUELCST,HRDLBR)
      CALL HAULDRY(HDCST)
      FMLYLBR=23.33
      DO 35 M=1,ND
35    RETLND(M)=GROSINC(M)-CSHCST-EQUPCST-FUELCST-HRDLBR-FMLYLBR-HDCST
C  OUTPOUT FORMAT ROUTINES
C  PAGE HEADER ROUTINE
      WRITE(2,42)
   42 FORMAT(*1*,47X,*SAGINAW  VALLEY  CROPPING  SYSTEMS  MODEL*)
      WRITE(2,44)ROTNO
   44 FORMAT(*0*,4X,*ROTATION  NUMBER  *,F3.0)
      WRITE(2,46)
   46 FORMAT(*0*,4X,*CROPS  IN  THIS  ROTATION  ARE:*)
      JJ=1
   47 IF(JJ.GT.ICROPS)GO TO 78
      IF(CROPNO(JJ).NE.1.)GO TO 52
      WRITE(2,50)YIELD(JJ),PRICE(JJ)
   50 FORMAT(8X,*CORN*,8X,*EXPECTED  YIELD  *,F5.0,*  BU/ACRE  EXPECTE
     *D  PRICE  $*,F6.2,*/BU*)
      GO TO 76
   52 IF(CROPNO(JJ).NE.2.)GO TO 56
      WRITE(2,54)YIELD(JJ),PRICE(JJ)
   54 FORMAT(8X,*NAVYBEANS *,2X,*EXPECTED  YIELD  *,F5.0,*  CWT/ACRE  E
     *XPECTED  PRICE  $*,F6.2,*/CWT*)
      GO TO 76
   56 IF(CROPNO(JJ).NE.3.)GO TO 60
      WRITE(2,58)YIELD(JJ),PRICE(JJ)
   58 FORMAT(8X,*SOYBEANS*,4X,*EXPECTED  YIELD  *,F5.0,*  BU/ACRE  EXP
     *ECTED  PRICE  $*,F6.2,*/BU*)
      GO TO 76
   60 IF(CROPNO(JJ).NE.4.)GO TO 64
      WRITE(2,62)YIELD(JJ),PRICE(JJ)
62    FORMAT(8X,*SUGARBEETS  EXPECTED  YIELD  *,F5.0,*  TON/ACRE  EXPEC
     +TED  PRICE  $*,F6.2,*/TON*)
      GO TO 76
   64 IF(CROPNO(JJ).NE.5.)GO TO 68
      WRITE(2,66)YIELD(JJ),PRICE(JJ)
   66 FORMAT(8X,*OATS*,8X,*EXPECTED  YIELD  *,F5.0,*  BU/ACRE  EXPECTE
```

```
     *D  PRICE  $*,F6.2,*/BU*)
      GO TO 76
  68 IF(CROPNO(JJ).NE.6.)GO TO 72
      WRITE(2,70)YIELD(JJ),PRICE(JJ)
'0    FORMAT(8X,*ALFALFA*,5X,*EXPECTED  YIELD  *,F5.1,*  TON/ACRE   EXPE
     +CTED  PRICE  $*,F6.2,*/TON*)
      GO TO 76
'2    IF(CROPNO(JJ).NE.7.)GO TO 77
      WRITE(2,74)YIELD(JJ),PRICE(JJ)
'4    FORMAT(8X,*WHEAT*,7X,*EXPECTED  YIELD  *,F5.0,*   BU/ACRE   EXPECT
     +ED  PRICE  $*,F6.2,*/BU*)
      GO TO 76
'7    WRITE(2,79)YIELD(JJ),PRICE(JJ)
'9    FORMAT(8X,*OAT STRAW*,3X,*EXPECTED  YIELD  *,F5.0,*  TON/ACRE   EX
     +PECTED  PRICE  $*,F6.2,*/TON*)
  76 JJ=JJ+1
      GO TO 47
  78 WRITE(2,80)
l0    FORMAT(*-*,10X,*GROSS*,11X,*CASH*,8X,*MACHINERY*,9X,*FUEL*,
     +9X,*HIRED*,8X,*HAULING*,8X,*FAMILY*,10X,*RETURN*)
      WRITE(2,81)
:1    FORMAT(* *,9X,*INCOME*,10X,*COSTS*,11X,*COST*,11X,*COST*,9X,
     +*LABOR*,9X,*DRYING*,9X,*LABOR*,9X,*TO  LAND*)
      WRITE(2,84)GROSINC(1),CSHCST,EQUPCST,FUELCST,HRDLBR,HDCST,
     +FMLYLBR,RETLND(1)
      WRITE(13,94) RETLND(1)
l4    FORMAT(10X,F6.2,9X,F6.2,9X,F6.2,10X,F5.2,9X,F5.2,8X,F6.2,9X,
     +F6.2,9X,F7.2)
      DO 82 I=2,ND
      WRITE(13,94) RETLND(I)
2     WRITE(2,86)GROSINC(I),RETLND(I)
6     FORMAT(10X,F6.2,97X,F7.2)
2     FORMAT(F3.0)
4     FORMAT(F7.2)
      END
```

```
      SUBROUTINE MVBETA
      REAL K1,K2
      COMMON /BLOCK2/   K1(20),K2(20),BL(20),BU(20),FACT(20)
      COMMON /BLOCK3/   C(20,20),COR(20,20),PAR(20,20),V(20),MN,ISYS
      COMMON /BLOCK4/   Y(20,110),RHO(20,20),ND
      DIMENSION RV(20),U(20),VALN(110),ARG(110),E(20),X(20,110)
      DIMENSION RJ(20,110),PDF(20,110)
      DATA SMALL/0.0/
      NIN=0
      NOUT=10
      IOPT=3
      CALL UGETIO(IOPT,NIN,NOUT)
      RD=ND
      DIFF=1.0/RD
      K=ND
      KN=ND+1
      WRITE(10,201)
201   FORMAT(5X,* PARAMETERS FOR DISTRIBUTION*,I3)
      DO 5 I=1,MN
      V(I)=1.0
      WRITE(10,202)K1(I),K2(I),BL(I),BU(I)
 202  FORMAT(5X,* K1=*,F5.2,3X,* K2=*,F5.2,3X,* BL=*,F6.2,5X,* BU=*,
     *F6.2)
  5   CONTINUE
  GENERATE VALUES OF VALN FOR NORMAL TABLE LOOK UP
      VALN(1)=0.00000001
      VALN(2)=DIFF
      VALN(KN)=0.99999999
      DO 6 I=3,ND
      J=I-1
      VALN(I)=VALN(J)+DIFF
      DO 8 I=1,KN
      Z3=VALN(I)
      CALL MDNRIS(Z3,Z4,IER)
      ARG(I)=Z4
  CONSTRUCT LOWER TRIANGULAR MATRIX C FOR GENERATION OF MULTIVARIATE
  NORMAL RANDOM VARIABLES
      CALL COEF
      DO 109 I=1,MN
      RJ(I,1)=0.0
09    CONTINUE
  GENERATE MARGINAL DISTRIBUTIONS FOR TABLE LOOK UP FUNCTIONS
      NP=K+1
      DO 15 I=1,MN
      Z1=K1(I)
      Z2=K2(I)
      X(I,1)=BL(I)
      P=0.
      DO 10 J=2,KN
      P=P+DIFF
      CALL MDBETI(P,Z1,Z2,R,IER)
  10  X(I,J)=R*(BU(I)-BL(I))+BL(I)
  15  CONTINUE
      WRITE(10,204)
204   FORMAT(49X,* MARGINAL DISTRIBUTIONS*)
      DO 136 I=1,MN
      Z1=K1(I)
      Z2=K2(I)
      P=0.0
      DO 138 J=1,KN
      CALL MDBETA(P,Z1,Z2,R,IER)
      RJ(I,J)=R
      P=P+DIFF
38    CONTINUE
36    CONTINUE
      DO 25 J=1,NP
  25  WRITE(10,205)(X(I,J),I=1,MN)
 205  FORMAT(1X,12F10.2)
      CALL DATANAL(MN,X,ND)
      DO 120 I=1,MN
      K=1
      DO 122 J=2,KN
      PDF(I,K)=(RJ(I,J)-RJ(I,J-1))
      K=K+1
22    CONTINUE
20    CONTINUE
      DO 125 I=1,MN
```

```
      PX=0.0
      DO 126 J=1,ND
      PX=PX+DIFF
      WRITE(65,209)PX,PDF(I,J)
126   CONTINUE
125   CONTINUE
209   FORMAT(F7.2,F7.4)
C  BEGIN TO GENERATE SAMPLE VECTORS
      DO 50 KK=1,ND
C  GENERATE VECTOR OF MULTIVARIATE NORMAL RANDOM NUMBERS
      CALL MVNOR(ISYS,E)
      DO 35 I=1,ISYS
      RV(I)=0.0
      DO 30 J=1,ISYS
 30   RV(I)=RV(I)+C(I,J)*E(J)
 35   CONTINUE
C  USE TABLE LOOK UP TRANSFORM TO GENERATE VECTOR OF UNIFORM RANDOM
C  NUMBERS
      DO 40 I=1,ISYS
      U(I)=TABLI(VALN,ARG,RV(I),KN)
 40   CONTINUE
C  GENERATE BETA RANDOM NUMBERS USING TABLE LOOK UP
      DO 45 I=1,MN
      MX=FACT(I)
 45   Y(I,KK)=TABLIE(I,SMALL,DIFF,K,U(MX),X)
 50   CONTINUE
      WRITE(2,215)
 215  FORMAT(10X,* CORRELATION MATRIX*)
      DO 55 I=2,MN
      MJ=I-1
      DO 52 J=1,MN
      IF(J.GE.I) GO TO 55
      CALL COREL(I,J)
 52   CONTINUE
  55  WRITE(2,206) (RHO(I,M),M=1,MJ)
 206  FORMAT(5X,12F8.5)
      WRITE(10,207)
 207  FORMAT(50X,* SAMPLE OBSERVATIONS*)
      DO 60 J=1,ND
  60  WRITE(10,205) (Y(I,J),I=1,MN)
      CALL DATANAL(MN,Y,ND)
      RETURN
      END
```

```
VE RORDER      74/175   OPT=1                          FTN 4.8+508        10/13/80 .22.

      SUBROUTINE RORDER(X,NP)
      DIMENSION X(110)
      NP1=NP-1
      DO 400 J=1,NP1
      AM=X(J)
      N=J
      JJ=J+1
      DO 401 K=JJ,NP
      IF(AM.LE.X(K))GO TO 401
      N=K
      AM=X(K)
  401 CONTINUE
      X(N)=X(J)
      X(J)=AM
  400 CONTINUE
      RETURN
      END
```

```
ON TABLI       74/175   OPT=1                          FTN 4.8+508        10/13/80 .22.

      FUNCTION TABLI(VAL,ARG,DUMMY,K)
      DIMENSION VAL(1),ARG(1)
      DUM=AMAX1(AMIN1(DUMMY,ARG(K)),ARG(1))
      DO 1 I=2,K
      IF(DUM.GT.ARG(I)) GO TO 1
      TABLI=(DUM-ARG(I-1))*(VAL(I)-VAL(I-1))/
     1(ARG(I)-ARG(I-1))+VAL(I-1)
      RETURN
    1 CONTINUE
      RETURN
      END
```

ON TABLIE 74/175 OPT=1 FTN 4.8+508 10/13/80 .22

```
      FUNCTION TABLIE(J,SMALL,DIFF,K,DUMMY,X)
      DIMENSION X(20,110)
      DUM=AMIN1(AMAX1(DUMMY-SMALL,0.0),FLOAT(K)*DIFF)
      I=1.0+DUM/DIFF
      IF(I.EQ.K+1) I=K
      TABLIE=(X(J,I+1)-X(J,I))*(DUM-FLOAT(I-1)*DIFF)/DIFF+X(J,I)
      RETURN
      END
```

NE COREL 74/175 OPT=1 FTN 4.8+508 10/13/80 .22

```
      SUBROUTINE COREL(M,N)
      COMMON /BLOCK4/   Y(20,110),RHO(20,20),ND
      V1=0.0
      V2=0.0
      V3=0.0
      V4=0.0
      V5=0.0
      DO 5 I=1,ND
      V1=V1+Y(M,I)*Y(N,I)
      V2=V2+Y(M,I)
      V3=V3+Y(N,I)
      V4=V4+Y(M,I)**2
      V5=V5+Y(N,I)**2
    5 CONTINUE
      XNUM=FLOAT(ND)*V1-V2*V3
      DNOM=SQRT((FLOAT(ND)*V4-V2**2)*(FLOAT(ND)*V5-V3**2))
      RHO(M,N)=XNUM/DNOM
      RETURN
      END
```

```
:NE MVNOR      74/175   OPT=1                    FTN 4.8+508        10/13/80 .22

      SUBROUTINE MVNOR(MN,E)
      DIMENSION E(1)
      DO 5 I=1,MN
      R1=RANF(-1)
      R2=RANF(-1)
      E(I)=(-2.0*ALOG(R1))**.5*COS(6.2831*R2)
    5 CONTINUE
      RETURN
      END
```

```
NE COEF        74/175   OPT=1                    FTN 4.8+508        10/13/80 .22

      SUBROUTINE COEF
      COMMON /BLOCK3/    C(20,20),COR(20,20),PAR(20,20),V(20),MN,ISYS
      DO 10  I=1,ISYS
      DO 10  J=1,ISYS
   10 C(I,J)=0.
      DO 20  I=1,ISYS
 20   PAR(I,1)=COR(I,1)
      IF(ISYS.LT.2) GO TO 70
      DO 60  J=2,ISYS
      JM1=J-1
      SUM=0.
      DO 30  K=1,JM1
 30   SUM=SUM+PAR(J,K)**2
      IF(SUM.GT.COR(J,J)) SUM=COR(J,J)
      PAR(J,J)=SQRT(1.-SUM)
      IF(J.EQ.ISYS) GO TO 70
      JP1=J+1
      DO 50  I=JP1,ISYS
      PAR(I,J)=0.
      IF(PAR(J,J).EQ.0.) GO TO 50
      SUM=0.
      DO 40  K=1,JM1
   40 SUM=SUM+PAR(I,K)*PAR(J,K)
      PAR(I,J)=(COR(I,J)-SUM)/PAR(J,J)
   50 CONTINUE
   60 CONTINUE
   70 DO 80  I=1,ISYS
      DO 80  J=1,I
   80 C(I,J)=PAR(I,J)*SQRT(V(I))
      RETURN
      END
```

```
      SUBROUTINE CASH(CROPS,ROTNO,CSHCST)
      DIMENSION ARRAYIN(40),PRICE(40),ARRAY(10,40)
      KOUNT=0
      IROT=ROTNO
  100 CONTINUE
      IF(EOF(5).NE.0) GO TO 105
      KOUNT = KOUNT + 1
      READ(5,107)PRICE(KOUNT)
      WRITE(7,900)KOUNT,PRICE(KOUNT)
  900 FORMAT(* KOUNT = *,I5,*  PRICE = *,F8.2)
      GO TO 100
  105 KOUNT = KOUNT - 1
      NCT = KOUNT - 10
  107 FORMAT(F8.2)
      IND=0
  108 CONTINUE
      READ(6,111)IRONAM,IRONAM2,ICRNAM
 111  FORMAT(A10,A10,A10)
      IF (EOF(6).NE.0) GO TO 110
      READ(6,109)(ARRAYIN(JF),JF=1,KOUNT)
      IF(ARRAYIN(28).NE.IROT) GO TO 108
      IND=IND+1
      DO 120 JG=1,KOUNT
 120  ARRAY(IND,JG)=ARRAYIN(JG)
      WRITE(7,901)(IND,JF,ARRAY(IND,JF),JF=1,KOUNT)
 901  FORMAT(* *,4(*  ARRAY(*,I3,*,*,I3,*)=*,F8.2))
      GO TO 108
 110  CONTINUE
      COST=0.0
  109 FORMAT(7F10.0)
      DO 300 II=1,IND
      ARRAY(II,10)=ARRAY(II,10)
      ARRAY(II,12)=ARRAY(II,12)
      DO 310 JJ=1,NCT
 310  COST=COST+(ARRAY(II,JJ)*PRICE(JJ))
  300 CONTINUE
      CSH=COST/CROPS
      CSHCST=CSH+(CSH*.0600)
      REWIND5
      REWIND6
      RETURN
      END
```

```
NE MACHINE     74/175   OPT=1                    FTN 4.8+508          10/13/80 .22

        SUBROUTINE MACHINE(ROTNO,EQUPCST,FUELCST,HRDLBR)
  102   IF(EOF(8).NE.0) GO TO 104
        READ(8,100)V1,V2,V3,V4
  100   FORMAT(F5.0,F10.2,F10.2,F10.2)
        IF(V1.NE.ROTNO) GO TO 102
        EQUPCST=V2
        FUELCST=V3*1.00
        HRDLBR=V4
        REWIND 8
  104   RETURN
        END
```

```
NE HAULDRY     74/175   OPT=1                    FTN 4.8+508          10/13/80 .22

        SUBROUTINE HAULDRY(HDCST)
        COMMON /BLOCK5/ ICROPS,DIVISOR,YIELD(20),CROPNO(20)
        READ(9,100) PCTDRY,GNCST,HAYCST,BTCST
  100   FORMAT(4(F5.0))
        HDCST=0.0
        DO 20 I=1,ICROPS
        IF(CROPNO(I).NE.1.) GO TO 30
        W=PCTDRY*.02*YIELD(I)
        HAUL=((YIELD(I)*GNCST)+W)/DIVISOR
        GO TO 90
   30   IF(CROPNO(I).NE.2.) GO TO 40
        HAUL=(YIELD(I)*GNCST*1.67)/DIVISOR
        GO TO 90
   40   IF(CROPNO(I).NE.4.) GO TO 50
        HAUL=(YIELD(I)*BTCST)/DIVISOR
        GO TO 90
   50   IF(CROPNO(I).NE.6.) GO TO 60
        HAUL=(YIELD(I)*HAYCST)/DIVISOR
        GO TO 90
   60   HAUL=(YIELD(I)*GNCST)/DIVISOR
   90   HDCST=HDCST+HAUL
   20   CONTINUE
        REWIND 9
        RETURN
        END
```

```
      SUBROUTINE DATANAL(MN,D,ND)
      DIMENSION D(20,110)
      DIMENSION SUM(40),SX(40),SV(40),SS(40)
      DO 10 I=1,MN
      SUM(I)=0.0
      DO 20 J=1,ND
20    SUM(I)=SUM(I)+D(I,J)
10    SX(I)=SUM(I)/ND
      DO 30 II=1,MN
      SUM(II)=0.0
      DO 40 JJ=1,ND
40    SUM(II)=SUM(II)+(D(II,JJ)-SX(II))**2.
30    SV(II)=SUM(II)/(ND-1)
      DO 50 III=1,MN
      SUM(III)=0.0
      DO 60 JJJ=1,ND
60    SUM(III)=SUM(III)+((D(III,JJJ)-SX(III))**3./(SV(III)**.5))
50    SS(III)=SUM(III)/ND
      WRITE(10,100)
100   FORMAT(*1*,10X,*MOMENTS OF SAMPLE DISTRIBUTIONS*)
      WRITE(10,110)
110   FORMAT(*0*,5X,*MEAN*)
      WRITE(10,135)(SX(I),I=1,MN)
      WRITE(10,120)
120   FORMAT(*0*,5X,*VARIANCE*)
      WRITE(10,135)(SV(I),I=1,MN)
      WRITE(10,130)
130   FORMAT(*0*,5X,*SKEWNESS*)
      WRITE(10,135)(SS(I),I=1,MN)
135   FORMAT(4(5X,F8.3))
      RETURN
      END
```

APPENDIX H

MULTIVARIATE PROCESS GENERATOR

APPENDIX H

MULTIVARIATE PROCESS GENERATOR

Introduction

The process generator employed in this study to generate "net returns to land" is based on standard computer simulation procedures (e.g., Naylor, 1966; Manetsch and Park, 1974). These procedures were developed to generate observations from a multivariate, cumulative distribution function with user specified marginal distributions and correlation matrix (King, 1979). Key concepts are summarized here for convenience.

Multivariate Normal

Anderson (1958) has demonstrated that if z is a vector of standard normal [i.e., N C(0,1)], random variables, then there exists a unique lower triangular matrix such that,

$$x = Cz + \mu$$

where x represents a vector of normal random variables with mean μ and variance covariance matrix V, in which,

$$V = CC'$$

where C can be obtained from V by use of a recursive method given by:

$$C_{i1} = \frac{\sigma i1}{\sigma_{11}^{1/2}} \qquad \text{for} \quad 1 \le i \le M$$

$$C_{ii} = \left[\sigma_{ii} - \sum_{k=1}^{i-1} C_{ik}^2\right]^{1/2}$$

$$C_{ij} = \frac{\left[\sigma_{ij} - \sum_{k=1}^{j-1} C_{ik}\, C_{ij}\right]}{C_{jj}} \qquad \text{for } 1 < j < i \le M$$

where σ_{ij} are elements of variance covariance matrix V.

Once C is obtained, the x_i of vector x is generated as normally distributed random variables with specified mean, variance, and correlations among marginal distributions. In the particular case outlined, the multivariate normal is generated with standard normal marginals.

<u>Multivariate Uniform</u>

The next step is to employ the vector of multivariate normals to generate a set of multivariate uniform distributed random variables. A general procedure for generating random variables having any desired cumulative distribution function is the inverse transform method (Manetsch and Park, 1974).

The procedure may be illustrated with the aid of Figure 1. A random number, r_i, is selected from a uniform (0, 1) distribution. F(x) represents the cumulative distribution function for x. x_i may then be computed as:

$$x_i = F^{-1}(r_i) \qquad i = 1, 2, \ldots , n.$$

In this particular case it is desired to go from a set of normally distributed random numbers to a set of uniform distributed random numbers. Therefore:

$$r_i = F^{-1}(x_i)$$

At this point, r_i is a vector of uniformly distributed random variables with a specified covariance. A reapplication of the above process with F(x) as the cumulative distribution function of a beta random variable and employing the vector of r_i correlated uniformly distributed random variables, yields a vector of correlated beta distributed random variables.

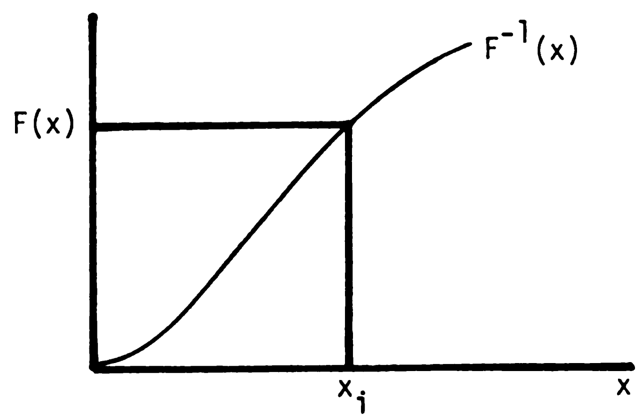


Figure H.1 Illustration of Inverse Transform Method.

The entire procedure developed rests on the hypothesis that the correlation coefficients among the marginal distributions are maintained as the distribution is successively transformed from normal to uniform to beta. That this hypothesis is true, has not been established analytically. However, Monte Carlo experiments indicate the correlation coefficients among the generated sample vectors tend to converge to the user specified coefficient values as the number of sample draws is increased (Appendix A; King, 1979).

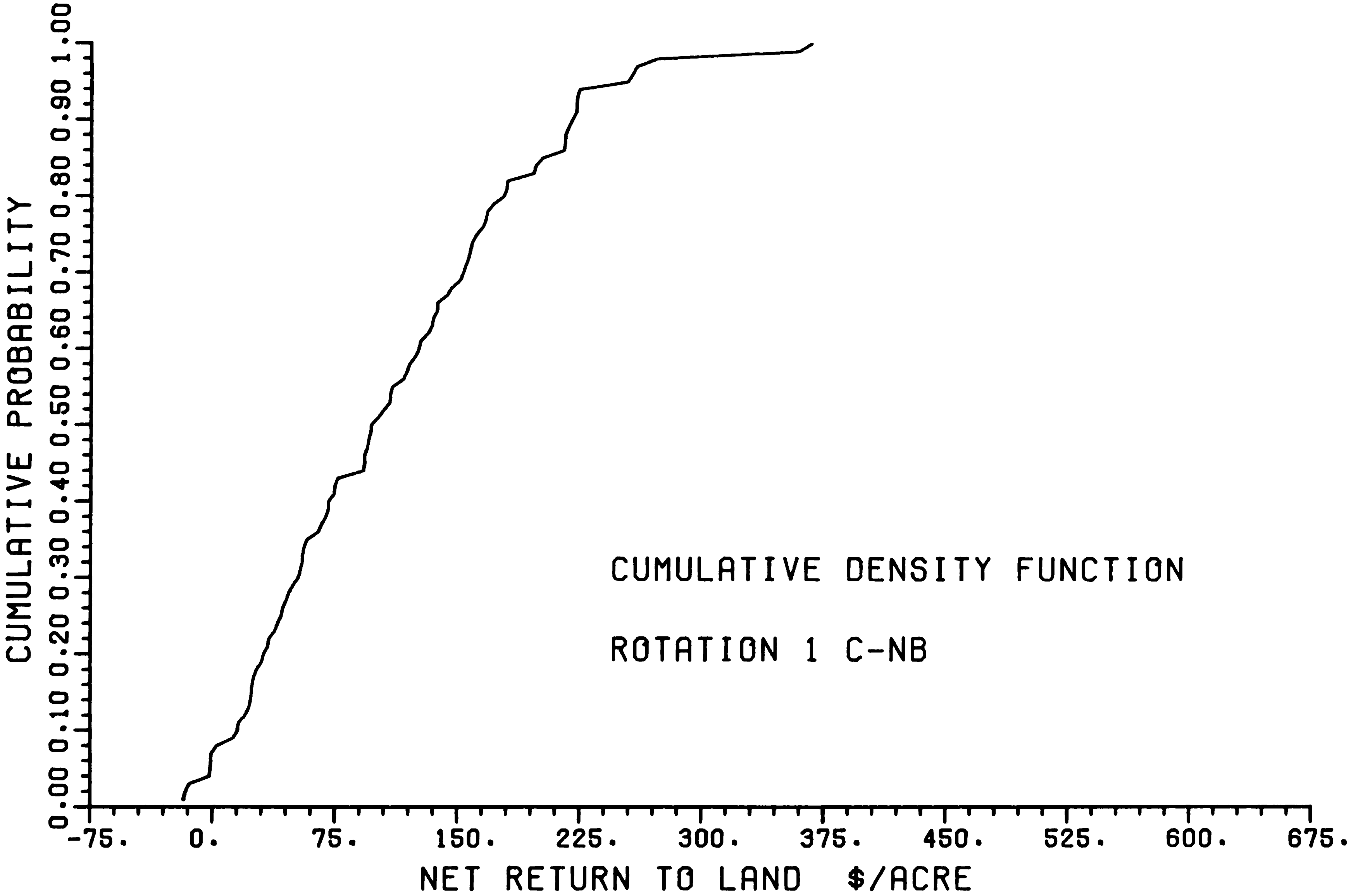
APPENDIX I

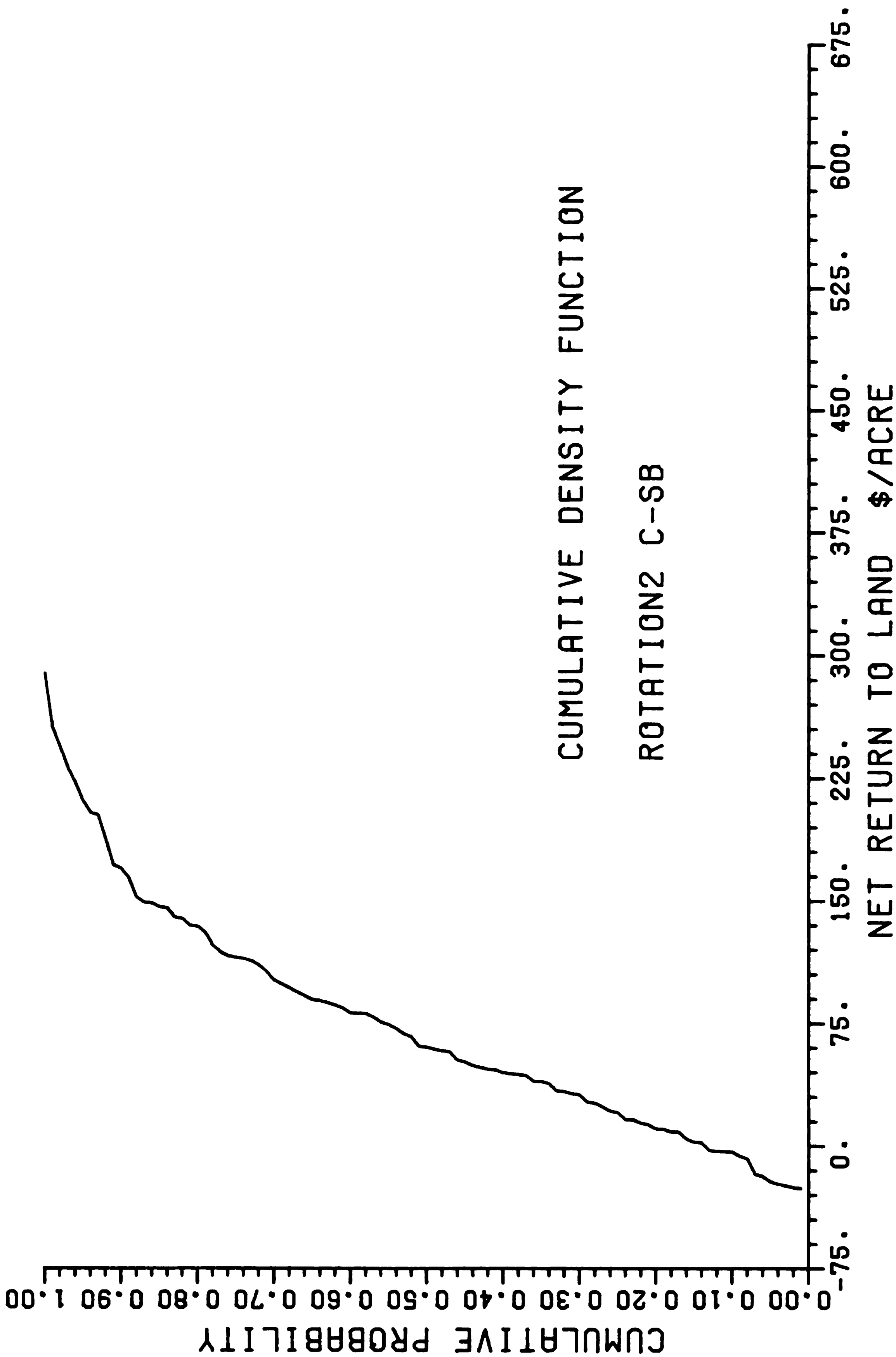
CUMULATIVE DENSITY FUNCTIONS

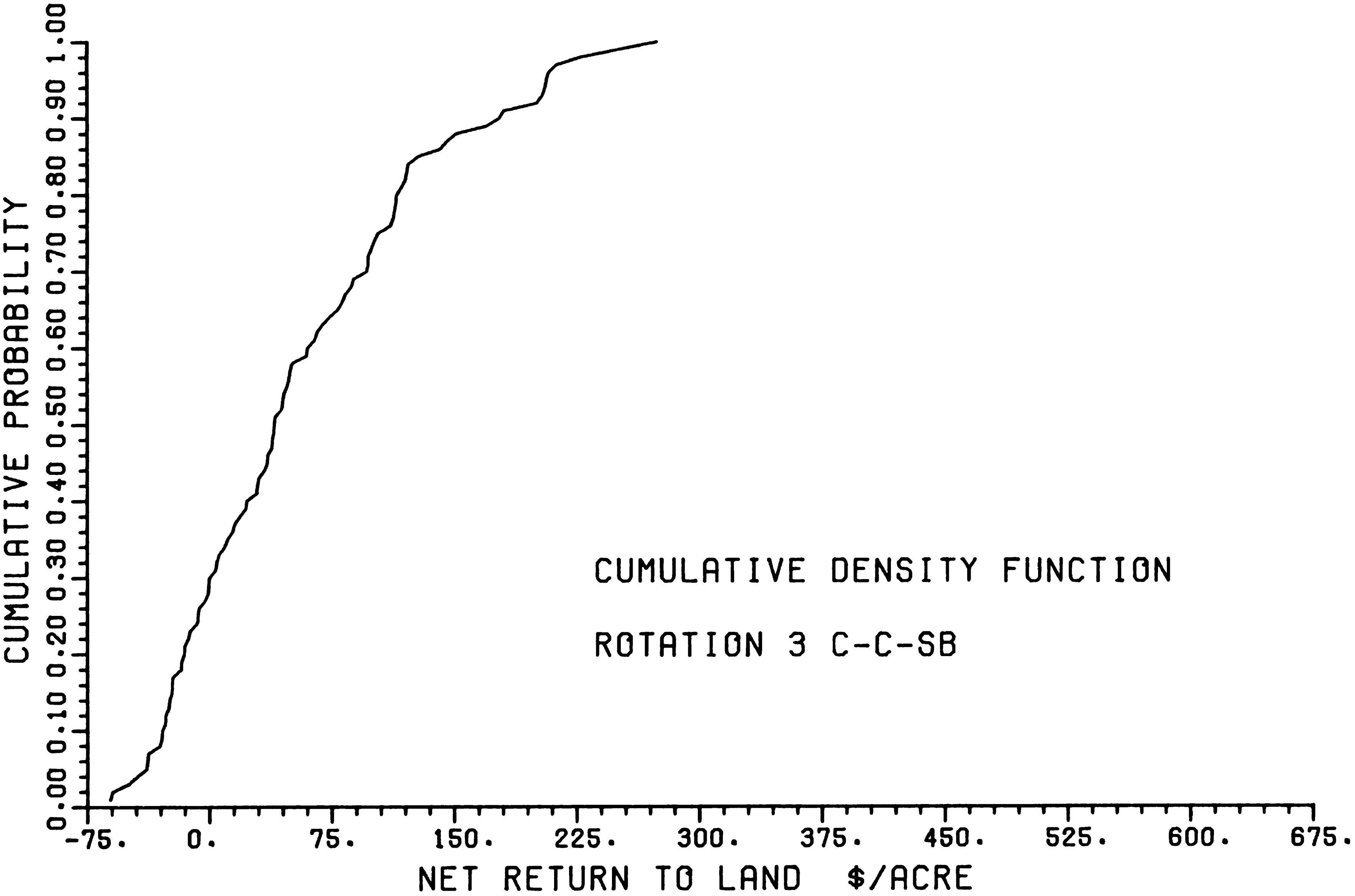
APPENDIX I

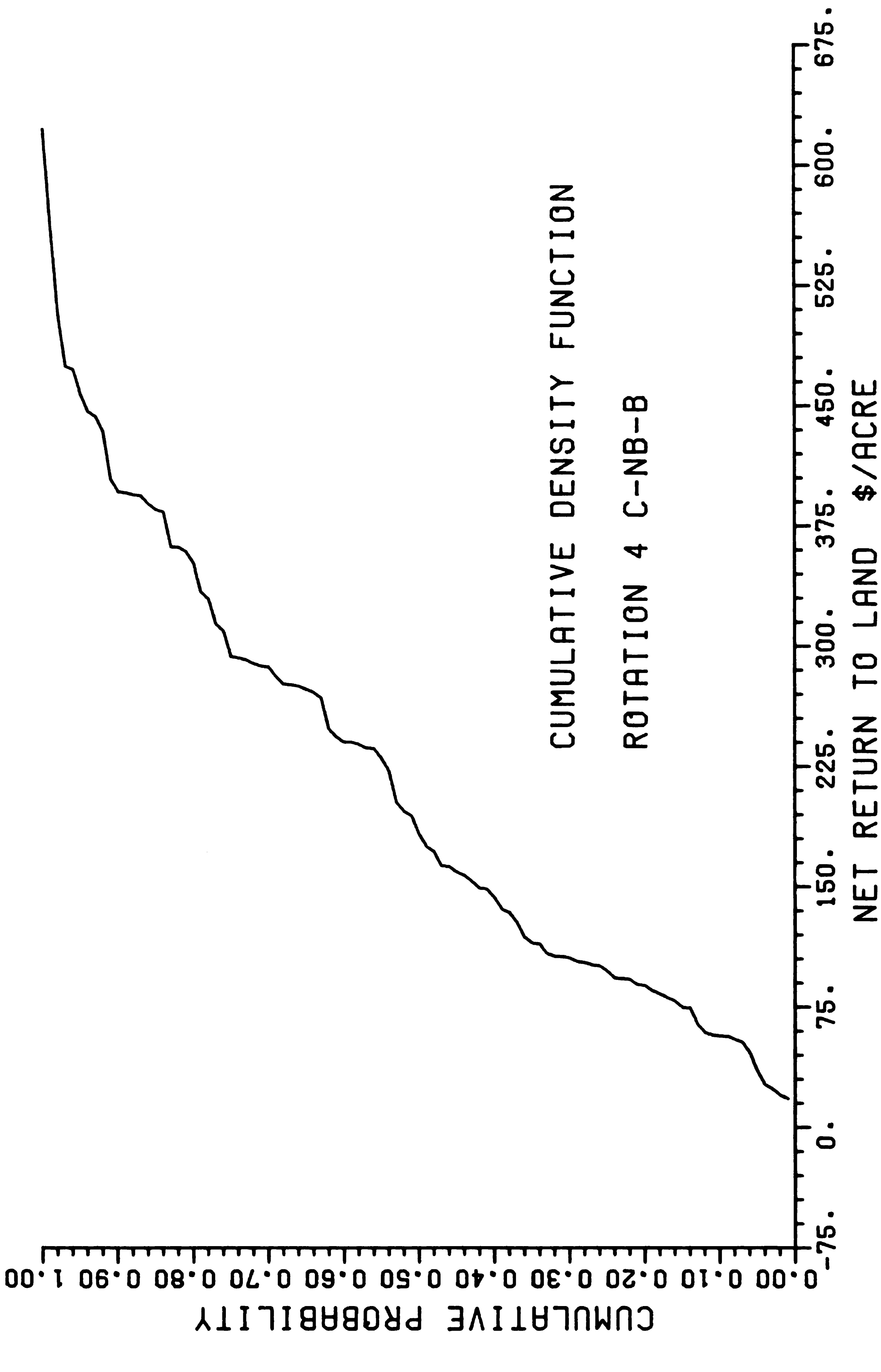
CUMULATIVE DENSITY FUNCTIONS

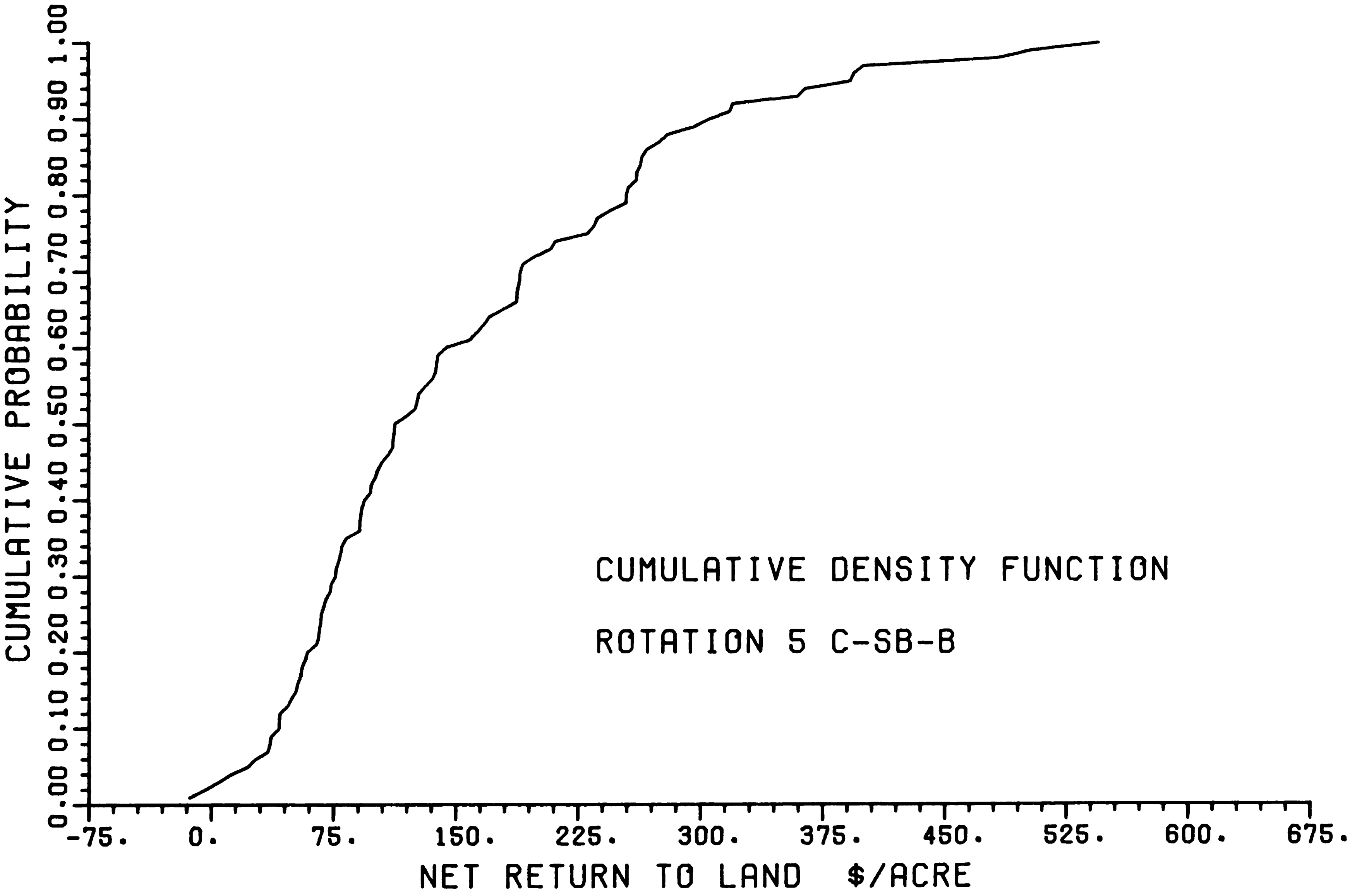
Appendix I presents the cumulative density function estimates for each of sixteen Saginaw Valley crop rotations.

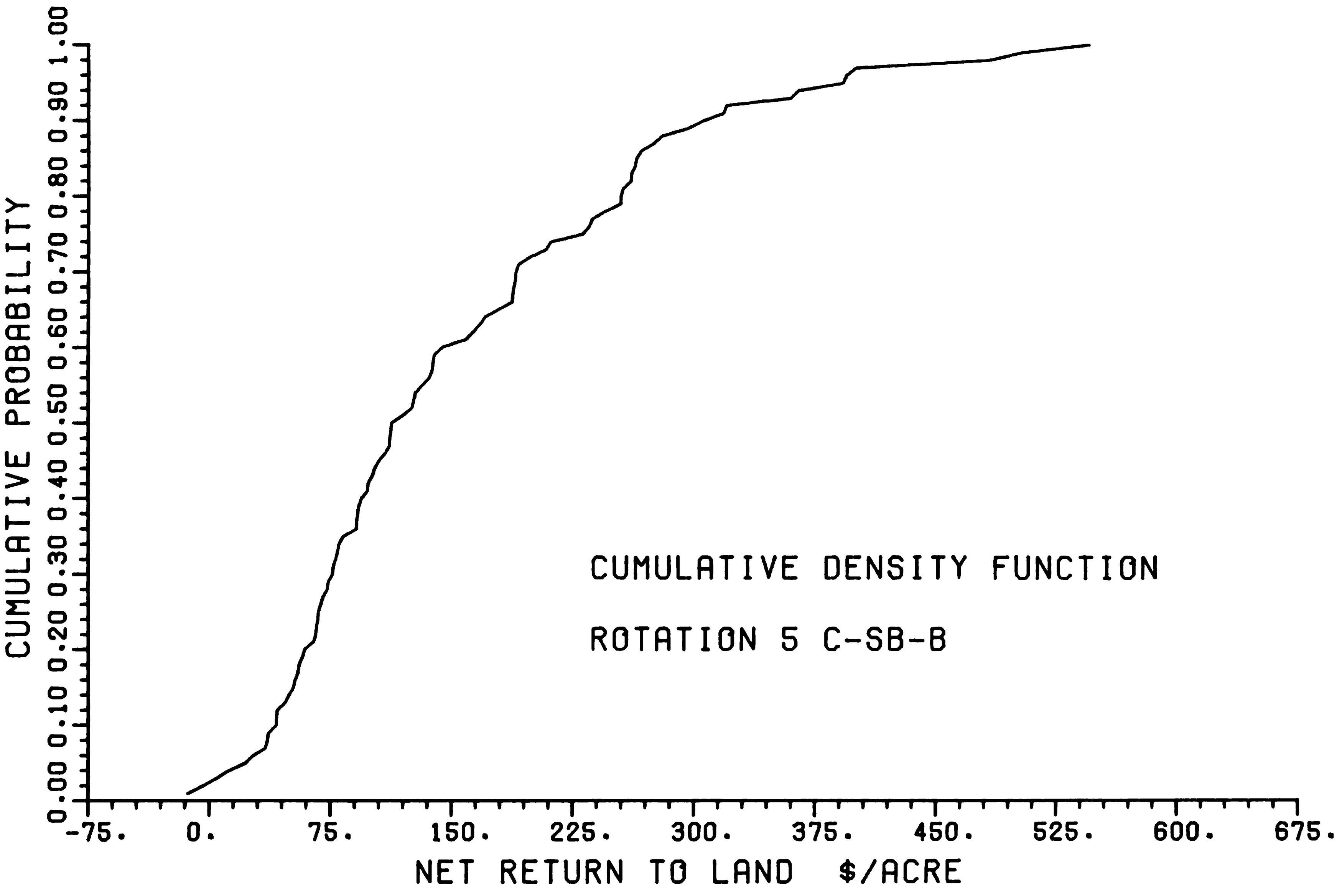

CUMULATIVE DENSITY FUNCTION
ROTATION 1 C-NB
CUMULATIVE PROBABILITY
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
-75. 0. 75. 150. 225. 300. 375. 450. 525. 600. 675.
NET RETURN TO LAND $/ACRE

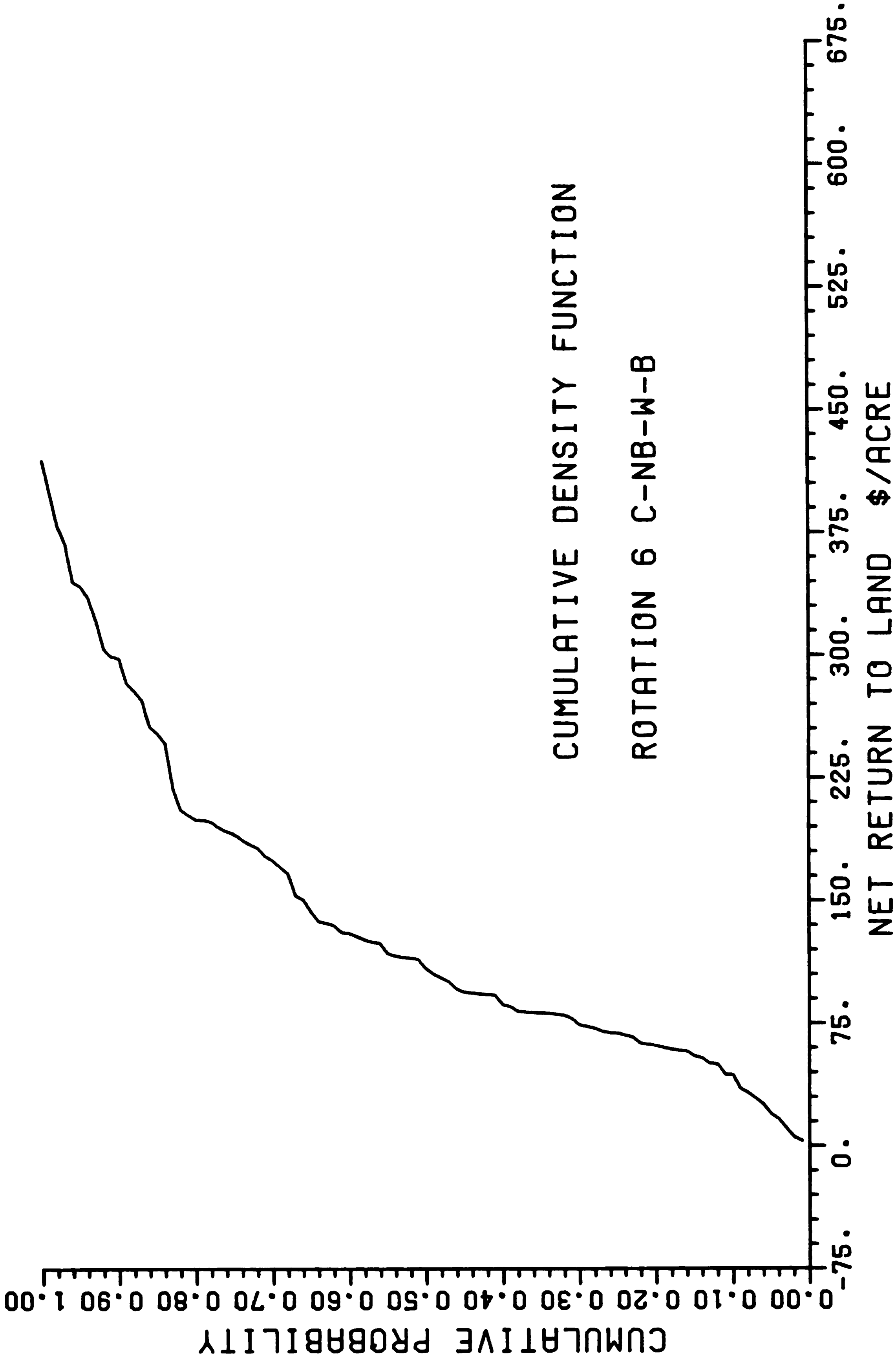

CUMULATIVE DENSITY FUNCTION
ROTATION2 C-SB
NET RETURN TO LAND $/ACRE
-75. 0. 75. 150. 225. 300. 375. 450. 525. 600. 675.
CUMULATIVE PROBABILITY
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

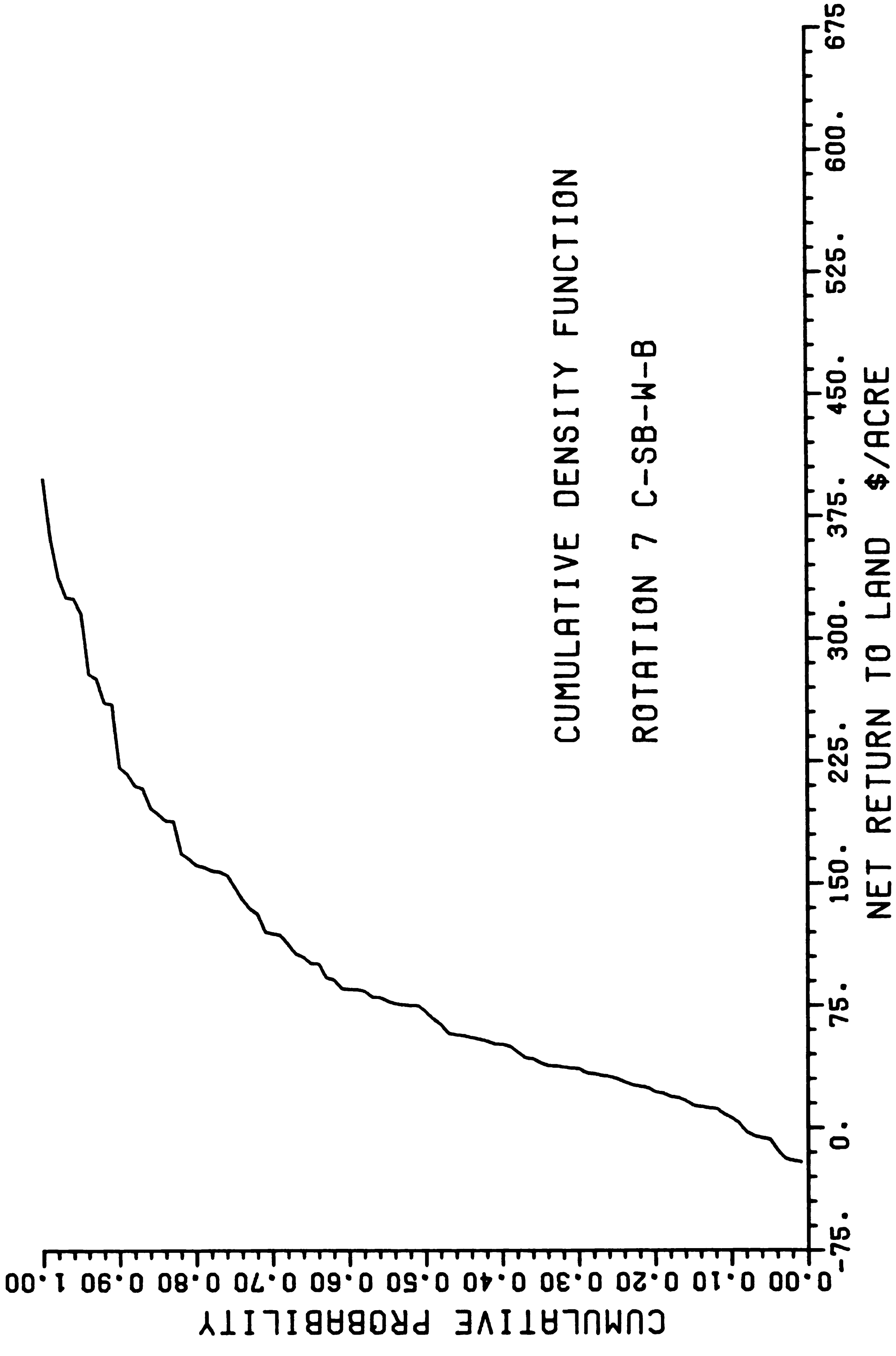

CUMULATIVE DENSITY FUNCTION
ROTATION 3 C-C-SB
CUMULATIVE PROBABILITY
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
-75. 0. 75. 150. 225. 300. 375. 450. 525. 600. 675.
NET RETURN TO LAND $/ACRE

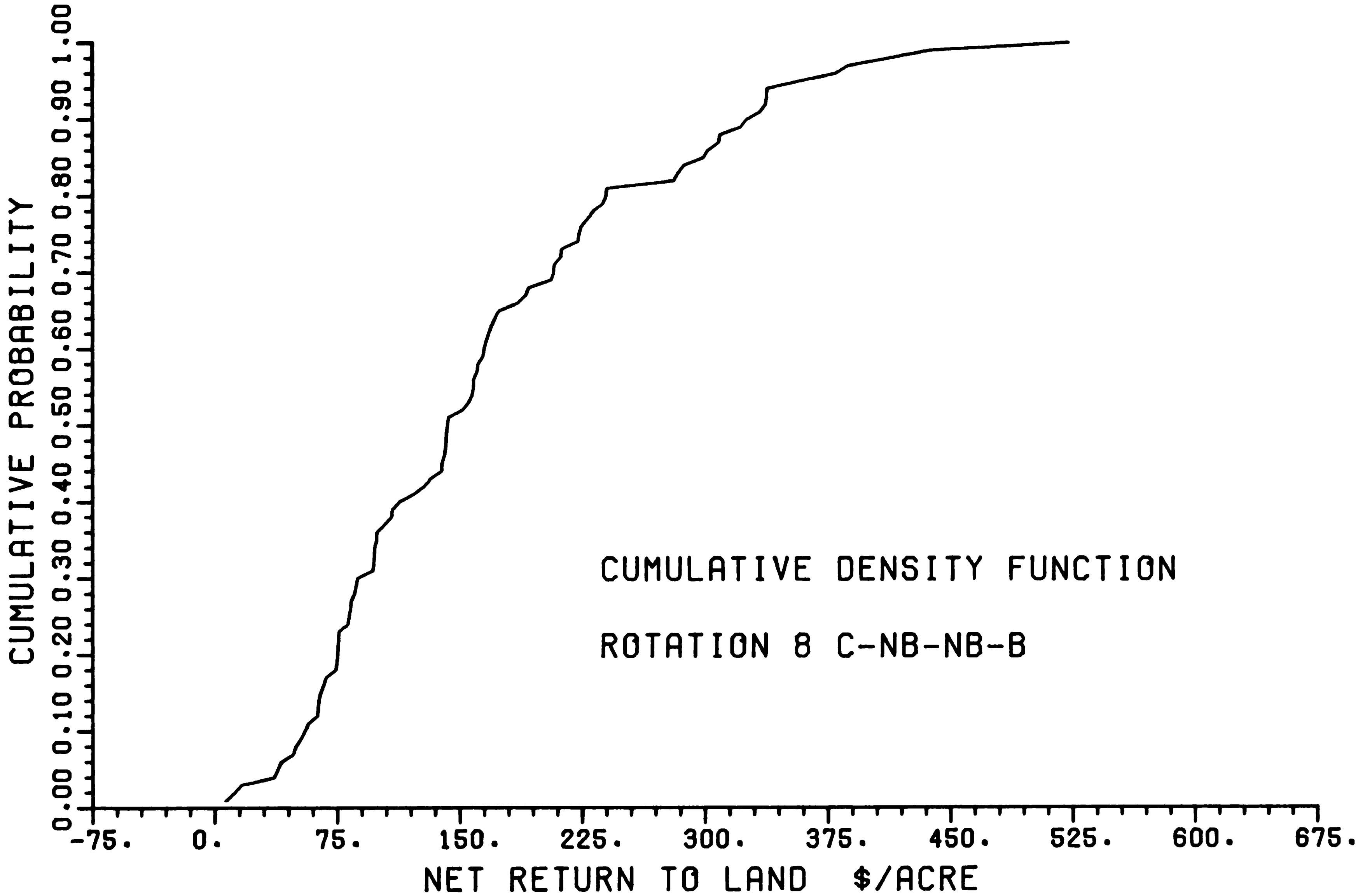

CUMULATIVE DENSITY FUNCTION
ROTATION 4 C-NB-B
NET RETURN TO LAND $/ACRE
-75. 0. 75. 150. 225. 300. 375. 450. 525. 600. 675.
CUMULATIVE PROBABILITY
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

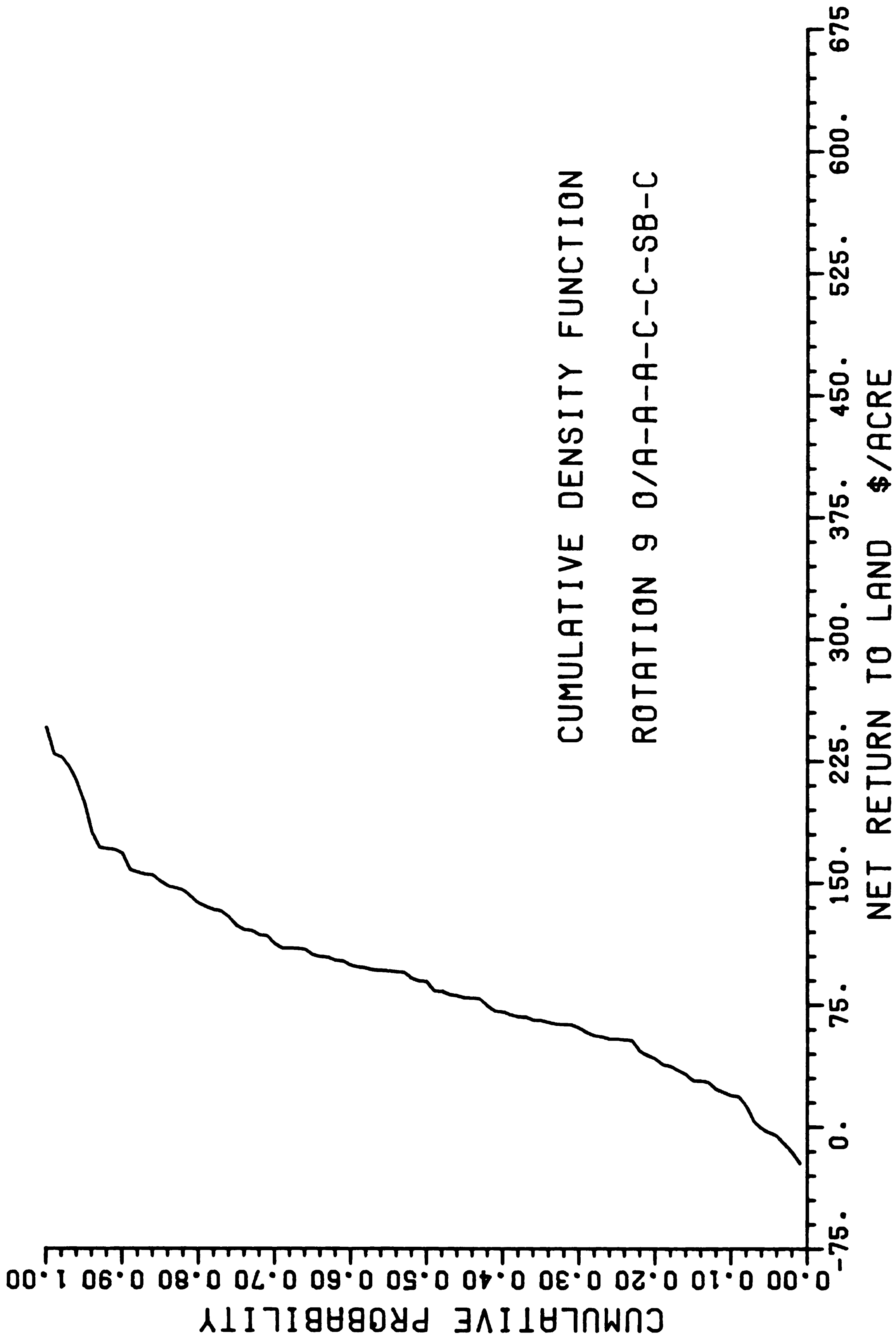

CUMULATIVE DENSITY FUNCTION
ROTATION 5 C-SB-B
CUMULATIVE PROBABILITY
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
-75. 0. 75. 150. 225. 300. 375. 450. 525. 600. 675.
NET RETURN TO LAND $/ACRE

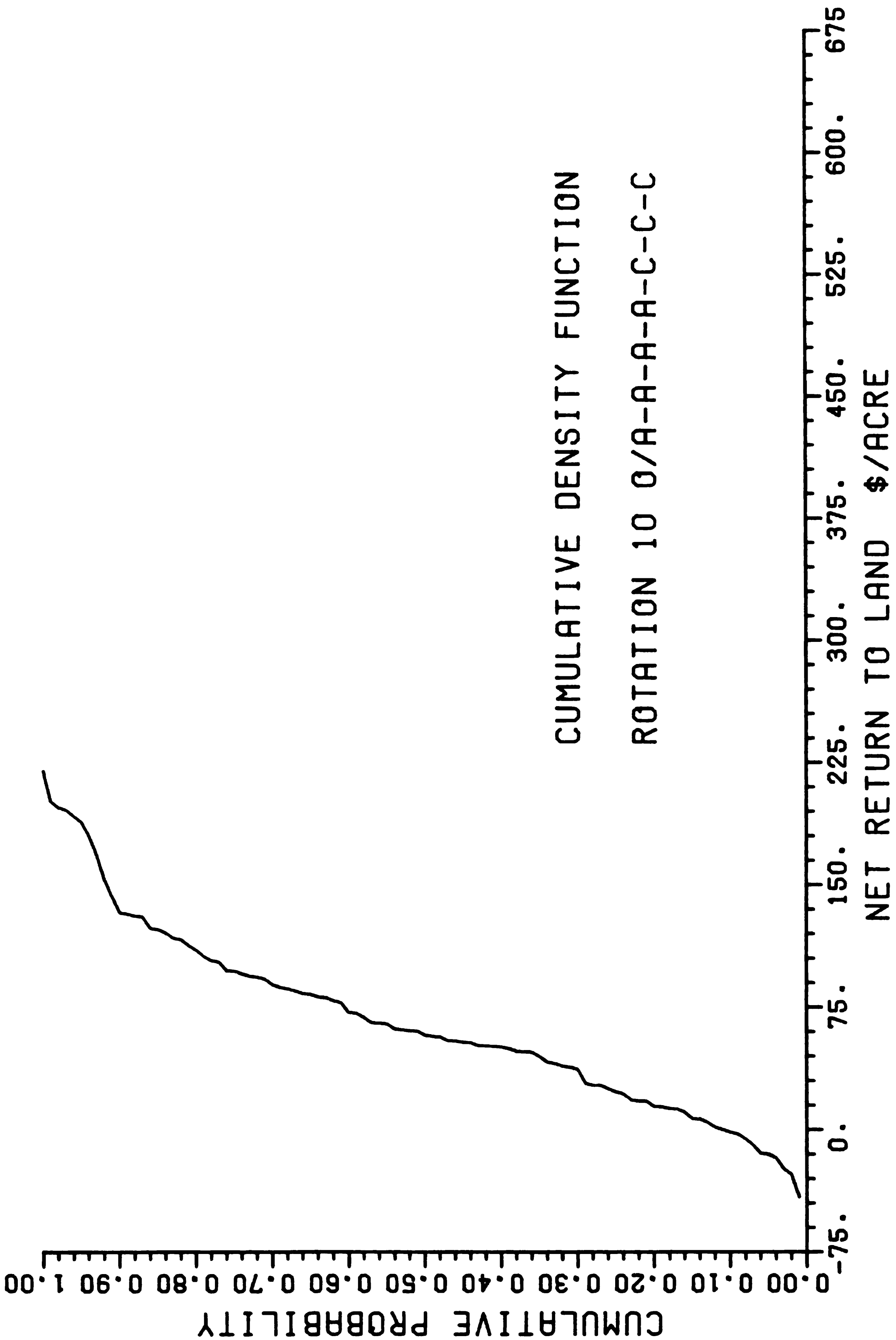

CUMULATIVE DENSITY FUNCTION
ROTATION 5 C-SB-B
CUMULATIVE PROBABILITY
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
-75. 0. 75. 150. 225. 300. 375. 450. 525. 600. 675.
NET RETURN TO LAND $/ACRE

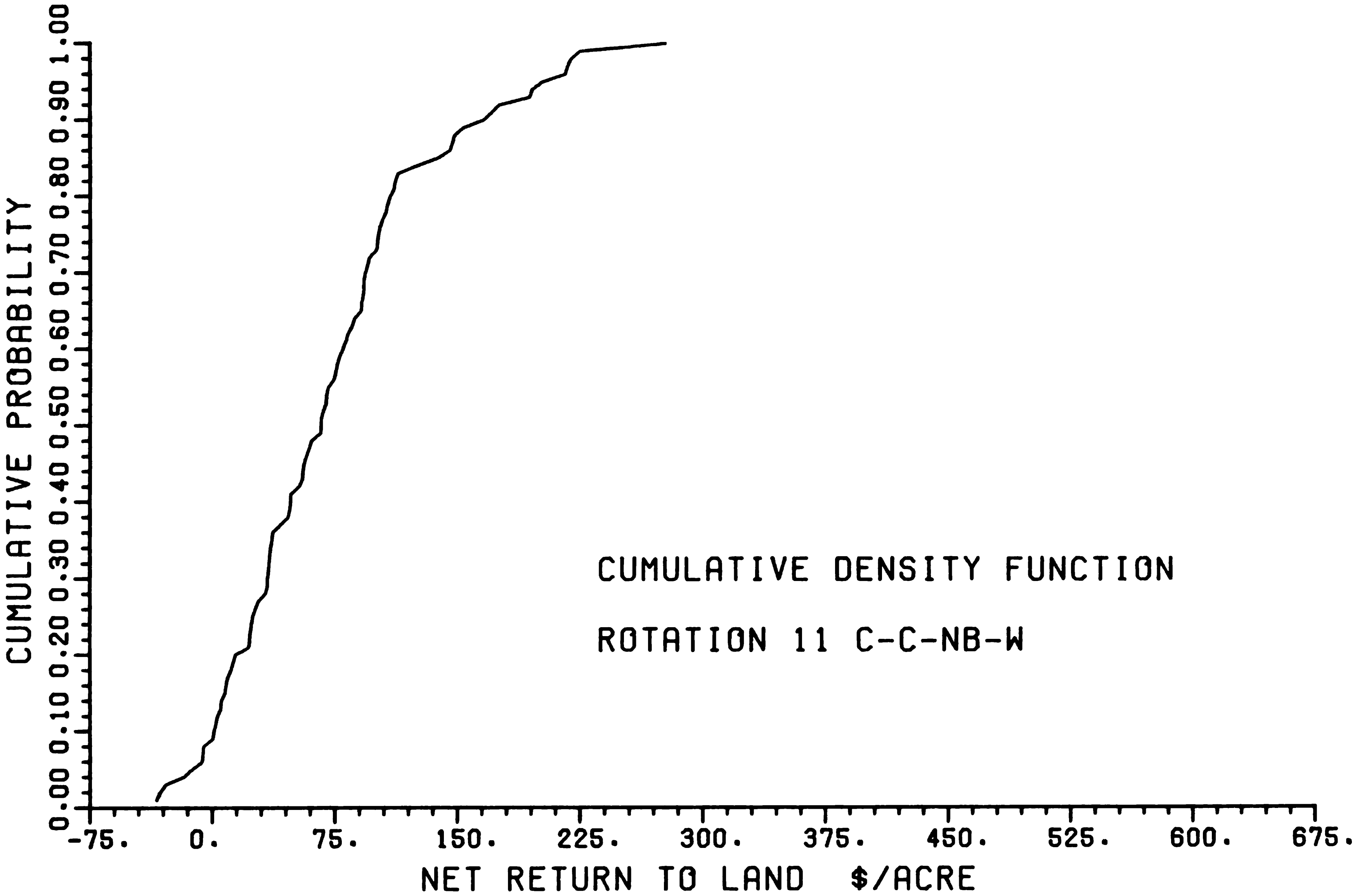

CUMULATIVE DENSITY FUNCTION
ROTATION 6 C-NB-W-B
NET RETURN TO LAND $/ACRE
-75.
0.
75.
150.
225.
300.
375.
450.
525.
600.
675.
CUMULATIVE PROBABILITY
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

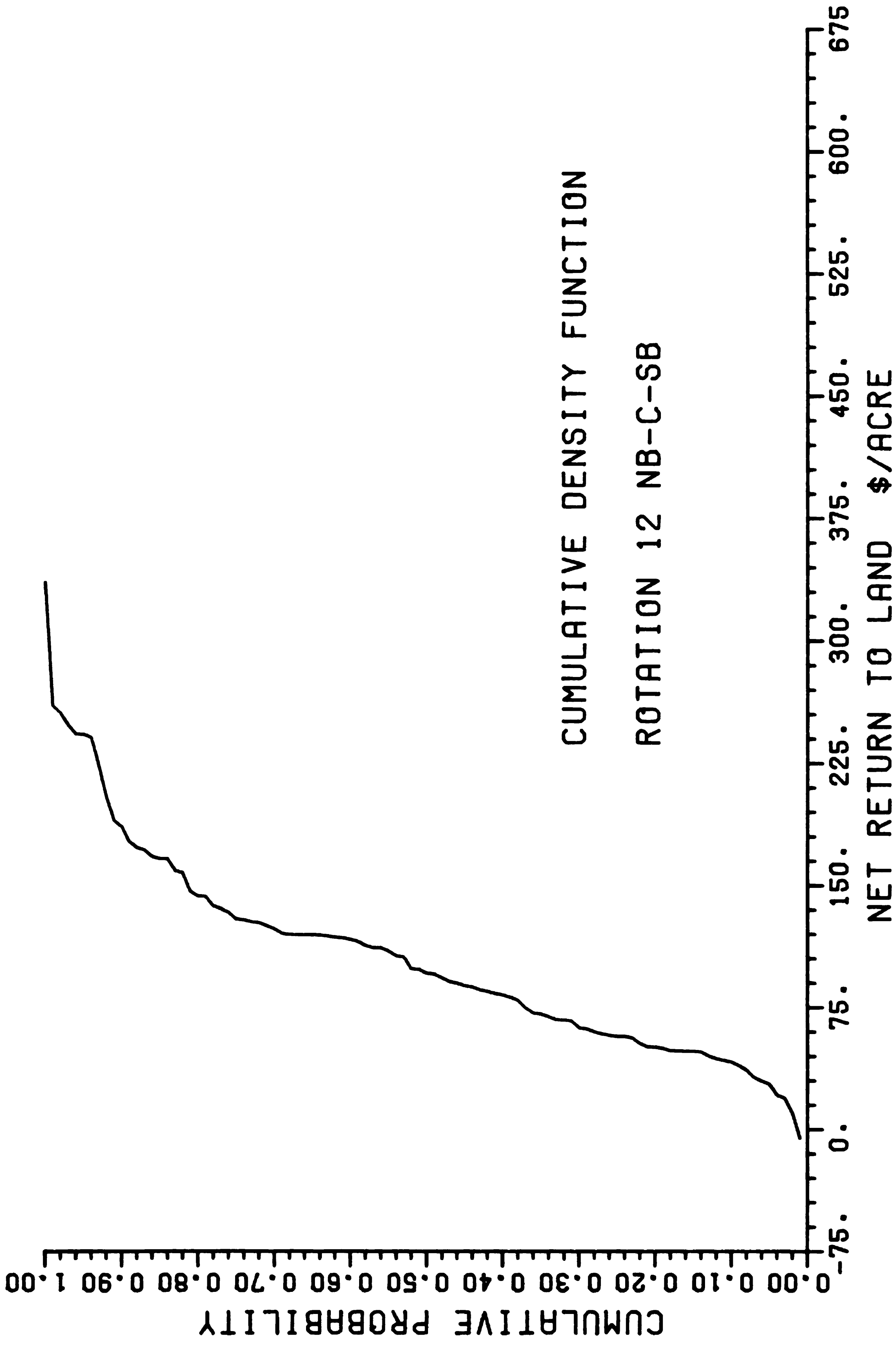

CUMULATIVE DENSITY FUNCTION
ROTATION 7 C-SB-W-B
NET RETURN TO LAND $/ACRE
CUMULATIVE PROBABILITY
-75.
0.
75.
150.
225.
300.
375.
450.
525.
600.
675.
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

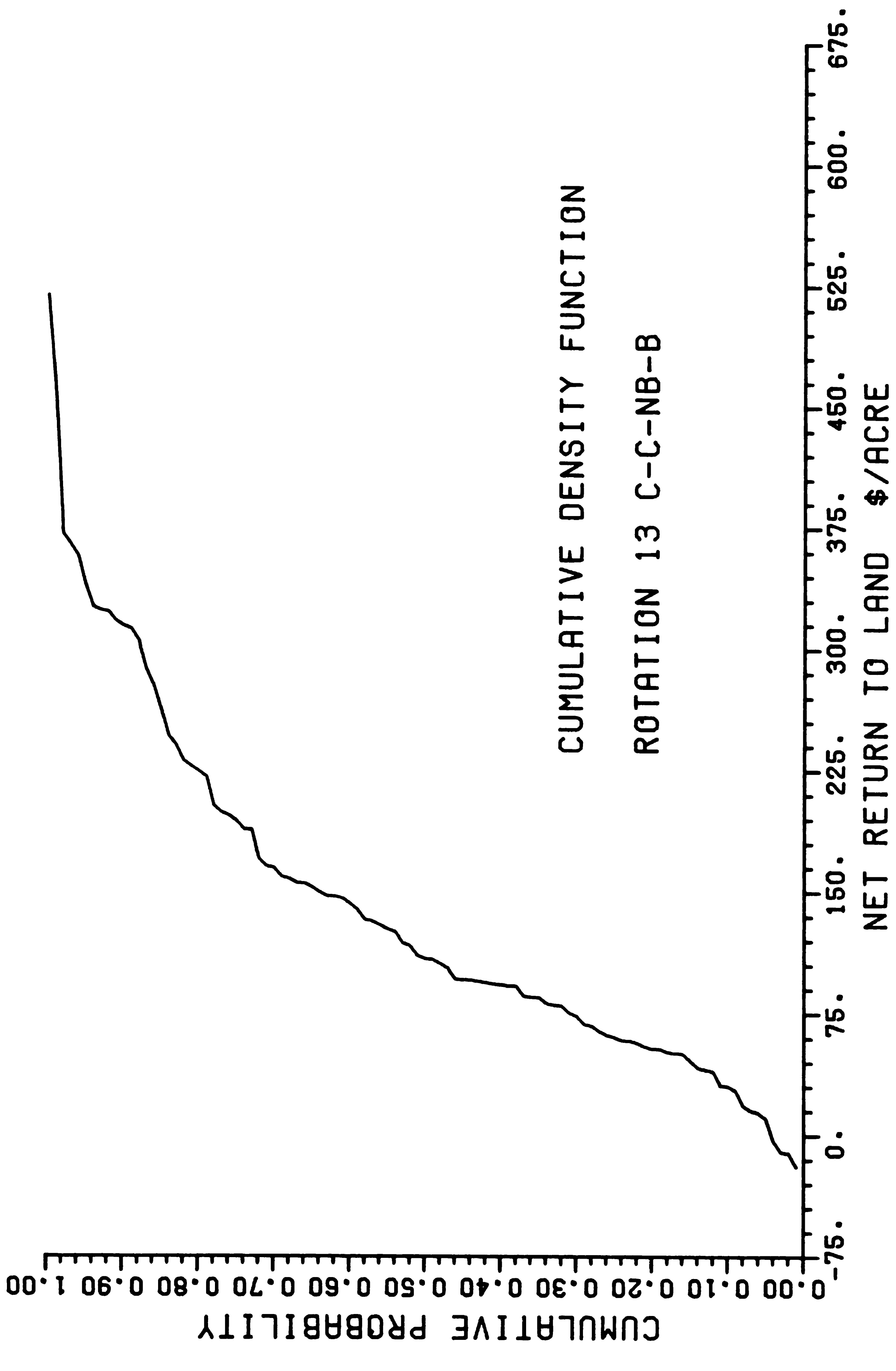

CUMULATIVE DENSITY FUNCTION
ROTATION 8 C-NB-NB-B
CUMULATIVE PROBABILITY
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
-75. 0. 75. 150. 225. 300. 375. 450. 525. 600. 675.
NET RETURN TO LAND $/ACRE

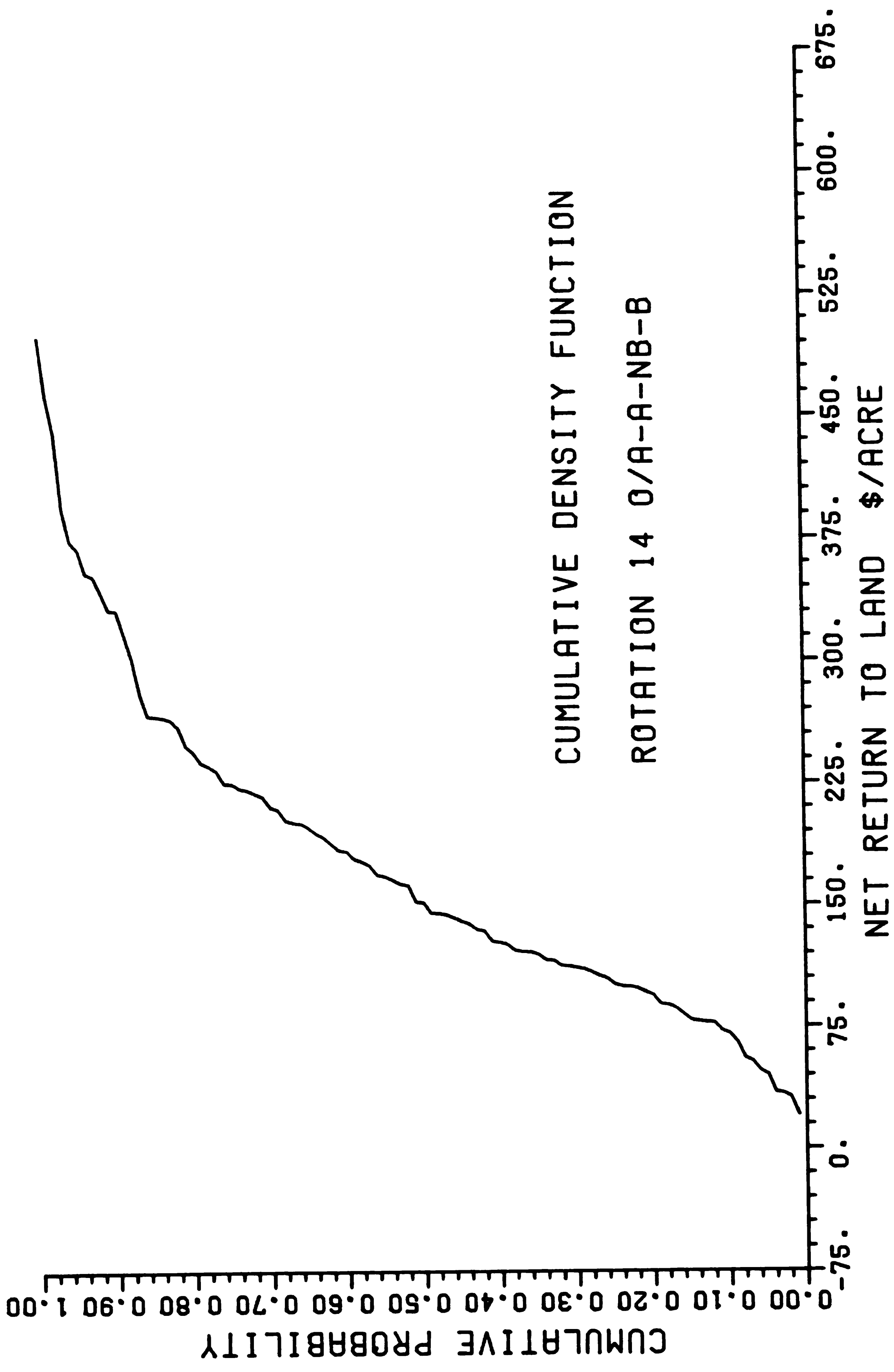

CUMULATIVE DENSITY FUNCTION
ROTATION 9 O/A-A-A-C-C-SB-C
NET RETURN TO LAND $/ACRE
CUMULATIVE PROBABILITY
-75.
0.
75.
150.
225.
300.
375.
450.
525.
600.
675.
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

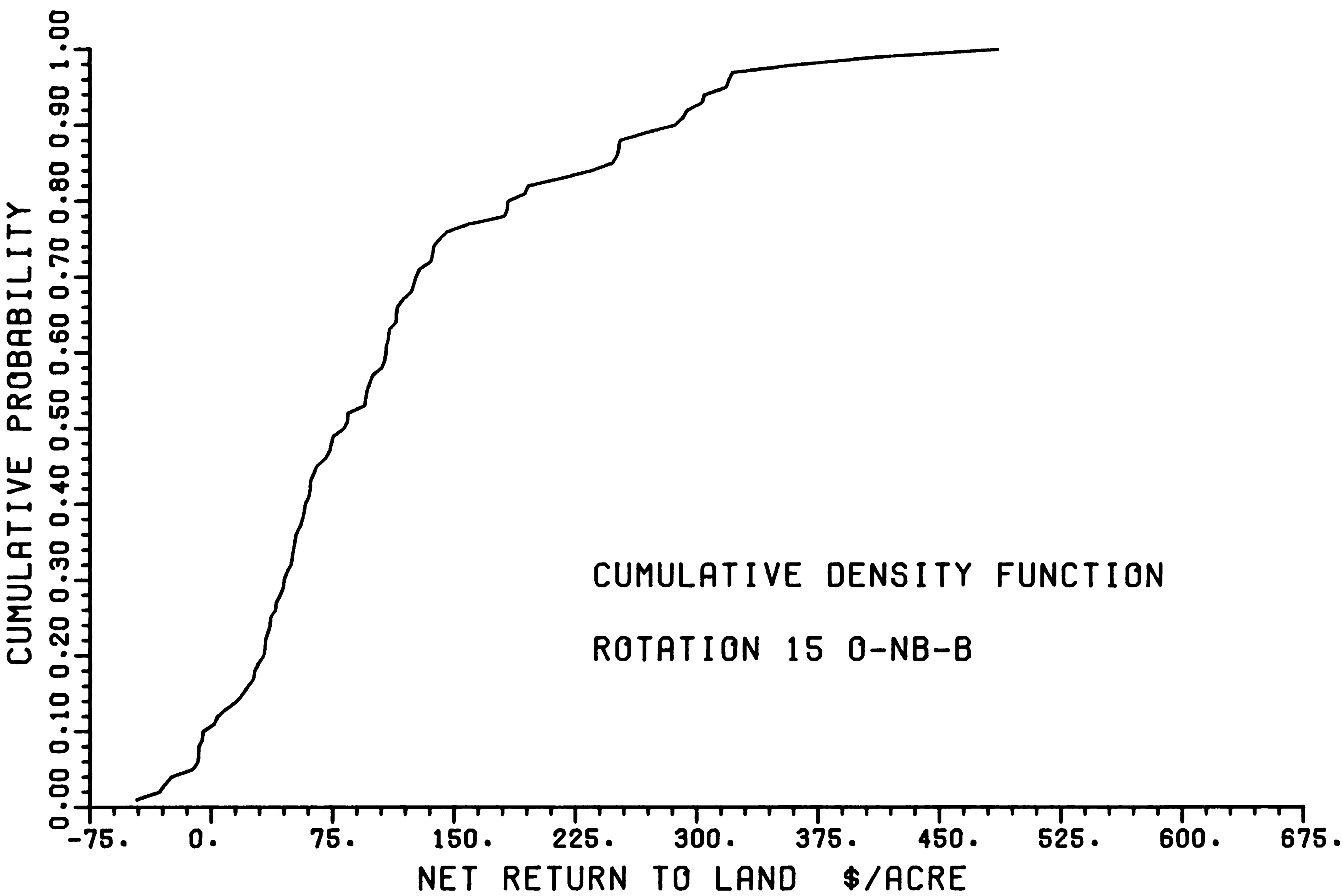

CUMULATIVE DENSITY FUNCTION
ROTATION 10 O/A-A-A-A-C-C-C
NET RETURN TO LAND $/ACRE
-75.
0.
75.
150.
225.
300.
375.
450.
525.
600.
675.
CUMULATIVE PROBABILITY
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00

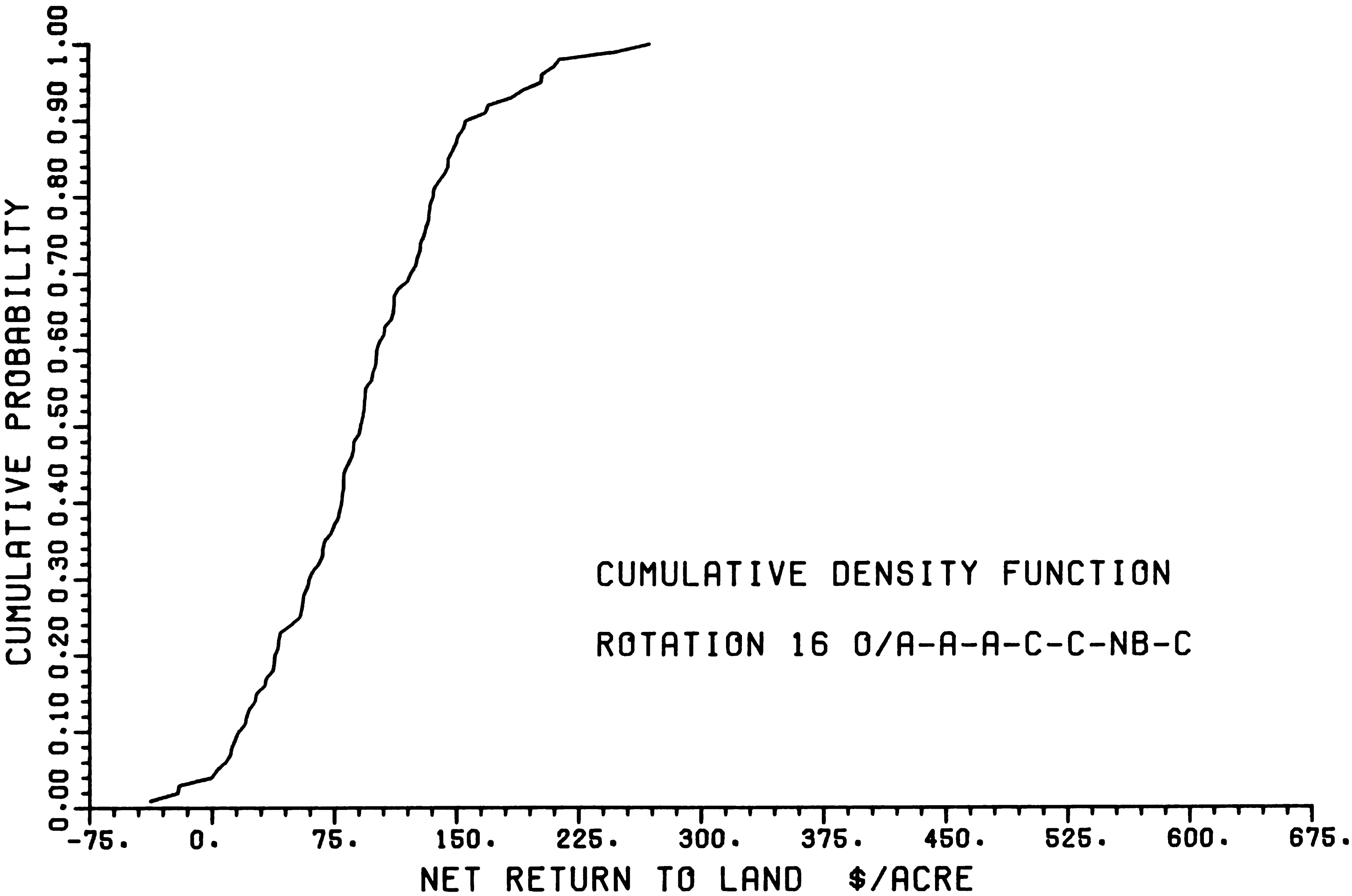

CUMULATIVE DENSITY FUNCTION
ROTATION 11 C-C-NB-W
CUMULATIVE PROBABILITY
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
-75. 0. 75. 150. 225. 300. 375. 450. 525. 600. 675.
NET RETURN TO LAND $/ACRE


CUMULATIVE DENSITY FUNCTION
ROTATION 12 NB-C-SB
NET RETURN TO LAND $/ACRE
CUMULATIVE PROBABILITY
-75. 0. 75. 150. 225. 300. 375. 450. 525. 600. 675.
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00


CUMULATIVE DENSITY FUNCTION
ROTATION 13 C-C-NB-B
NET RETURN TO LAND $/ACRE
-75. 0. 75. 150. 225. 300. 375. 450. 525. 600. 675.
CUMULATIVE PROBABILITY
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00


CUMULATIVE DENSITY FUNCTION
ROTATION 14 O/A-A-NB-B
NET RETURN TO LAND $/ACRE
-75. 0. 75. 150. 225. 300. 375. 450. 525. 600. 675.
CUMULATIVE PROBABILITY
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00


CUMULATIVE DENSITY FUNCTION
ROTATION 15 O-NB-B
CUMULATIVE PROBABILITY
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
-75. 0. 75. 150. 225. 300. 375. 450. 525. 600. 675.
NET RETURN TO LAND $/ACRE

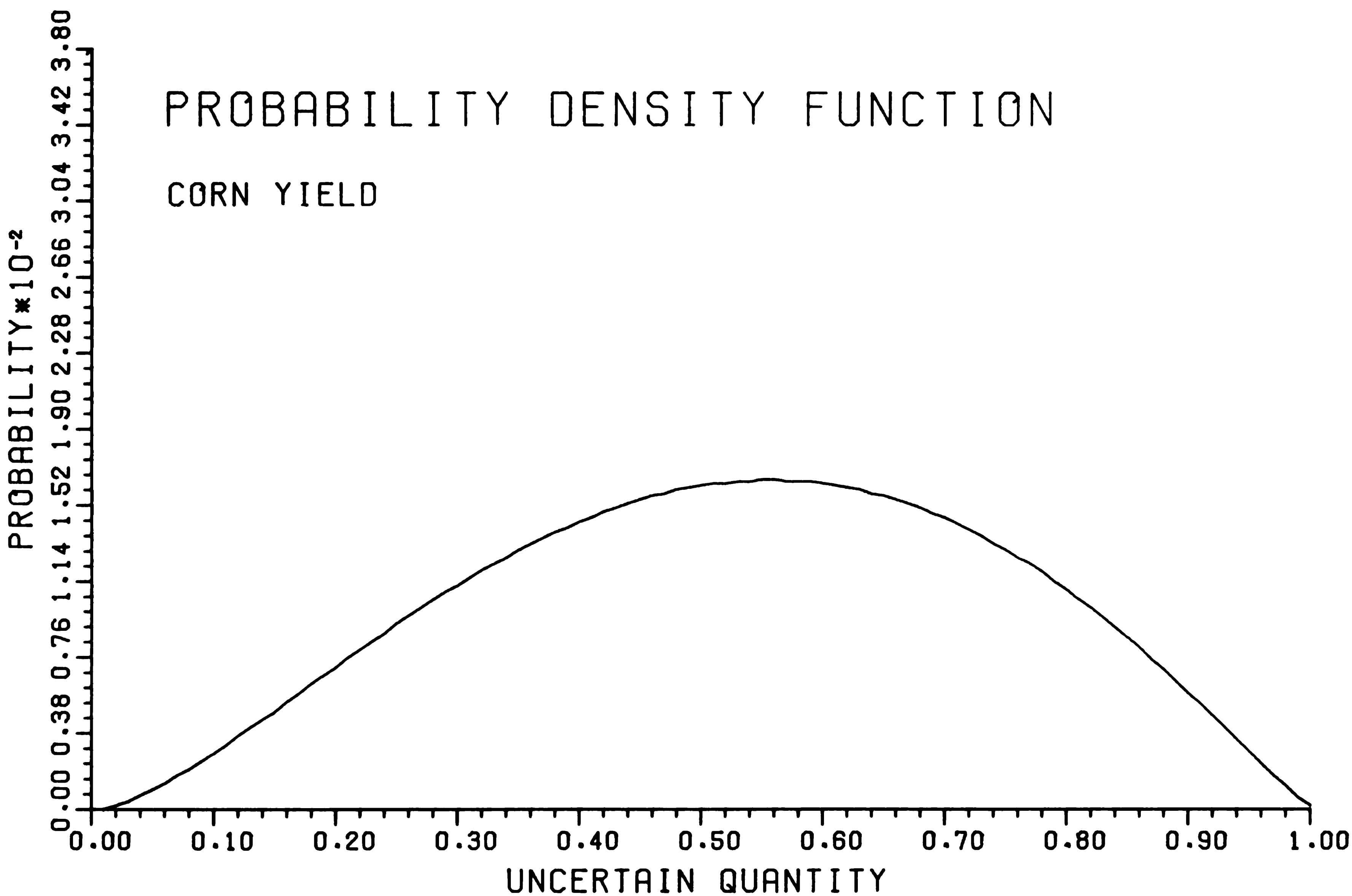

CUMULATIVE DENSITY FUNCTION
ROTATION 16 O/A-A-A-C-C-NB-C
CUMULATIVE PROBABILITY
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
-75. 0. 75. 150. 225. 300. 375. 450. 525. 600. 675.
NET RETURN TO LAND $/ACRE

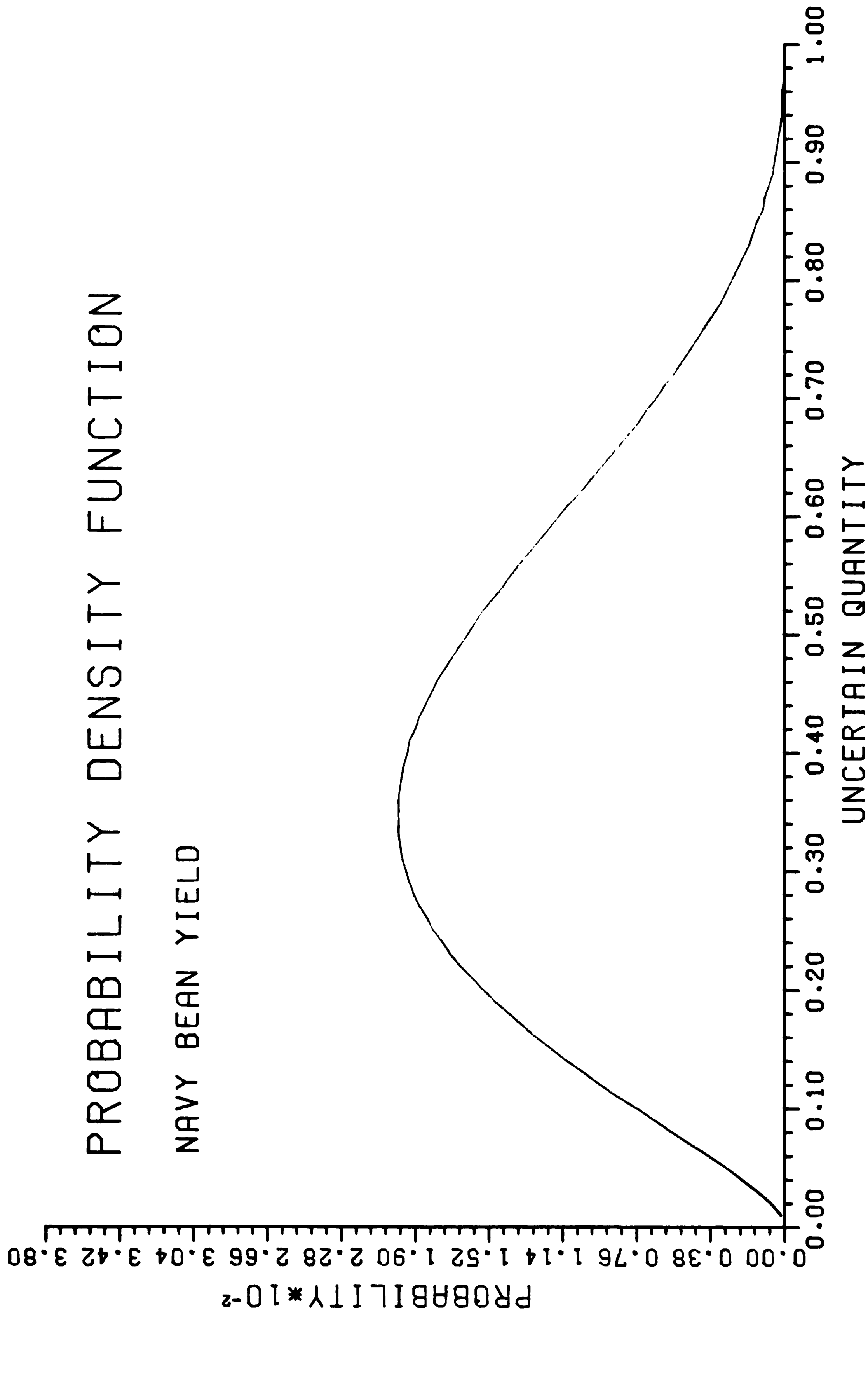
APPENDIX J

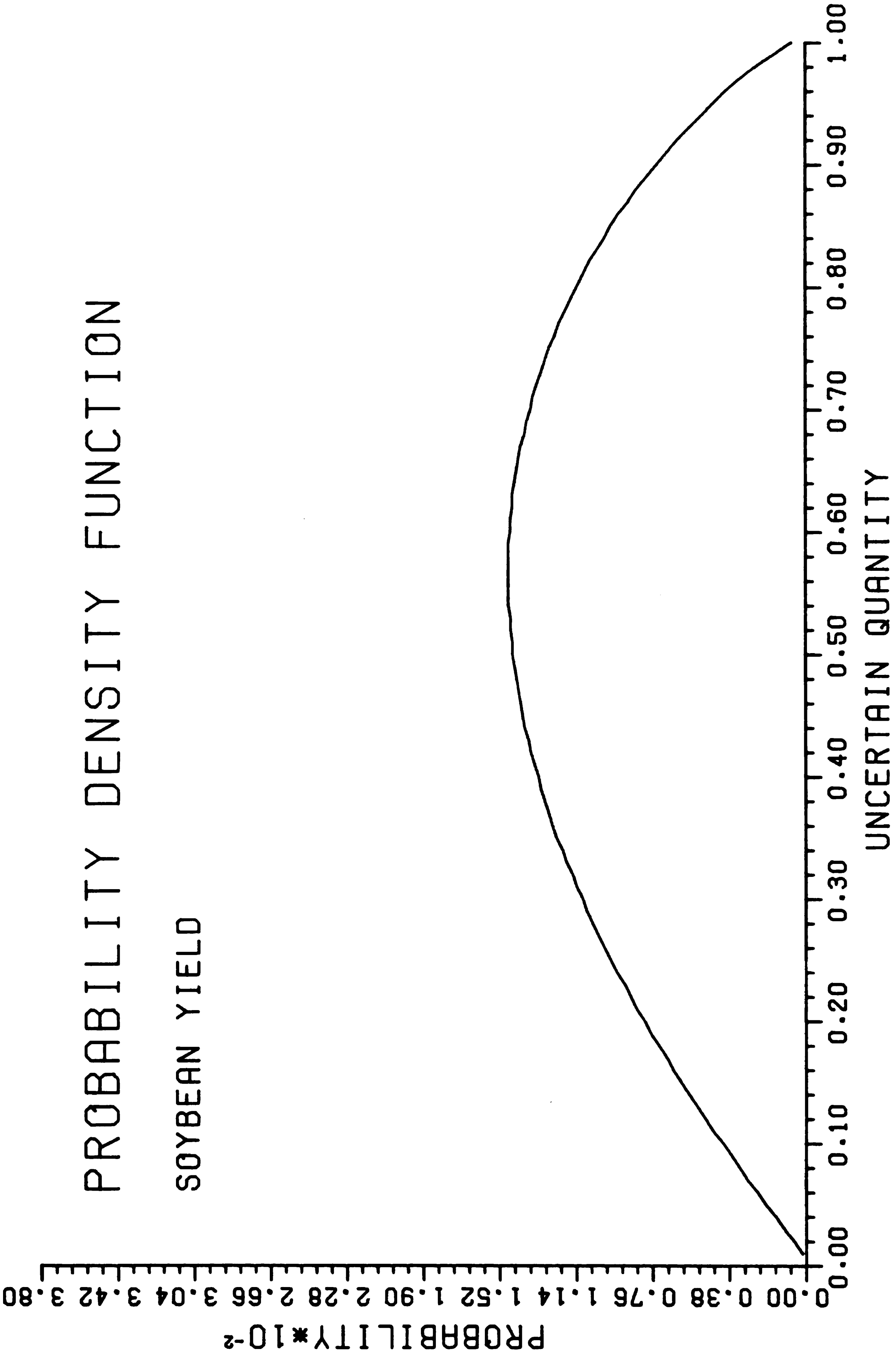
PROBABILITY DENSITY FUNCTIONS

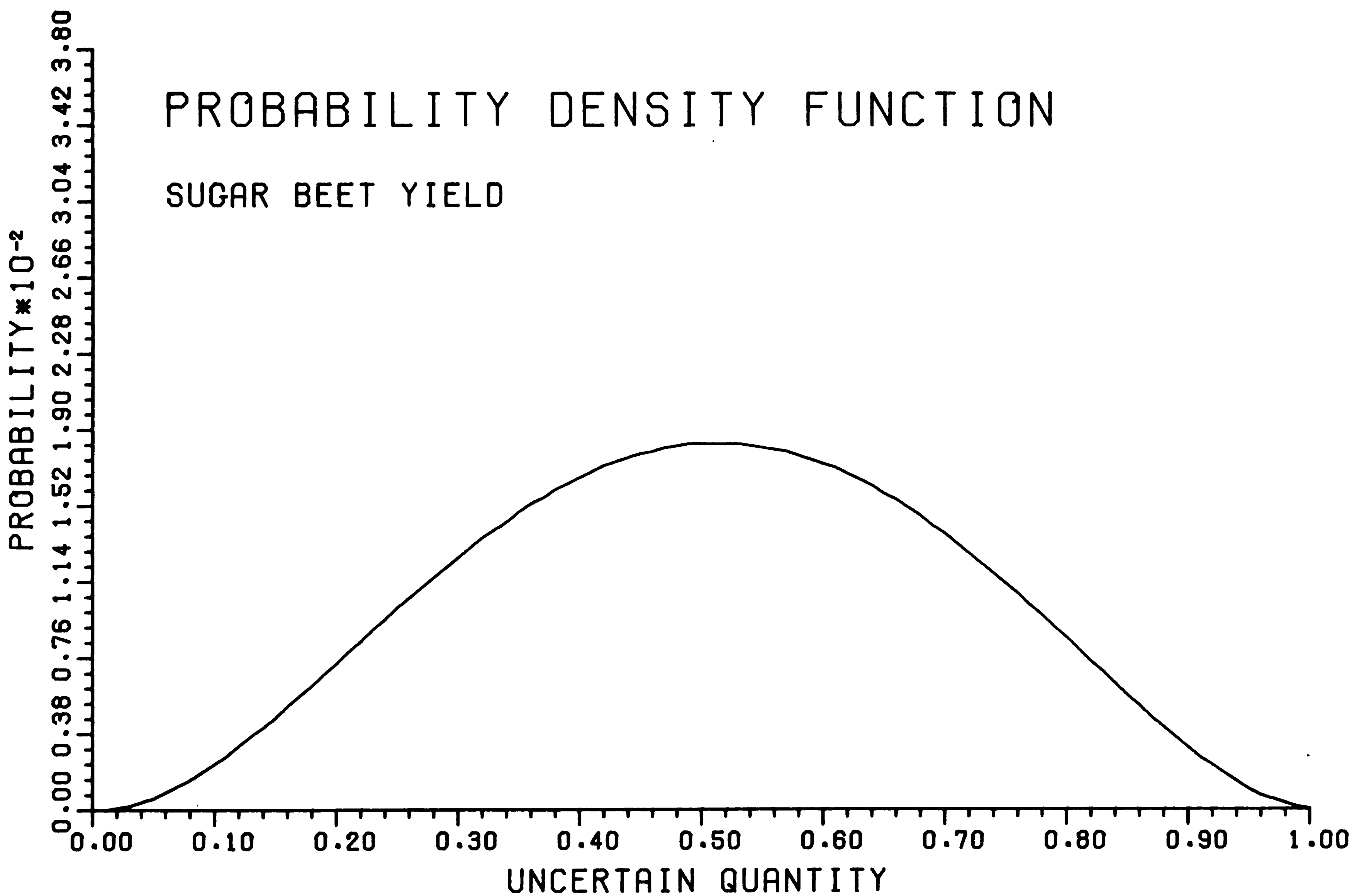
Appendix J presents the probability density functions estimated for each crop price and crop yield. Price and yield are the random variable components of gross income. Price and yield random variables were estimated as Beta distributions. Beta distributions are defined on a zero-one [0, 1] interval. The graph presents the Betas used on their standard interval. The linear transformation to the appropriate yield or price interval scale was calculated elsewhere.

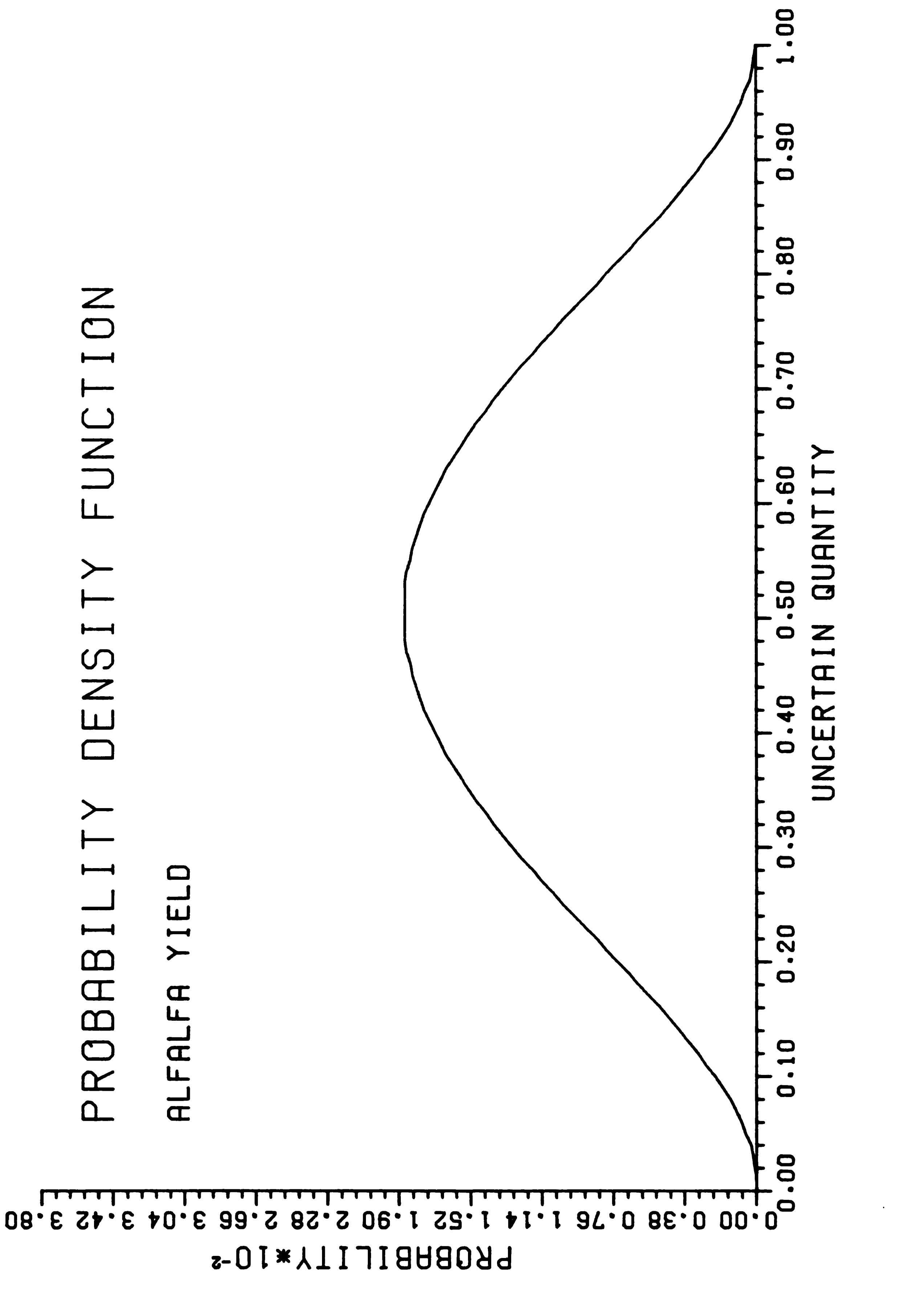
The oat straw yield distribution is implausible. It is believed to be mis-specified. The price distributions appear too exponential in shape. It is believed that the data used to estimate them encompassed two separate eras in agricultural price behavior.

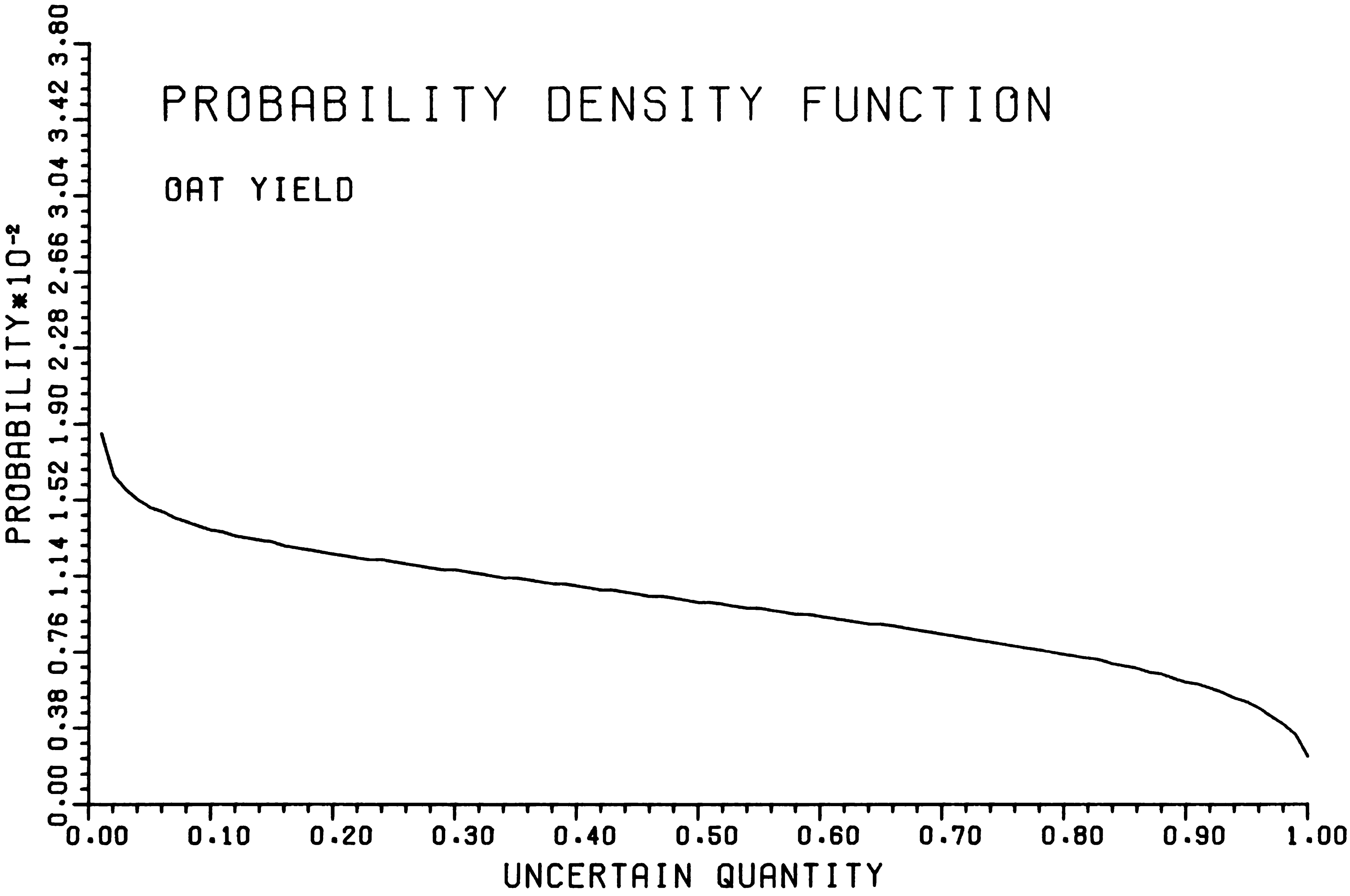

PROBABILITY DENSITY FUNCTION
CORN YIELD
PROBABILITY*10⁻²
0.00 0.38 0.76 1.14 1.52 1.90 2.28 2.66 3.04 3.42 3.80
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
UNCERTAIN QUANTITY

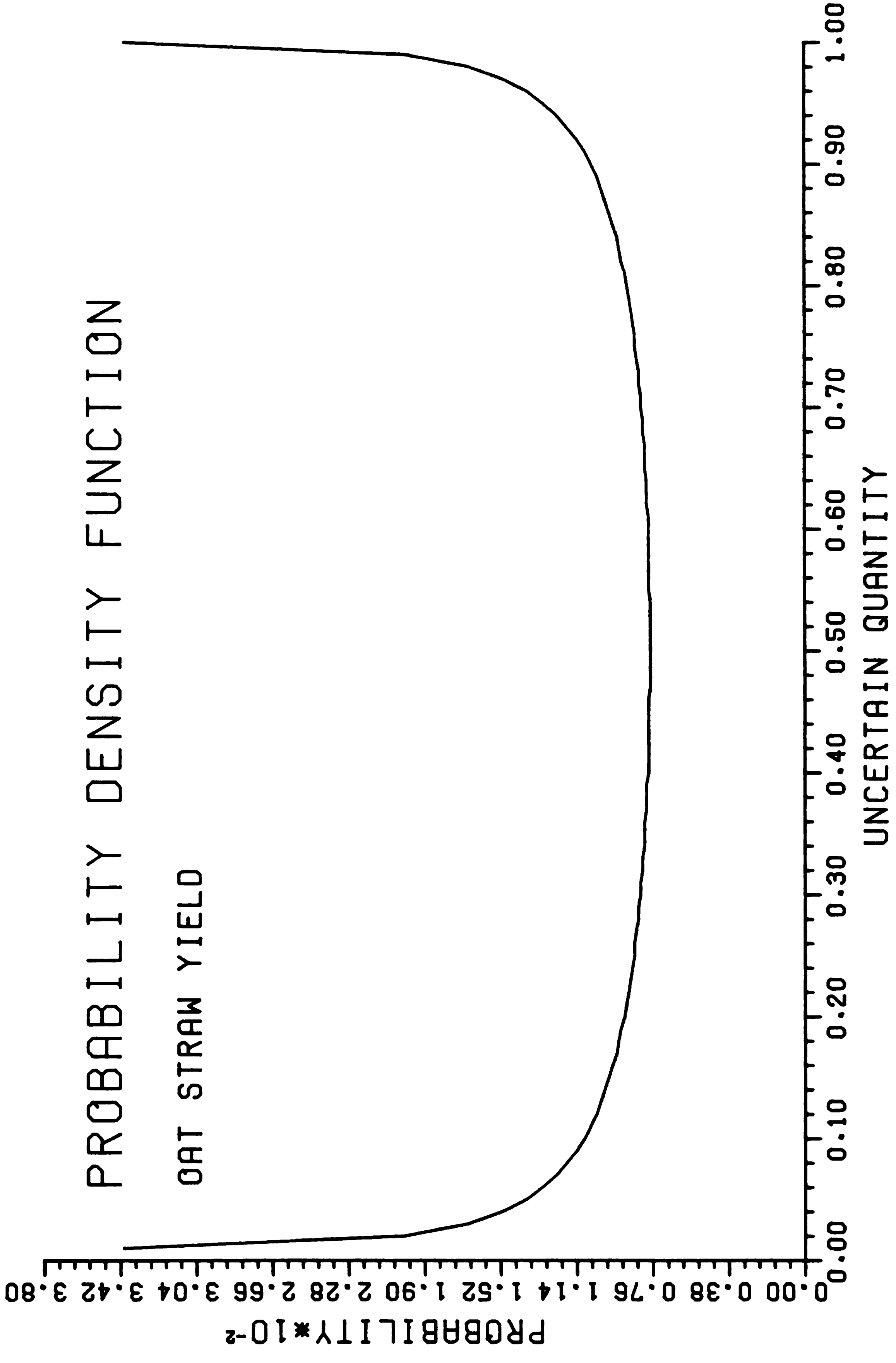

PROBABILITY DENSITY FUNCTION
NAVY BEAN YIELD
UNCERTAIN QUANTITY
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
PROBABILITY*10-2
0.00 0.38 0.76 1.14 1.52 1.90 2.28 2.66 3.04 3.42 3.80

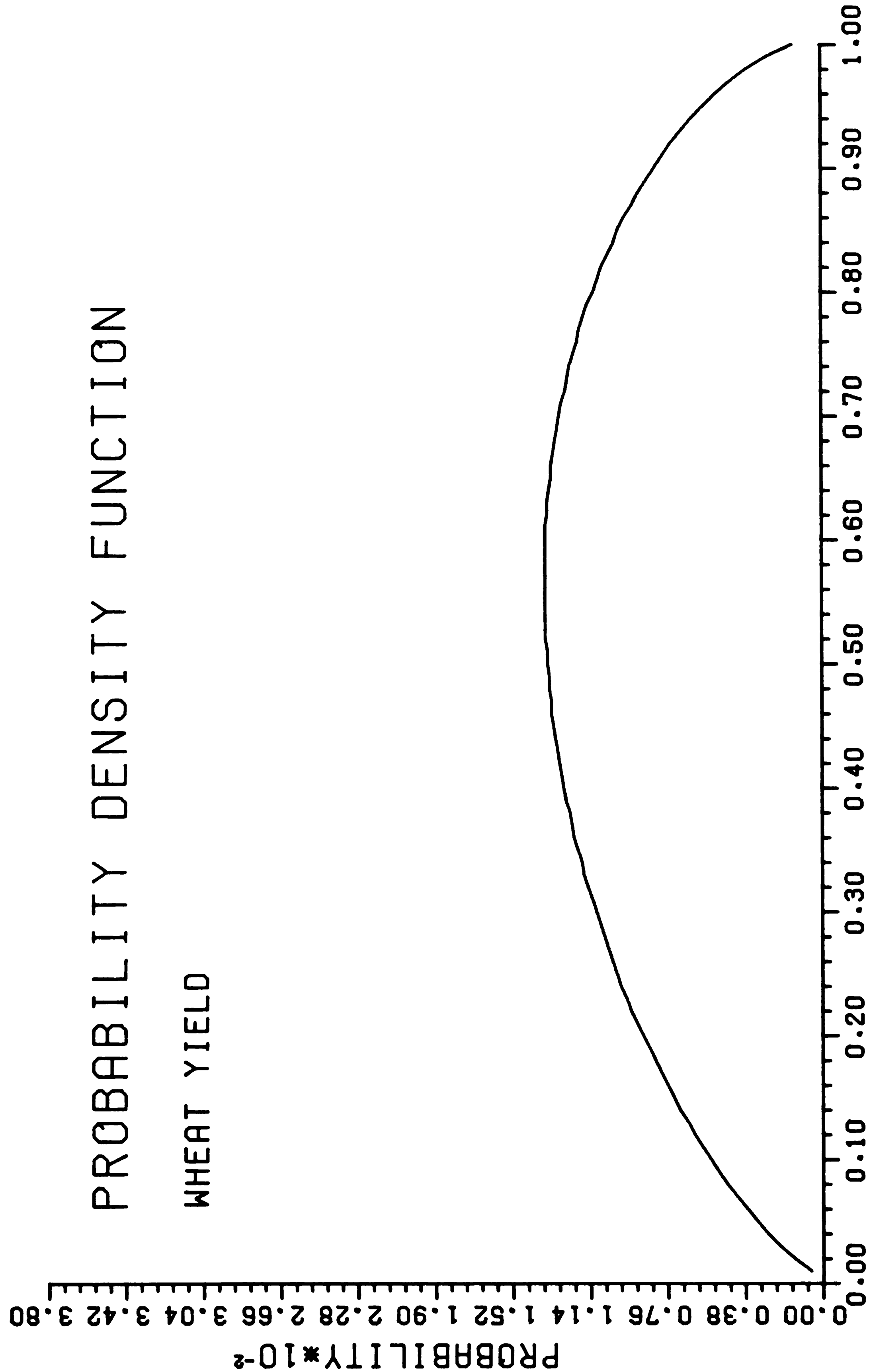

PROBABILITY DENSITY FUNCTION
SOYBEAN YIELD
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
UNCERTAIN QUANTITY
0.00
0.38
0.76
1.14
1.52
1.90
2.28
2.66
3.04
3.42
3.80
PROBABILITY*10-2

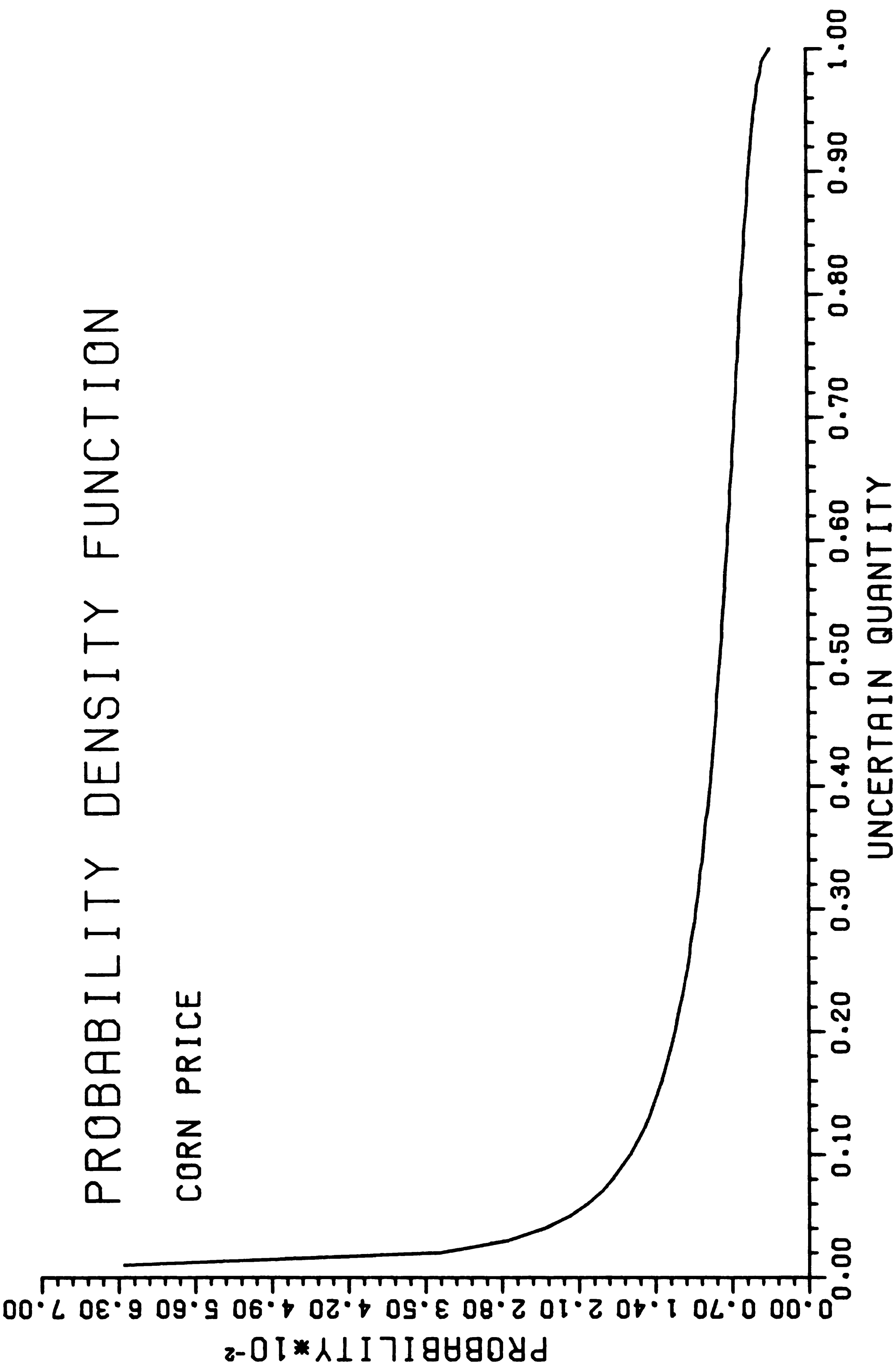

PROBABILITY DENSITY FUNCTION
SUGAR BEET YIELD
PROBABILITY*10-2
0.00 0.38 0.76 1.14 1.52 1.90 2.28 2.66 3.04 3.42 3.80
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
UNCERTAIN QUANTITY

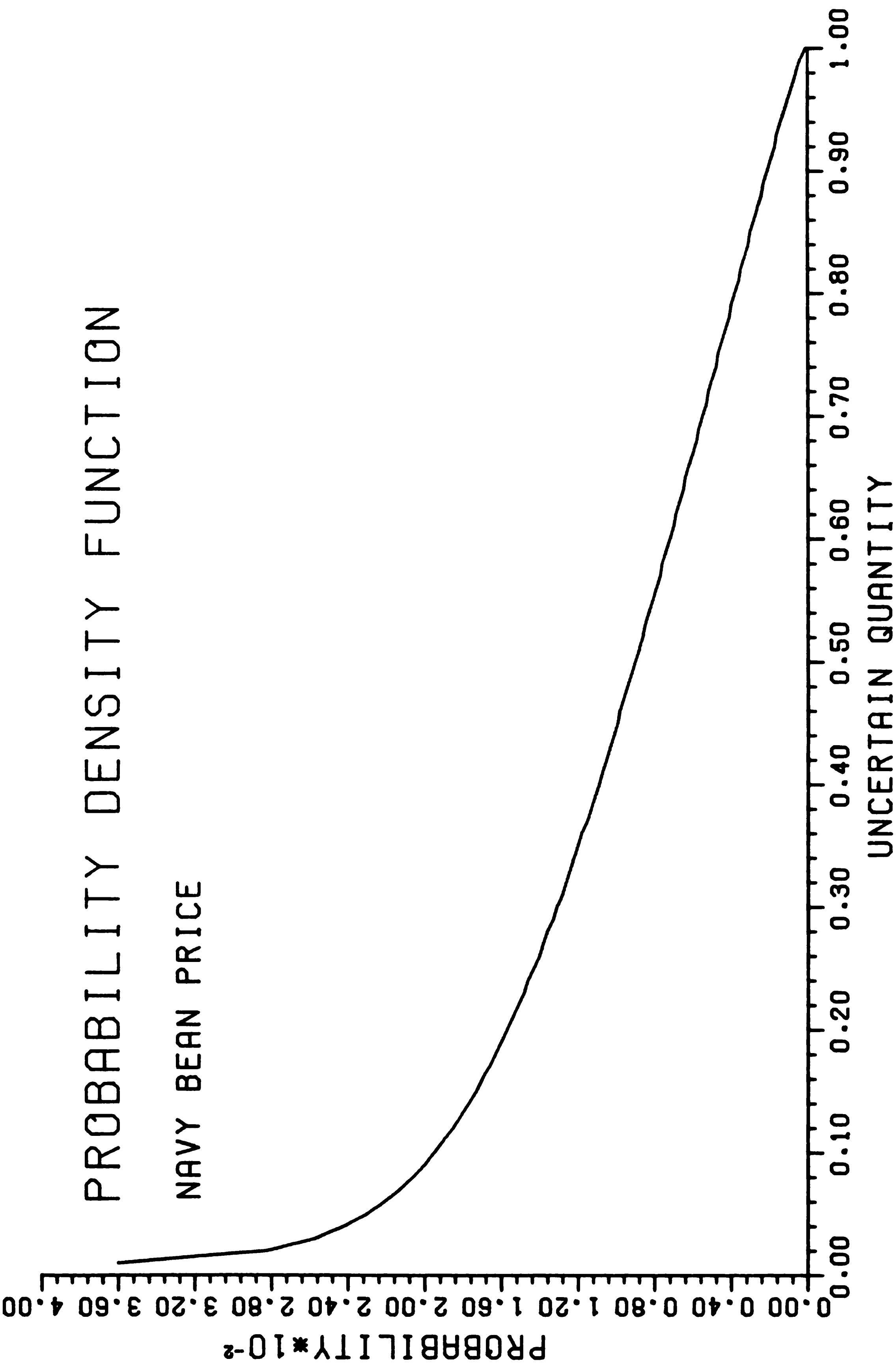

PROBABILITY DENSITY FUNCTION
ALFALFA YIELD
UNCERTAIN QUANTITY
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
PROBABILITY*10-2
0.00 0.38 0.76 1.14 1.52 1.90 2.28 2.66 3.04 3.42 3.80

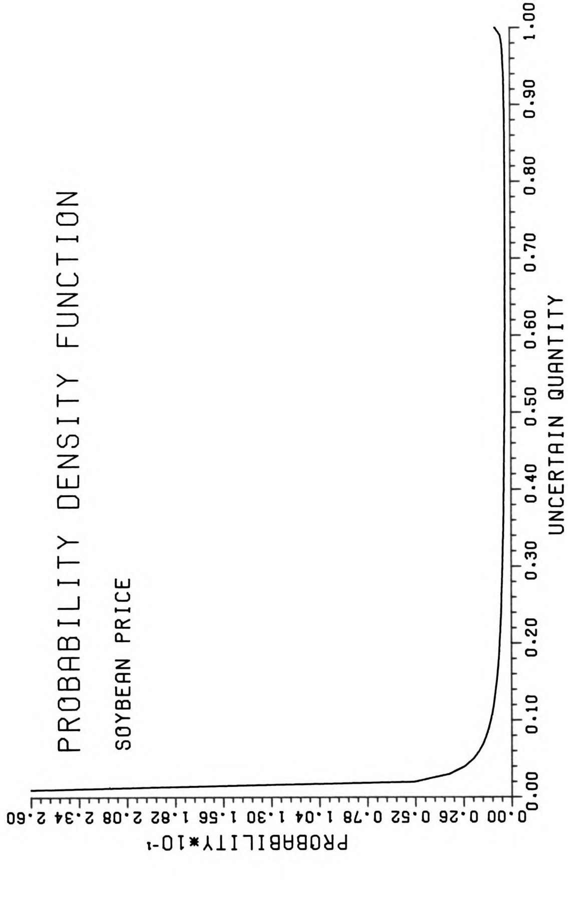

PROBABILITY DENSITY FUNCTION
OAT YIELD
PROBABILITY*10-2
0.00 0.38 0.76 1.14 1.52 1.90 2.28 2.66 3.04 3.42 3.80
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
UNCERTAIN QUANTITY

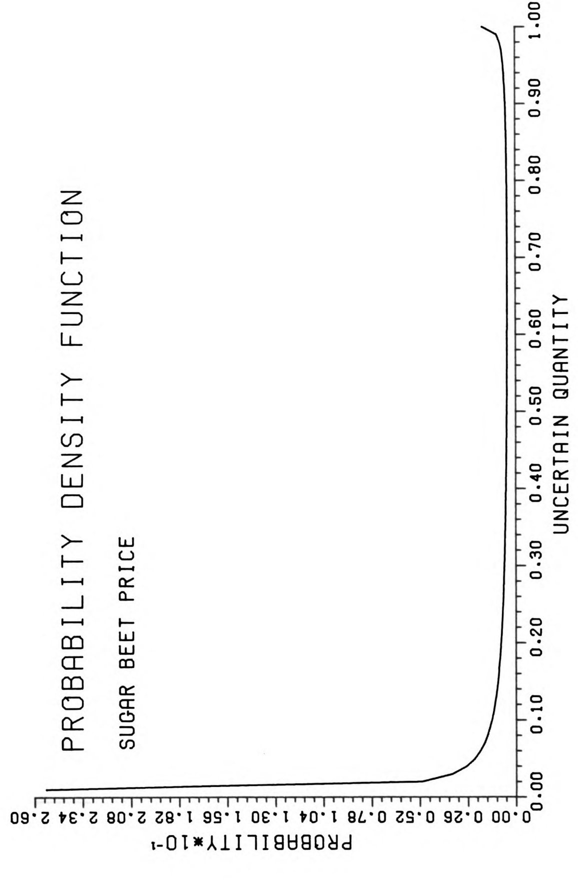

PROBABILITY DENSITY FUNCTION
OAT STRAW YIELD
UNCERTAIN QUANTITY
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
PROBABILITY*10-2
0.00 0.38 0.76 1.14 1.52 1.90 2.28 2.66 3.04 3.42 3.80


PROBABILITY DENSITY FUNCTION
WHEAT YIELD
UNCERTAIN QUANTITY
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
PROBABILITY*10-2
0.00 0.38 0.76 1.14 1.52 1.90 2.28 2.66 3.04 3.42 3.80

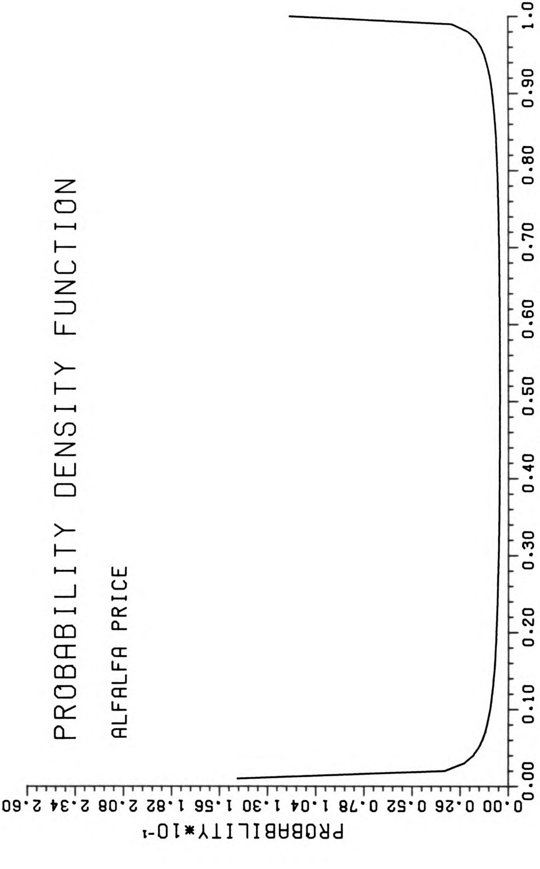

PROBABILITY DENSITY FUNCTION
CORN PRICE
UNCERTAIN QUANTITY
PROBABILITY*10-2
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
0.00 0.70 1.40 2.10 2.80 3.50 4.20 4.90 5.60 6.30 7.00


PROBABILITY DENSITY FUNCTION
NAVY BEAN PRICE
UNCERTAIN QUANTITY
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
PROBABILITY*10-2
0.00 0.40 0.80 1.20 1.60 2.00 2.40 2.80 3.20 3.60 4.00

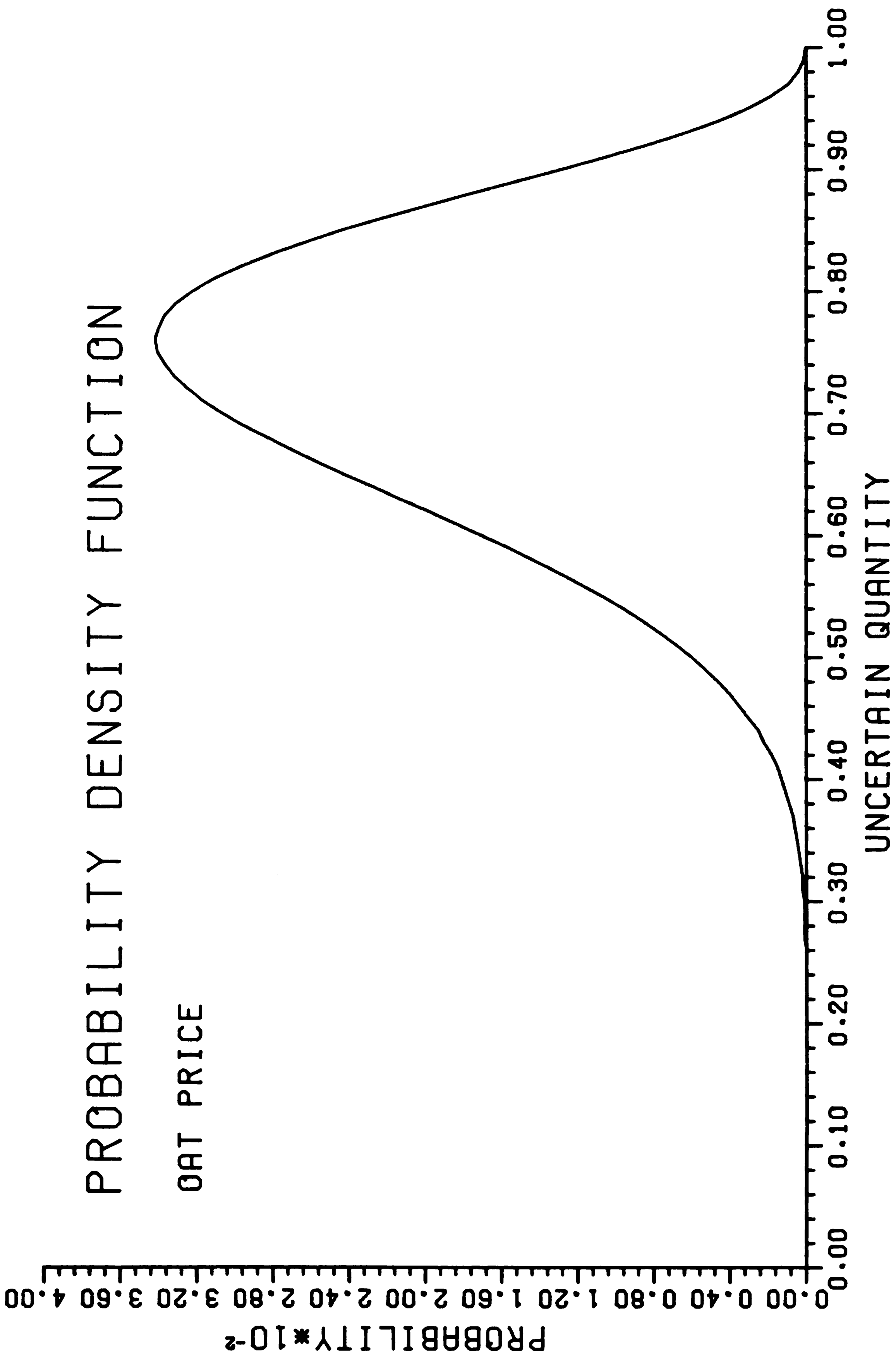

PROBABILITY DENSITY FUNCTION
SOYBEAN PRICE
UNCERTAIN QUANTITY
PROBABILITY*10-1
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
0.00 0.26 0.52 0.78 1.04 1.30 1.56 1.82 2.08 2.34 2.60

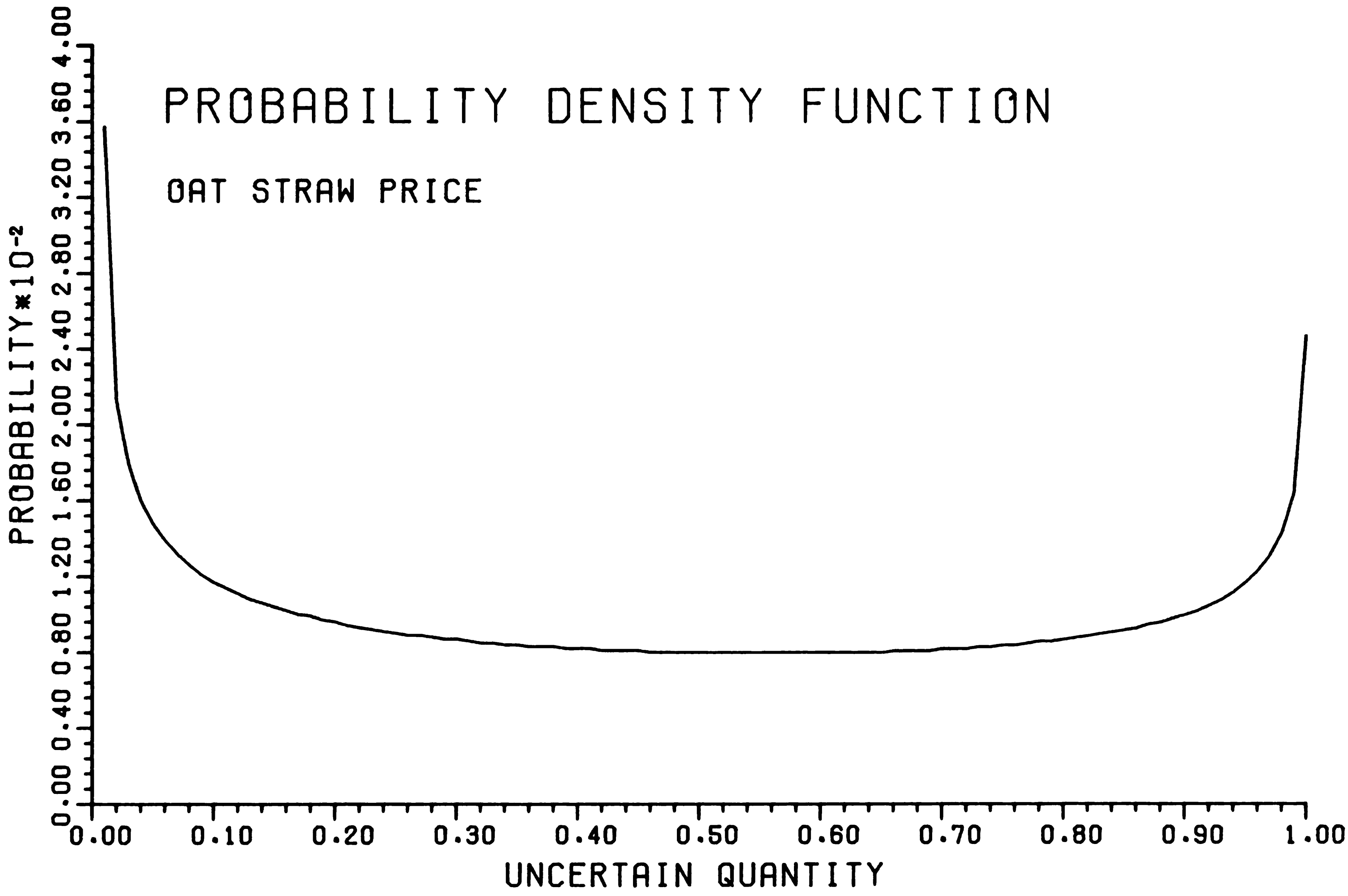


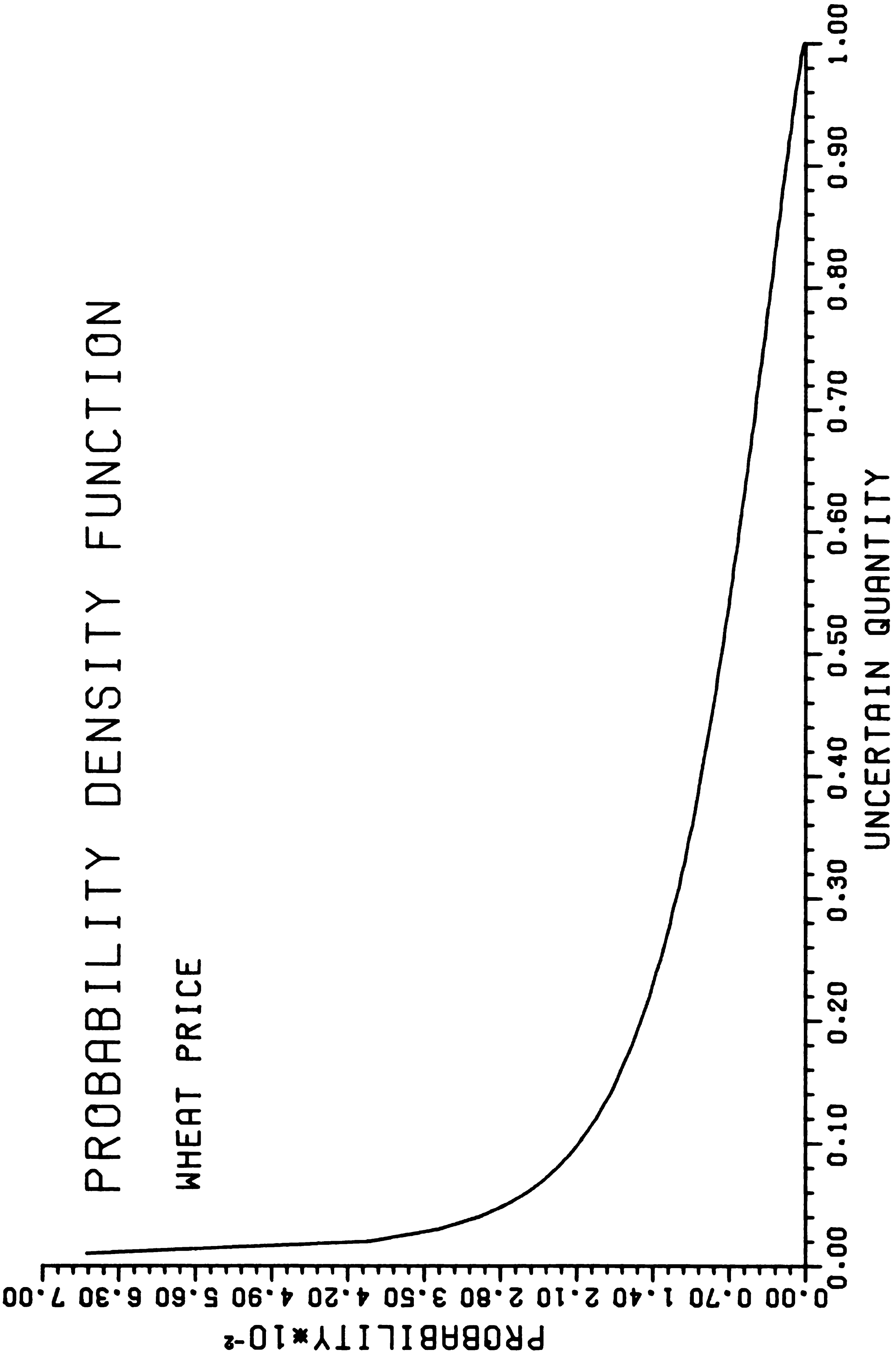
PROBABILITY DENSITY FUNCTION
SUGAR BEET PRICE
UNCERTAIN QUANTITY
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
PROBABILITY*10-1
0.00 0.26 0.52 0.78 1.04 1.30 1.56 1.82 2.08 2.34 2.60



PROBABILITY DENSITY FUNCTION
ALFALFA PRICE
UNCERTAIN QUANTITY
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
PROBABILITY*10-1
0.00 0.26 0.52 0.78 1.04 1.30 1.56 1.82 2.08 2.34 2.60


PROBABILITY DENSITY FUNCTION
OAT PRICE
UNCERTAIN QUANTITY
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
PROBABILITY*10-2
0.00 0.40 0.80 1.20 1.60 2.00 2.40 2.80 3.20 3.60 4.00


PROBABILITY DENSITY FUNCTION
OAT STRAW PRICE
PROBABILITY*10-2
0.00 0.40 0.80 1.20 1.60 2.00 2.40 2.80 3.20 3.60 4.00
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
UNCERTAIN QUANTITY


PROBABILITY DENSITY FUNCTION
WHEAT PRICE
UNCERTAIN QUANTITY
PROBABILITY*10-2
0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00
0.00 0.70 1.40 2.10 2.80 3.50 4.20 4.90 5.60 6.30 7.00

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