Economic instability and choices involving income and risk in primary or crop production

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Economic Instability and Choices Involving Income and Risk in Primary or Crop Production

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SUMMARY

Economic uncertainty is the foremost problem in Iowa agriculture. Because of the several forces which have their roots in uncertainty, farmers produce the wrong combinations of crops and livestock. Products are often produced by techniques and on scales which are inconsistent with the most efficient use of agricultural resources. Perfect foresight in farming would allow perfect decisions in the use of all resources. While perfect foresight is impossible, the sources of uncertainty in the form of yield, cost and price variability can be analyzed.

The current study is a fundamental one dealing with (a) the basic nature and relationships of variability in primary or crop production in Iowa, (b) the possibilities of lessening and minimizing variability through diversified production patterns and resource use and (c) the fundamentals of choice dealing with alternatives of income and variability.

Analysis of variability in crop income involves use of historic yields, prices and cost figures. Two samples were designed to allow income variability estimates for the major soil areas of Iowa and for the state as a whole. One was a stratified sample with random selection within strata; the other was a purposive sample selected to represent specific soil associations.

Variability measures used in this study were the "mean of squared differences," the square root of this measure and the ratio of the latter to the mean of the series of crop yields, incomes or costs. Comparisons of the relative magnitude or ranks between crops, crop combination and locations were facilitated by these measures. Limitations in the use of these measures caused by auto-correlation of observation in the series, lack of normality in the distributions and price and yield trends are discussed. Difficulties in the use of statistical tests are also taken up.

SECTION I. DEGREE OF VARIABILITY

1. Variability of yields and costs are presented first. Combinations of the sources of variability are made through estimation of gross income variability which includes prices and yields and their effects. Measures of net income variability were calculated to illustrate the effects of all three sources of variability together. Both the variances and coefficients of variation for yields, gross incomes and net incomes of crops are presented.

2. In the state as a whole, corn offers least average variability on the basis of dispersion relative to the mean income. Oats are most variable. Soybeans, flax and wheat in order of least variability are intermediate between corn and oats.

3. Since variability within cropping areas is most meaningful to individual farm plans, estimates of variability of crop yields, cost, gross and net income are presented for each of the five sample areas. Greatest variability for all crops tended to be in western and southern areas where drouths are most prevalent. Significant differences exist between areas in yields and net income variability (5 percent level) although costs and gross do not vary significantly.

4. Within areas, coefficients of variation for yields and gross incomes did not vary significantly between crops. However, the relative variabilities of costs and net incomes were different between crops within areas.

5. A sample of 14 townships, each considered representative of a-
specific soil association used to estimate variability of yields and incomes on particular soil types, indicated Tama-Muscatine-Garwin and Clarion-Webster-Nicollet as having lowest relative variability of yields, while Shelby-Seymour-Edina and Grundy-Haig-Shelby have the highest. Relative variability of net incomes tended to follow a similar pattern.

SECTION II. DIVERSIFICATION AND CROP COMBINATIONS WHICH MINIMIZE INCOME VARIANCE

1. The second major portion of this study deals with the manner in which income variability can be lessened through diversification or alternative crop combinations. It illustrates the amount of variability which accompanies each level of income and predicts the amount by which income must be sacrificed for a given reduction in income variance through alternative combinations of crops.

2. The pure theory of minimizing income variances is set out, both in ordinary logic and mathematical form. The combinations of crops that will minimize income variability for selected townships are specified.

3. For each specific location (soil area), the variance and coefficient of variation of net income are worked out with crops combined in varying proportions. The relationship between level of income over time and variability under each crop combination is illustrated by tables and figures. Complementary and competitive ranges between level of income and income variability are uncovered when crops are combined in varying proportions in each township (soil area).

4. The extent to which the operator should select the possibility of higher income while sacrificing possible stability of income, or greater stability at a sacrifice in income, depends on many factors including his own preferences or dislike for risk, his capital and equity position, the scale of his operations and his family responsibilities.

5. Diversification as studied here is a planning procedure to meet uncertainty. Minimization of income variance is a short-run production pattern which prevents bankruptcy; the farmer is able to "stay in the game" so that he has an opportunity to maximize returns in the long run.

6. The attainment of individual income stability through diversification involves less efficient use of resources than would otherwise be necessary. Society sacrifices since less total product is produced from given resources. While society cannot eliminate the variations in production, it can exercise precautions which offset the income effects of major fluctuations in yield and production. Stable farming patterns become an intermediate goal of farming that should be recognized by land-grant colleges. However, some of the greatest opportunities for handling the variability problem fall at the national level and require economic policies on a large scale.
Economic Instability and Choices
Involving Income and Risk
In Primary or Crop Production

By Earl O. Heady, Earl W. Kehreng and Emil H. Jabe

Each year 200,000 Iowa farmers go about making production plans. The combinations and amounts of specific crops and livestock to be produced on each farm must be decided annually. Similarly, decisions must be made for longer-term investments such as the purchase of a farm, the construction of buildings or the purchase of breeding stock, equipment and machinery. Unfortunately, ours is a changing world; the prices which prevail when the farmer makes his production and investment plans may have little relationship to those which prevail after costs have been committed and the harvest is ready for the market. Then, too, the mere “planning to produce” 50 bushels of corn to the acre provides no assurance that this yield will in fact be realized; drouths and corn borers do not broadcast their intentions in advance.

Efficient farming demands that the procedure of making production and investment decisions be more than a hit or miss affair. The approximately 1.5 billion dollars in annual produce from Iowa farms and the 10 billion dollars in capital and 250,000 man-years in labor which go into it represent an important fraction of the nation’s total resources used in agriculture; it is a major part of the resources used in the total industry of Iowa. The most important force standing in the way of perfection in the use of the state’s capital, labor, land and management resources is uncertainty or imperfect knowledge in predicting price and yield outcomes. With perfect foresight in predicting prices and yields of the future, the farmer could make highly successful decisions. The gains in yields and production rates forthcoming from changes in techniques would be relatively unimportant in farming success; ability to predict price and income of the future could have much greater importance in attainment of wealth and high levels of living by the farm family.

Economic uncertainty is the foremost problem of Iowa agriculture. If it were not for economic uncertainty, problems of limited capital would disappear as would most of those involving tenure difficulties; in the absence of uncertainty in the production and decision-making process, capital would generally be available in unlimited quantities, and fewer resources would be rented by farmers. Perfect foresight in farming would allow perfect decisions in the use of all resources. Great strides have been made in improving the techniques of producing crops and livestock, yet little progress has been made even in elementary analysis of those facts of uncertainty which plague farmers in making annual production decisions or long-term investment decisions.

Inefficient use of resources will continue in agriculture so long as decisions must be made in a highly uncertain environment; the farmer sacrifices in terms of profit while the consuming society sacrifices by realizing fewer goods and services than could be produced from the quantity of resources employed in agriculture and the economy generally. Inefficient production or resource use comes about under uncertainty for several reasons: It comes about when farmers expect the price of one product to be high relative to another but find themselves in error as the commodity is ready for the market. The farmer sacrifices profit when he produces too much pork and too little beef, while the consumer
sacrifices in satisfactions and utility. Inefficiency comes about as risk or uncertainty causes farmers to plan only for the immediate future and consequently to follow farming systems which exploit the soil and tie up resources in short-lived assets; in the absence of time and uncertainty considerations in production, problems of soil conservation would be elementary and optimum investments could be made in terraces, dams and other practices which contribute to production overtime. Inefficiency also comes about as farmers limit their use of capital and operate small-scale and high-cost units. Finally, inefficiency comes about as uncertainty causes farmers to invest in precautions reflected in flexible producing systems, which, although they do not allow a maximum product from given resources or minimum costs for a given output, help minimize the probability of bankruptcy. Because of these several forces which have their roots in uncertainty, farmers produce the wrong combinations of crops and livestock or produce products with techniques and on a scale which are inconsistent with the most efficient use of agricultural resources.

Since uncertainty and decision-making under imperfect knowledge is a problem which not only touches upon all farmers but is perhaps the foremost farming problem in the state, studies dealing with uncertainty are being initiated in the Iowa Agricultural Experiment Station. These studies will deal with the nature of risk and uncertainty in the primary, or crop, and secondary, or livestock, industries of Iowa agriculture. Investigations will be made of the components of uncertainty, the manner in which farmers formulate expectations and plan under imperfect knowledge, the misuses of resources which arise under uncertainty, the accuracy of various predicting or expectational schemes as a basis for planning and methods by which uncertainty or its consequences can be lessened. The current study is a fundamental one dealing with (a) the basic nature and relationships of variability in primary, or crop, production in Iowa, (b) the possibilities of lessening and minimizing variability through diversified production patterns and resource use and (c) the fundamentals of choice dealing with the alternatives of level of income and income variability.

OBJECTIVES AND METHOD

The purpose of this study is to analyze some of the basic relationships in variability of crop production and crop income. It has been outlined as a foundation upon which more detailed studies will be based. Directly, it has been initiated to describe the “degree of risk and uncertainty” which exists for different crops and for different areas of the state. Also, it is to be used in estimating the relative importance of yield and price variability as components of income variability. Finally, the effect of certain diversification or crop combination procedures on income variability is tested. The study also indicates the nature of production or choice possibilities open to farmers for selection between money income and income variability. It outlines patterns of production which allow minimum income variability and relates these to sacrifices in income.

UNCERTAINTY AND USE OF DATA

In economic literature, the term uncertainty is used to denote situations in which knowledge is imperfect and outcomes can be predicted only in a subjective manner. The term risk is used to denote variability of yield, price or other outcomes which can be predicted in an empirical manner; the mean, standard deviation, skewness and other
parameters of the probability distribution can be predicted in a fashion which allows unfavorable outcomes to be incorporated into the cost structure of the business. Other distinctions can also be made between risk, subjective risk and subjective uncertainty; or still other distinctions can be made simply between risk and uncertainty. While these distinctions are not of particular importance for this study they can be found in such studies as Knight, Hart, Tintner and Schackle. Uncertainty is a purely subjective phenomenon and is unique to each individual farm manager; it is characterized by the degree of confidence which he has in his estimates of future prices, costs, yields or production rates. In this sense, uncertainty cannot be subjected to empirical measurement except as an attitude study of farmers. (A study of this nature is now under way in the Iowa Agricultural Experiment Station.) As an attempt to “describe and characterize the degree of uncertainty” prevailing in Iowa crop production, however, various indexes of variability are employed in this study. Actually, the study centers on variability in yields, prices, costs, gross income and net income of crop production. The supposition here is that variability indexes and other characteristics of probability distributions may provide some reflection of the “amount of uncertainty” which faces farmers in their planning and may be suggestive of the inaccuracy with which farm plans are made. The degree of uncertainty is reflected not only in the estimated dispersion (variance, range, standard deviation) of expected outcomes, but also in the skewness and kurtosis of the subjective price, yield or income distribution. Accordingly, this study has been designed to measure not only variability of production and income but also to measure other characteristics of the relevant cost, price and yield distributions.

The data provided in this study should serve not only as a foundation upon which later and more refined estimates of uncertainty and variability phenomena might be based but also as a basis for recommendations to farmers and for analysis of certain policy questions. By indicating the amount of income variability which attaches to certain farm products, the study provides an improved basis of choice by farmers. Quite often educational institutions assume that the single goal of farming is profit maximization. While profit is an important end of farming, it is not necessarily the goal which has priority over all other alternatives. Actually, the farmer or farm family is more concerned with maximizing utility or attaining a high level of living over the life span. Profit is a means which generally contributes to the end of utility maximization, but it can also act as an end which competes with maximum satisfactions and enjoyment by the farm family. Most farmers could make greater dollar returns by working 16 hours per day for 365 days per year but do not do so since, at some point, leisure and recreational activities have greater value than profit.

5 This consideration is one of firm-household interdependence and is inseparable from the problem of risk and uncertainty. For additional details on these points, see Heady, Earl O., Back, W. B. and Peterson, G. A. Interdependence between the farm business and the farm household. Iowa Agr. Exp. Sta. Res. Bul. 398; and Heady, Economics of agricultural production. Chap. 14. Prentice-Hall. New York, 1952.
While profit contributes to levels of farm living, it is not always the dominant goal in the short-run planning of the operator. He may choose instead to select single products, combinations of products and producing techniques which minimize the variability and uncertainty of income rather than those which promise very great rewards should prices and yields prove favorable. While cattle feeding may give very great returns to labor and capital if the year is favorable, the enterprise similarly may result in heavy losses. The established operator who has ample capital and a 100 percent equity still may choose the enterprise since he knows that if the outcome is unfavorable in one year, his capital position will allow him to “stay in the game” in order that he may “capture the high profits of cattle feeding” in a later year. In contrast, the beginning operator or the farmer with little capital or a small equity may wish to select a “more certain” enterprise. While one farmer with a full equity in $100,000 may choose, because he has funds enough to carry him through lean years into profitable ones, enterprise A which averages a 20 percent return over a long period of time but is associated with great variability and uncertainty, another operator with a 40 percent equity in $10,000 may be equally rational in his choice of enterprise B which averages only 5 percent but which has low year-to-year variability or a small chance of loss. While both operators may, within certain limits, be interested in maximum profits over the long run, the selection of an alternative with both lower returns and lower variability becomes a relevant short-run goal. By selecting enterprises and production systems which involve small chances of loss, the manager attempts to obtain a guarantee against loss and bankruptcy. If he is successful in safeguarding the survival of his business in the immediate future, he helps guarantee that his firm will exist for profit maximization over his lifetime.

For this reason, a selected group of farmers may be as interested in minimizing the variance of income and the probability of loss as in maximizing profits in the short run. This study furnishes data on income and yield variability and thus provides a basis for choice where farmers must choose between the alternatives of (a) large possible profits and the chance of large losses and (b) smaller but more certain prospective profits. Farmers of Iowa have long expressed notions and hypotheses about the crops and livestock enterprises which involve a large amount of risk or uncertainty; similar expressions are made in regard to the locations which involve varying degrees of variability and uncertainty. The data of the following sections provide, for the first time, a basis for examining these hypotheses and for extending information to farmers who wish to select cropping and farming systems which may result in lower income variance. In providing basic data on variability for different crops and areas of Iowa, the study also provides the basis for certain policy recommendations in regard to stabilizing farm income.

HISTORIC MEASUREMENT AND SAMPLES IN TIME

While uncertainty deals with estimates and phenomena which extend into the future, this study is devoted to measurement of variability over a 32-year period starting with 1917. It is possible, of course, that the future need not parallel the past in any manner whatsoever. This


7 In some instances, the longest period for which data were available was less than 32 years, e.g., soybeans, which have been grown in important amounts for only about 22 years.
is an overstatement, however, since weather and certain other physical forces affecting yield and income are characterized by sequences which exhibit similarities when viewed over sufficiently long periods of time. Then, too, not only do economic phenomena in general possess characteristics which are repeated over time, but different products may possess attributes of price and cost variability which differ from other crops under any economic environment. (The authors fully recognize that the economy is in a constant state of change as capital accumulation, population growth, technical change and other items of economic progress take place; also, world political pressures and governmental policy may provide a future which differs greatly from the past.) Any attempt to characterize the relative economic variability or uncertainty of various crop and livestock products in an empirical fashion must (aside from purely subjective attitude studies based on farmer opinion) be based upon a sample in time. The adequacy of a "sample in time" depends, of course, on the extent to which it provides a basis for inference to a future "population of economic environment"; aside from a sample in time or a historical study of economic variability, no other basis exists for analyzing the phenomena in question. Further, the time approach has merit in the sense that history provides an important base upon which farmers formulate expectations of the future. Analysis of variability data from a past period, while it must be used with qualification for inferences about the future, should help eliminate erroneous comparisons which might be made between products for periods in the past.

SOURCE OF DATA

While the authors were able to outline sources of data and procedures more nearly optimum (in terms of their efficiency in measuring variability and other quantities) than the one employed, the time and funds necessary to obtain them were not at their disposal. The problem under investigation centers on the degree of variability which attaches to the production, costs and income of crop products in various areas of Iowa. Concern in all instances is measurement of variability over time. The source of data most desirable for these estimates would include a combination time-series and cross-sectional sample of farms from the important soil and climatic areas in Iowa. Since the variability figures must be estimated for each producing unit rather than for a complete area or for the state as a whole, a cross-sectional sample of sufficient size would be necessary to allow acceptable estimates for the particular region while eliminating the needs for computation of variability figures for all farms of the population. A time-series sample for these same farms would be required to provide measures of variability over time. In the judgment of the investigators, sample data of this nature would be necessary on individual farms for a period of 25 years or longer. Records would be necessary on costs, yields, prices and incomes for each crop enterprise on the sample of farms. Unfortunately, large numbers of farmers do not keep such records; not enough observations are available over time even from record-keeping farms to allow estimates for the several different areas of Iowa. Of course a random sample could be selected at the present and extended over the next 25 years. However, availability of funds and limited life expectancy of research workers prohibits this approach to the problem. Also, there is current need for information on economic variability; a sample selected currently and extended over the next several decades would not allow predictions of a type useful for farmer planning and policy formation in the interim period.

Faced with these difficulties in estimating economic and physical instability, the investigators were forced to consider alternative pro-
cedures, which, while less efficient from the economic and statistical sense, might provide an acceptable basis for estimating the degree of income variability for the various crops and geographic areas of the state. A possible substitute source of background data was that of experiments; the Agricultural Experiment Station has maintained yield records over a period of years in a few selected locations. These data are of limited value to the present study, however, since they are available for a sufficient period on Clarion-Webster soils only. Too, they are for experimental plots and thus tend to overestimate variability over time for individual farms; the yield of a fractional acre may be reduced to zero by frost, insect, drouth or other damage while that of a farm field of many acres would not.

A second source of data is county yield figures. However, because of the variation in soils, climatic conditions and natural hazards within a county, variance of average county yields tends to be less, because of the greater acreage and the chance for a low yield in one part of the county to be offset by a high yield in another part of the county, than for yields of smaller acreages on individual farms. Another source of data is the assessor's reports for townships. Township yields have been reported over a sufficient time period for all major crops except hay which is reported on a county basis. As a basis of estimating the degree of variability which faces individual farmers, these data fall between experimental plot figures and county figures. While they likely provide an underestimate of yield variability for acreages which commonly make up a field on the individual farm, this difference may not be very great; many single townships tend to be relatively homogeneous in respect to weather, insects and other forces which cause crop yields to fluctuate about their mean. Accordingly, these township assessor records were used as the source of the yields upon which this study is based. A few data are also presented on a county basis.8

**SAMPLING**

Analysis of variability in crop income involved the use of historic yields, prices and cost figures. In order to limit the computational process to a manageable scale, a stratified random sample of townships was selected. The sample was designed to allow variability estimates for the major soil areas for Iowa and for the state as a whole. While similar estimates can be worked out for each township of the state, this procedure is prohibited in terms of computational costs and the writers, as well as other scientists contacted, think the estimates provided here are sufficient for preliminary inferences to the major soil associations of the state.

The state sample mentioned above was chosen to represent the major geographic areas shown in fig. 1. The state was stratified by area and the sample weighted by size of area. Townships were selected randomly in each area stratum. Figure 1 presents a map outlining the five areas and the location of sample townships in each. Names of the individual townships for this sample are listed in Appendix A.

**PURPOSIVE SAMPLE**

A second sample of 14 townships also was selected for certain phases of the analysis. This group of townships represents a purposive or

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8 Had data been available for a sufficient time period on yields of individual farms within townships, knowledge of the total components of variance estimates for a township (that due to individual farms within townships and that due to difference between years) could have been used to predict variance magnitudes for individual farms over a longer period. While individual farm yields are available in assessors' records, these extend only over 2 years at any one point in time and are not sufficient for the measures outlined.
Fig. 1. Areas and townships of the stratified sample.

PRINCIPAL SOIL ASSOCIATIONS
CW: Clarion and Webster
CC: Carrington and Clyde
CpC: Carrington and Clyde, plastic till phase
TM: Tama and Muscataine
B: Soils of Bottomlands
TD: Tama and Downs
MT: Mahaska* and Taintor*
CL: Clinton and Lindley

SSW: Shelby, Sharpsburg* and Winterset*
F: Fayette
FDS: Fayette, Dubuque and Stony Land
GPS: Galva*, Primghar* and Sac*
GH: Grundy and Haig*
M: Marshall
Mo: Moody*
MIH: Monona*, Ida* and Hamburg*

*New names not on county soil maps

SSP: Storden*, Clarion and Webster
SGH: Shelby, Grundy and Haig*
SSE: Shelby, Seymour* and Edina
WL: Weller and Lindley

—— Abrupt Boundary
--- Tentative Boundary
----- Gradational Boundary

0 24 Miles approx. Scale
judgment sample selected with the objective of including townships representative of homogeneous soil types. These townships represent major soil associations except for the Harrison Township, Benton County, and Oakland Township, Louisa County, which represent distinctly sandy and bottomland soils. For all major soils, a township was selected which is uniform in respect to type and topography and which represents, in the judgment of agronomists, the townships most distinctly characterizing a particular soil situation. Each soil association of the state is thus represented by a sample township except for Clarion-Webster; two townships were drawn in this soil area. They include Harrison Township in Kossuth County to provide a situation of "greater" variability in weather and Lincoln Township in Polk County to represent the opposite. A list of the townships, their county location and the soils represented are included in table 1.

The type of sample indicated previously might also have been employed for the detailed estimates relating to specific soil types; a sample of townships could have been selected to allow inference to each soil association. However, the resources available for the study allowed computations of statistics for a total number of townships approximating the total number of major soils or one township per soil area. Thus, selection of a single township would involve the possibility of large and unknown error; the township drawn randomly might, for example, fall on the extremes of the level Clarion-Webster soil area and include either bottom or hilly land not typical of the area in general. Thus, the purposive set of townships was selected to conform with agronomic judgments of the soils concerned. While this procedure leads to certain difficulties in inferences, we do not believe that any other procedure could be considered with our resources and available data.

**Types of Uncertainty and Source of Data**

Economic literature recognizes four major types of uncertainty or variability which relate to decision and choice-making. These include variations in prices of products and resources, variations in yields (the coefficients of production for a single production function), changes in techniques and changes growing out of the relationships between in-

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**Table 1. Townships Included in Purposive Sample.**

<table>
<thead>
<tr>
<th>Township</th>
<th>County</th>
<th>Soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Troy</td>
<td>Clarke</td>
<td>Grundy-Haig-Shelby</td>
</tr>
<tr>
<td>Grand Meadow</td>
<td>Clayton</td>
<td>Tama-Downs</td>
</tr>
<tr>
<td>Saratoga</td>
<td>Howard</td>
<td>Carrington-Clyde</td>
</tr>
<tr>
<td>Harrison</td>
<td>Kossuth</td>
<td>Clarion-Webster-Nicollet</td>
</tr>
<tr>
<td>Cedar</td>
<td>Lee</td>
<td>Grundy-Haig</td>
</tr>
<tr>
<td>Logan</td>
<td>Lyon</td>
<td>Moody</td>
</tr>
<tr>
<td>Jordan</td>
<td>Monona</td>
<td>Ida-Monona-Napier</td>
</tr>
<tr>
<td>Lincoln</td>
<td>Montgomery</td>
<td>Marshall</td>
</tr>
<tr>
<td>Lincoln</td>
<td>Polk</td>
<td>Clarion-Webster-Nicollet</td>
</tr>
<tr>
<td>Sheridan</td>
<td>Scott</td>
<td>Tama-Muscatine-Garwin</td>
</tr>
<tr>
<td>Reading</td>
<td>Sioux</td>
<td>Galva-Primghar-Sac</td>
</tr>
<tr>
<td>Harrison</td>
<td>Benton</td>
<td>Sandy loam soils</td>
</tr>
<tr>
<td>Oakland</td>
<td>Louisa</td>
<td>River bottom soils</td>
</tr>
<tr>
<td>Washington</td>
<td>Appanoose</td>
<td>Shelby-Seymour-Edina</td>
</tr>
</tbody>
</table>

---

9 The second sample was selected by A. A. Aandahl, Agronomy Department, Iowa State College and the Division of Soil Survey, B.P.I., U. S. Department of Agriculture. Frank Riecken and W. O. Shrader of Iowa State College also provided helpful assistance.
dividuals and groups of individuals. This study is concerned alone with price and technical or yield variability. Change and uncertainty growing out of relationships between persons and groups (uncertainty of contracts, leasing arrangements, institutions, etc.) are not included because the data available are not readily adapted to the type of analysis under way. Technological change or variation growing out of trends in technique has been removed from the analysis because (1) this type of variability is in itself desirable and (2) while changing techniques will take place in the future, techniques of the remote past bear no relationships to decisions which must be made by farmers or society in the future. While the process and method have limitations, changes due to techniques have been removed in the manner outlined below.

In order to measure the degree of variability attaching to the income of different crops and in different areas, two types of data were necessary: (1) data on yields over time and (2) data on product prices and input prices (costs) over time. From data of this nature, measurements of the variability of yields, gross revenue, costs and net returns may be obtained. Yields were obtained on a township basis directly from county assessor's records for all crops except hay; hay yields were available on a county basis only, and this difference should be remembered in the few instances where hay is included in the analysis of following sections. In order to remove yield variance due to technological advances, trend was eliminated, and levels of yield were adjusted to the average of the last 5 years. Variability in yields is thus computed from the adjusted base rather than from the trend regression; fluctuations are more nearly those due alone to weather variations than to both weather variations and trends in techniques which would be the case for unadjusted data.

In order to compute gross revenue per acre for each crop in each township, historic prices were obtained from various sources. Multiplication of yield per acre and price thus gave the gross revenue per acre for each year and provided the basis for computation of variability of gross revenue per acre during the time period 1917-48 except where otherwise indicated.

In order to obtain costs for each crop over time, a set of all inputs relating to "current" techniques was synthesized for each township. The prices of these inputs (labor, seed, fertilizer, fuel, machine depreciation, building inputs, etc.) were applied to the physical quantities to give the per-acre production costs. (Taxes and similar costs which are not inputs in the regular logic of production were also included.) Extreme care was used in assembling this group of inputs for each crop, township and year, depending on the level of yield. Fixed and variable costs were synthesized separately and were based upon tax data from the Iowa State Tax Commission, the BAE indexes of costs of particular items, farm equipment catalogs, building material price lists and miscellaneous sources. Variable costs, those differing with level of yield, included such items as harvesting, shelling and hauling costs (to the nearest elevator). These cost compilations are based on a farm of 160 acres in size, the predominant farm-size group in all sections of the state. By subtracting these from net revenue, the per-acre net return figures of the following sections have been obtained. Land rent and interest on investment have not been included in cost calculations. Two sets of cost and income figures have been employed, one without attaching a cost to labor and one with labor costs included. These procedures were employed since they allow inferences to the problems of those farm families who furnish their own labor at no direct cost and those who hire labor.
Selection of measures or statistics to characterize relative differences in variability and uncertainty is not a simple task. Numerous indexes must be employed if adequate measures are to be obtained for depicting the "degree of uncertainty." One such measure recognized in the literature of economics is that of dispersion in yield, price or income. Dispersion can be measured in an empirical fashion through use of mean differences (means of first differences or the absolute deviation of observations from the mean of the series), standard deviation, variance and range. These measures perhaps are sufficient for comparisons of variability of single crops in different parts of the state where mean yields and income do not differ too greatly. However, where mean prices, yields and income differ greatly, these absolute measures do not serve satisfactorily in suggesting relative variability. For example, mean yield might be 20 bushels in one area while the absolute deviation from the mean averaged 8 bushels, while mean yield in another area might be 60 bushels with an average deviation of 12 bushels. Analysis of such variation would show the second area to have a greater absolute variability; yet the first area would possess the greater relative variability. Since this study is concerned with variability as a measurement per se (and not with variance as a basis for comparing differences in mean prices, yields and incomes), the coefficient of variation has been considered useful as an expression of relative variability. Use of the coefficient of variation, the standard deviation divided by the mean, causes certain difficulties in making comparisons because of the nature of the distributions of this measure itself. These details are discussed in Appendix B.

As shown in fig. 2, however, measures of dispersion alone do not sufficiently characterize uncertainty. The degree of uncertainty surrounding an economic venture is expressed as much in the skewness or kurtosis as in the several measures of dispersion (range, variance, standard deviation, coefficient of variation) attached the particular income probability distribution in question. The relationship of each of these characteristics of the probability distribution to the degree of certainty attached to alternative ventures can be expressed in abbreviated terms by means of the hypothetical probability distributions representing the expected (or the historic) outcome for five distinct enterprises. The modal or most likely income is identical with the mean since the probability is greatest in return in the neighborhood of Z in all cases (except E). However, the desirability (probability of realizing the expected outcome) differs widely among the five cases. While the variance is assumed equal for C and D, the probability of getting a return equal to or greater than Z is obviously greater for C because it is skewed in the direction of higher rather than lower returns. Alternative B is preferable to A both because of (a) its smaller variance (range, standard deviation) and (b) its "flat peak" (kurtosis). While the mean expectation of X income is as great under alternative E as under B, the firm's choice is largely an "either-or" one (becoming wealthy or going broke) under the bimodal distribution.

Accordingly, while measures of dispersion are used mainly in the following sections to suggest the degree of uncertainty surrounding different primary crops, skewness and kurtosis are also considered briefly. Again it should be emphasized that interest in this study centers on variability per se; our concern is with variance as an index of "uncertainty" and hence this should be the statistic of central interest to us. Acceptance of this primary measure of variability immediately brings to our attention methodological problems in its measurement.
The central core of this study is the comparison of variability in income between different crop enterprises and different combinations of crops. Variability is used as one index of uncertainty facing farmers as they make decisions in respect to crops. We simply suppose that whereas some farmers are interested in profit maximization as a goal, others (particularly those with small amounts of capital and unable to undertake great risks or income fluctuations) may have minimum variability of income as a goal. It is likely, however, that most farmers try to attain some degree of both of these goals. Whereas a great majority of farm management studies focus on measures relating to the maximum income phase of farmers' decisions, this one revolves more nearly around income variability. We do not present minimization of income variability as a goal but simply measure this variability so that farmers may take the data, along with that from other studies showing income, and make their own choices between level of income and variability of income.

If we were concerned with showing farmers what the magnitude of income per acre had been for different crops, our task of measurement would be less difficult than that encountered here. We could simply measure the income per acre for different crops over a relevant time period. This basic measure would, of course, have to come from some period of the past.

Just as we might use income per acre as a measure or index of returns, we must also have a measure of variability. Many measures of variability might be used. One such measure or index would be year-to-year differences in income for different crops. Using this index we would subtract the income of one year from the income of the following year; positive and negative signs could be ignored, and the total of these year-to-year differences (i.e., all of the units of variability) could be divided by the number of years to give the average variability of income. A second measure of variability could be prepared by relating...
the income of any one year not to the income of the previous year but
to the mean of the series. Again with positive and negative signs dis·
regarded, the sum of these differences could be divided by the number
of years to give average variability figures. While both of these
indexes have been explained in terms of absolute quantities, they could
also be expressed in relative quantities. Relative variability might
be measured by dividing the absolute indexes, explained above, by the
mean of the series; variability then would be expressed in relative
indexes. All of these are simply measures of the phenomena which
we wish to observe. If we were interested in corn yield per acre we
could use "bushel" as the measure; bushel is the quantity with which
we are concerned. Similarly, we are interested in a measure of vari­
ability; we wish to measure variability for different crops. The above
indexes could serve in this manner just as bushel refers to corn yield.
Our ultimate goal, then, is the measurement of variability just as we
might measure corn yield.

Any of the measures outlined above might be employed to indicate
the quantity of importance to this study. While they have not been
worked out for this study, an examination of data from other investi­
gations shows that the year-to-year and the difference-from-mean (i.e.,
mean of first differences) measures of variability generally give the
same ranks for each crop when these measures of variability are com­
pared. We might have used either measure, in its absolute or relative
terms.

However, there are still other alternatives in the measurement of
variability. One other measure of variability may be computed as
follows: The differences may be calculated between the income or yield
of each year and the mean over all years and the differences squared
and divided by the number of years. A measure of variability again
exists; it could be called the "mean of squared differences." Under
certain assumptions, this quantity is an estimator of what statisticians
call the variance of a distribution. In our use of this quantity as a
measure of variability, we need not be concerned particularly with
the normality of distribution since we are not interested in establish­
ing confidence intervals of specified length or testing hypotheses about
the mean for different crops. Our desire is merely to secure reason­
able estimates of the variability itself. Next, we should note that we
can take the square root of our mean of squared differences as an index
of variability. This measure might be called a root mean square de­
viation. Again, we may point out that under certain assumptions,
this measure would estimate the statistic termed the standard de­
viation. As already noted above, this measure would have particular
value under normality assumptions.

We considered using the mean of the first difference as our measure
of variability. However, after discussing the point with the others,
we decided to use the mean of squared differences, and measures
directly related to it such as its square root and a ratio of the latter

— Specifically, the variance is the expected value of the variant squared
minus the square of the variant's expected value. In notation this is
usually simply expressed as \( \sigma^2 = E(X^2) - (EX)^2 \) where \( \sigma^2 \) denotes the var­i­
ance and the \( E \) indicates the average of all possible values of the variant
\( X \). Another way of saying the preceding is: variance equals the 2nd
moment of \( X \) minus the 1st moment of \( X \) squared.

— We should point out that a much simpler assumption, that of a symmetri­
cal distribution of deviations, i.e., positive or negative deviations from the
expected value equally likely, is of great importance with respect to our
measure, mean of squared differences. If, in fact, the distribution of devi­
ations is skewed to the right or left, some measure taking account of the
signs or the third moment of the distribution would be appropriate. We
have not investigated this matter of skewness sufficiently to report such
measures.
to the mean of the series (similar to a coefficient of variation) because relative magnitudes or ranks between crops, crop combination and locations are likely to be the same when this index of variability is used as when the first-difference measure is used. A further reason for using our measure is that it has facilitated certain crop combination comparisons which would require a great amount of arithmetic if they were computed separately for each acreage possibility for the past period for which we have data available.

Other questions can be raised in respect to these measures. One in particular arises where trends or autocorrelations are present in the series. For example, if the data followed a simple linear trend over time, our measure of variability would properly be based on this trend line; we might either compute our differences from the trend line or remove the trend and make the measurements accordingly. We could again use as our measurements of variability the average of the year-to-year differences, average of the deviations or the average of the squared differences (or other measures related to these). Trends of the nature mentioned best apply to increases in yields due to new techniques; the trend over the past three decades has been upward for some crops. Aside from random weather fluctuations, crop yields have moved always upward from this cause. They do not move upward for awhile as one set of techniques is adopted, fall to a lower level as a second set is adopted and continuously move through cycles of this nature.

The situation is different for prices, however. The major variable affecting prices of any one crop is the general price level. Prices for the commodities being examined have similar parallel movements in respect to the general price index; there have not been important trend differences between crops over time relative to the general price level, due mainly to the fact that the crops are feed substitutes and are priced not only relative to the general price level but also relative to each other. How does autocorrelation—the fact that the price or income magnitude of one year is correlated with that of the previous year due to the oscillations of prices following the general business cycle—negate our measures of income variability for different crops? This consideration would be important if different price trends relative to the general price level were experienced over time; but this has not been the case, and we believe that if the general price cycles of the past are to be repeated in the future, our measures of variability (to compare differences in the past between crops) will hold true for the future.

The question can be asked, of course, whether units of variability should actually be measured from the mean for the period or from a computed autoregression. Since the major price fluctuations for the commodities under investigation follow parallel paths with the cycle for the general price level, both methods might be expected to give the same relative differences between crops; if the variability index for oats is greater than for corn under one method of measurement, it may also be greater under some other measures. We have chosen to compute the variability units from the mean rather than an autoregression curve because the first measure has practical application in the sense that the quantities involved are those familiar to the mind and experience of the farmer. For example, the farmer may discuss corn returns and say that “while income has averaged $20 per acre over the last 20 years, the income is not always this amount; as an average, it has differed by $6 from this amount.” He is, of course, speaking of departures from the mean of $20. While our root mean square deviation (which can be computed from the mean of squared differences figures) departs somewhat from the mean of the deviations, it is in
the same general level and unit of measurement. Units of variability computed from an autoregression line would not be familiar to the experience of the farmer.

One additional point which should be mentioned is this: Not only does the general price level, and hence the prices of individual products, go through oscillations of the type outlined above, but also there has been an upward trend due to wars, continued inflation and general decline in the value of the dollar over time. Therefore should not this trend be removed? The writers are aware of this problem but are not sure that it should be removed or that adaptations should be made in respect to it. In the first place we have no basis for predicting what this trend will be in the future. National and world politics, more than anything else, will affect it over the next 20 or 30 years. We feel unqualified to say whether past trends will or will not extend into the future; it is likely that they will. In this case the mean of all prices will move upward, and the units of variability measured in respect to the mean of prices in the new period may have the same relative magnitude for different crops as in the period used for this study.

We have presented certain of the problems encountered in measuring variability. We think that the measures and procedures used may be acceptable for the main objective of our study—namely to indicate which crops and crop combinations have had and may be expected to have the greatest income variability (uncertainty) for particular locations. We have outlined the reasons why these data are of some use in inferring into the future. However, as subject matter research workers, we are willing to go further and say that our measures of relative variability between different crops can be used as an indication of relative variability for the future. Farmers have long expressed opinions as to which crop is most risky. Their observations are based on the past and, to date, there has been no verification of these observations; we have made an attempt to measure these quantities so that something objective (in contrast to mere opinions based on the past without any formal measurement) might be said, even though measurement is in terms of a past period.

As is evident from the preceding, there are still many problems in measurement of risk and uncertainty. Quantities other than those mentioned here can be used. Measurement must, however, mainly revolve around dispersion and variability of past observations. Further, not enough attention has been given to the appropriate procedures for

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12 In technical statistical terms, what we are saying in this paragraph relates to footnote 10. If we knew how to estimate the expected value for each of our series (particularly the series involving prices) then we might be in a position to obtain an unbiased estimate of the variance for each series. Such an estimate of the variance would be an acceptable and surely a preferred index of the variability we are seeking to measure. What we really need is a suitable model for each of our series and a procedure for estimating the parameters in the model. For our yield series, the average or a simple linear trend may represent the expected value quite well. But this is obviously not true for our data that include prices. The economic fluctuations that we have observed in the past 50 years seem to preclude acceptance of any of the currently available models and "refined" estimation techniques for a study of this kind. In fact, in many situations a rather naive model, the persistence estimator, i.e., next year will be the same as this year, will work as well as more complicated procedures. Thus, we must admit that our measure of variability may be an extremely crude one, yet we believe it yields information of considerable value for the comparisons we have made. On the other hand, we do not disparage in any sense the valuable efforts of economists and econometricians in building and fitting models for the dynamic world in which we live. Such work needs more workers and needs to be pursued with greater diligence.
autocorrelated data.\textsuperscript{18} Research by economists and statisticians is needed in these areas.

INCOME AND RISK CHOICES

The presentation of alternatives in land use and crop combinations involving level of income and variability of income is made through adaptation of certain variance equations and their mathematical consequences to the data. Since these equations are explained in detail at a later point, they will not be specified here.

TESTS OF SIGNIFICANCE

As has already been mentioned, inference relating to difference in relative variability cannot be made in the manner of conventional analysis of variance tests. While the standard variance tests are usable for this study where mean yields are near the same level and differences exist only in variation from the mean, they cannot be employed where mean quantities are of entirely different magnitudes. While use of the coefficient of variation eliminates some of these difficulties, it also is accompanied by others. In our analysis of relative variability the coefficients of variation\textsuperscript{14} have been computed for the specific crops of each township. These measures are then used to compare the variability between different crops within an area and between the same crops in different areas. In testing significance of differences in coefficients of variation between crops and areas, however, it must be recognized that these quantities do not follow a normal distribution. Nonparametric (distribution free) tests were therefore used to test for differences in relative variability of yields, costs and incomes between areas and crops. The ranked order of the medians (coefficients of variation used as observations) has been used in these tests to determine whether the differences in variability are significantly greater than one would expect as chance occurrences.\textsuperscript{25}

\textsuperscript{18}Our later development of the variability for combinations of enterprises has been based upon the use of the true correlations between the series for the crops entering into the combination. It is now becoming widely recognized that the ordinary sample serial correlation between two time series may be a poor estimator of the true serial correlation. Yet for want of a better measure, we have used this observed serial correlation in presenting some of our numerical results for enterprise combinations. To what extent the interpretation is invalidated by poor estimation of the true serial correlation, we do not know.

\textsuperscript{14}Actually, as pointed out above, we have used a root mean square deviation divided by the mean.

PART I. DEGREE OF VARIABILITY

Statistics designed to show the degree of variability or "risk" which is attached to different crops and locations are presented in the following sections. These estimates are based on the measures outlined below.

AGGREGATE MEASURES OF VARIABILITY

As already stated, the mean square deviation, root mean square deviation and coefficient of variation are used as measures of dispersion (variability) in this study. These measures are designed to show farmers and persons making recommendations to the farmers, which crops, soils and locations involve the greatest amount of variability or risk and which ones best conform to the planning environment of the individual operator. They were calculated for yield, gross income, costs and net income for each of the 50 townships of the sample. The township variability estimates were averaged to obtain variability indexes or measures of variability for each of the five areas. For example, the average variability of corn yields for Area 1 was calculated by averaging the corn yield mean square deviations of all of the townships sampled in that area.¹⁰

The state estimates of variability are weighted averages of the area estimates. Total corn production for each area during the period 1938-48 was used to weight corn yield variability for the state. The root mean square and coefficient of variation for corn were calculated for the state in the same fashion. The estimates of variability for yields, costs and returns for other crops were also calculated in this manner. A state root mean square is not therefore the square root of the corresponding state mean square measure of variation.

In making use of the state indexes of variability, the meaning of the quantities that we have calculated must be kept clearly in mind. The measures as used indicate more nearly the average variability experienced by individual farms in Iowa than they do the variability of aggregate average yields, costs or returns in Iowa as a state. Our concern is with the degree of variability attached to different crops and soils which faces individual farmers in their planning rather than with variance and other parameters of production and income for all farms aggregated together. Variability of production and income on single farms is greater than for the state because fluctuations tend to be averaged out as large numbers of farms are aggregated together into a single statistic.

VARIABILITY BETWEEN CROPS FOR IOWA

The farmer and policy maker are mainly interested in net income variability and in cost, yield and price variability to the extent that these contribute to the dispersion of net incomes. In studying the variability presented from these sources, the fact that there is interaction between the sources has to be considered. A high variability of costs, prices or yields need not of itself mean a large contribution to the variability of gross or net returns. Factors may offset each other, ¹⁰ What the appropriate averaging process should be in this case is not clear. From some points of view the median might be preferable. For yields alone which are reasonably independent when viewing the time series, a pooling of sums of squares might be quite satisfactory. Over all our data we have chosen the averaging procedure as a matter of uniformity.
e.g., high yields may be offset by low prices thus preventing a fluctuation in income during a particular year. The method of analysis used is, therefore, first one of presenting the variation of yields and costs. Combinations of the sources of variability then are made through analysis of variability of gross income, which includes prices and yields and their effects. Measures of net income variability are calculated and the effects of all three sources of variability are thus considered together. The variability figures reflect uncertainty only insofar as the returns from a crop in a particular year are unpredictable. However, the degree of imperfection with which farmers can predict yield, price and income quantities depends, to a large extent, on the variability of these quantities.

YIELD VARIABILITY

For the state as a whole, variability for corn yields is greater than for any of the four major crops studied. Flax is lowest and is followed in order by soybeans and wheat; oats falls in an intermediate position. Examination of the data presented in table 2 would suggest that farmers interested in level of income alone and who are in a capital position to withstand great risks would select corn; those with less capital and interested in stability more than level of income would select flax. These suggestions are the opposite of those ordinarily held by farmers who look upon flax as a more variable and less predictable crop than corn. The interpretation of the degree of risk (variability) in yields changes, however, when the figures on relative variability are examined. As the coefficients of variation show, flax has the greatest relative variability of yield while corn is second lowest. In this sense it can be said that of the five major cash crops studied, the degree of risk in yields is greatest for flax followed by wheat, soybeans, corn and oats. The high variability position of corn and oats is switched to a low one for the relative variability figures as compared to absolute variation because, while the mean square deviation of corn and oats yield is high, their mean yields also are higher than those of the other crops. Flax production involves greater yield risks than corn or other crops because the relative effects of weather, weeds and pests are greater for it; corn is relatively more efficient at withstanding these physical hazards. From the standpoint of yield risks alone, farmers for the state as a whole might have no preference between wheat and soybeans; the final choice in this case might then be in the direction of the crop which gives the greatest net income. As shown in later sections, soybeans give rise to a greater net income than wheat in most areas of the state.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Av. mean square deviation**</th>
<th>Root mean square deviation**</th>
<th>Coefficient of variation</th>
<th>Mean yield**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>134.8</td>
<td>11.5</td>
<td>27.4%</td>
<td>42.9</td>
</tr>
<tr>
<td>Oats</td>
<td>54.1</td>
<td>8.3</td>
<td>24.6%</td>
<td>34.2</td>
</tr>
<tr>
<td>Soybeans</td>
<td>22.5</td>
<td>4.6</td>
<td>28.2%</td>
<td>16.4</td>
</tr>
<tr>
<td>Wheat</td>
<td>26.6</td>
<td>5.0</td>
<td>28.3%</td>
<td>17.8</td>
</tr>
<tr>
<td>Flax</td>
<td>20.7</td>
<td>4.2</td>
<td>35.2%</td>
<td>11.0</td>
</tr>
</tbody>
</table>

* As explained in the text, these variability measures have been computed as weighted means of the same statistic for each area and township. They do not represent the variance, standard deviation, coefficient of variation or mean of state aggregates for the period.
** Bushels per acre.
TABLE 3. VARIABILITY OF GROSS INCOME. STATE OF IOWA, 1917-48

<table>
<thead>
<tr>
<th>Crop</th>
<th>Av. mean square deviation</th>
<th>Root mean square deviation</th>
<th>Coefficient of variation</th>
<th>Mean income per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>$347.4</td>
<td>$18.5</td>
<td>58.3%</td>
<td>$31.7</td>
</tr>
<tr>
<td>Oats</td>
<td>71.0</td>
<td>8.3</td>
<td>57.1</td>
<td>14.6</td>
</tr>
<tr>
<td>Soybeans</td>
<td>229.4</td>
<td>15.3</td>
<td>63.8</td>
<td>24.0</td>
</tr>
<tr>
<td>Wheat</td>
<td>157.5</td>
<td>12.3</td>
<td>56.6</td>
<td>21.7</td>
</tr>
<tr>
<td>Flax</td>
<td>319.6</td>
<td>17.7</td>
<td>68.4</td>
<td>25.9</td>
</tr>
</tbody>
</table>

VARIABILITY OF GROSS INCOME

Table 3 provides measures of variability of gross income for the five crops as averages for the state. These statistics are affected not only by variation in yields but also by variations in prices. Accordingly, they have greater implications for farm decisions and resources used than those presented in the previous section. Again, it is true that absolute variance is greatest for corn while flax jumps to second place and is followed by soybeans, wheat and oats. This change in position suggests that price itself has been much more variable for flax and soybeans than for oats and wheat. When the coefficients of variation are examined, flax again ranks highest while corn drops to third place in degree of risk. Soybeans are second, while wheat is lowest. These changes in position again occur because of the relationship of magnitude of variation as compared to magnitude of income. It is impossible to attribute the difference in position proportionately more to the difference between the means or the difference between the variation without examining the frequency distribution of incomes.

VARIABILITY OF COSTS

Even in the absence of yield and price variability, cost variability would give rise to instability of net income. Statistics on cost variability are therefore outlined below. Obviously, as indicated by the measures of variation presented in table 4, costs are less variable than yields or prices. Farmers can, therefore, predict costs more accurately than returns from crops. Many of the costs of agricultural production are determined to a large extent by other industries that can regulate the supply of machinery, equipment, etc. in order to assure a fairly constant price given the demand. Nevertheless, cropping costs do introduce some variability into net incomes.

Soybeans have the greatest variability of costs followed by flax, wheat, corn and oats in order. The relative variation of costs for these crops are of the same order except corn and oats which are switched as a result of the difference in means. Since farmers are interested in

TABLE 4. COST VARIABILITY PER ACRE.* STATE OF IOWA, 1917-48

<table>
<thead>
<tr>
<th>Crop</th>
<th>Av. mean square deviation</th>
<th>Root mean square deviation</th>
<th>Coefficient of variation</th>
<th>Average cost per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>$3.72</td>
<td>$1.93</td>
<td>14.9%</td>
<td>$13.0</td>
</tr>
<tr>
<td>Oats</td>
<td>3.0</td>
<td>1.7</td>
<td>18.0</td>
<td>9.6</td>
</tr>
<tr>
<td>Soybeans</td>
<td>7.4</td>
<td>2.7</td>
<td>25.1</td>
<td>10.8</td>
</tr>
<tr>
<td>Wheat</td>
<td>3.8</td>
<td>1.9</td>
<td>19.1</td>
<td>10.2</td>
</tr>
<tr>
<td>Flax</td>
<td>5.2</td>
<td>2.3</td>
<td>24.8</td>
<td>8.2</td>
</tr>
</tbody>
</table>

* Without operator’s labor included as a cost.
minimizing costs for a given level of output rather than maximizing as in the case of returns, the relative variation needs special interpretation. Where corn has a smaller coefficient of variation than oats, its costs are relatively more certain, but when examined in the light of level of costs, it has a higher mean than oats as well as a greater absolute variability. Oats would always be expected to have a lower cost in a particular year than corn. Similarly in the case of corn and wheat, the variation is similar, but wheat with a lower mean would always be expected to have a lower cost in a particular year even though its relative variability is greater. However, when two crops have the same mean costs, the crop with the least dispersion offers greater certainty of a lower cost as well as one nearer the mean. Soybeans and wheat have had nearly the same mean costs, and flax and oats were also about the same. Accordingly, wheat presents less uncertainty and greater expectation of a lower cost in a particular year; similarly oats are more certain of a lower cost than flax. In order to predict the complete ordering of crops with respect to lowest-cost expectations in a particular year, one must examine the distribution of costs. However, since costs themselves are of interest in this study mainly as a contribution of variability to net income, the relative dispersion is most important. Crops with the least relative dispersion of costs are apt to introduce the least variability into the net income from this source.

NET INCOME VARIABILITY

The most important criterion by which farmers select crops is that of net income; its magnitude and variability are both important in decision-making. Farmers with unlimited capital may select crops on the basis of magnitude of income with little regard for fluctuations. Farmers with limited capital may be nearly as interested in stability and the avoidance of bankruptcy as in level of income. Hence, information is necessary on not only the variation and relative variability of income from different crops but also on the skewness, kurtosis and similar characteristics of the frequency distribution. Level of income must be remembered, however, since crops with highly variable incomes may have minimum values of the distribution greater than the maximum values for alternative crops.

Net income variability is caused by variation in prices, costs and yields. (Both costs and gross income must be stable or offset each other if net income is to be stable.) Measures of net income variability for the five major Iowa crops are presented in table 5 for the state. Since corn has the largest net income per acre and also the least variability of net income per acre, as expressed by the coefficient of variation, it should rank in first place for the state as a whole except where other crops must be grown as complementary or supplementary enterprises. Oats have the greatest relative variability although their absolute variability is smallest. The low mean income of oats causes this difference.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Av. mean square deviation</th>
<th>Root mean square deviation</th>
<th>Coefficient of variation</th>
<th>Weighted mean income per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>$298.0</td>
<td>$17.1</td>
<td>70.8%</td>
<td>$24.2</td>
</tr>
<tr>
<td>Oats</td>
<td>50.5</td>
<td>6.4</td>
<td>168.2</td>
<td>5.8</td>
</tr>
<tr>
<td>Soybeans</td>
<td>172.0</td>
<td>12.9</td>
<td>93.9</td>
<td>13.1</td>
</tr>
<tr>
<td>Wheat</td>
<td>118.7</td>
<td>10.6</td>
<td>93.9</td>
<td>11.3</td>
</tr>
<tr>
<td>Flax</td>
<td>254.8</td>
<td>15.8</td>
<td>95.6</td>
<td>16.5</td>
</tr>
</tbody>
</table>

*Operator's labor has not been deducted in computing net income.
### TABLE 6. NET INCOME DISTRIBUTION.

<table>
<thead>
<tr>
<th>Percent above or below the average*</th>
<th>Corn (Av.)</th>
<th>Oats (Av.)</th>
<th>Soybeans (Av.)</th>
<th>Wheat (Av.)</th>
<th>Flax (Av.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>260-300</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>220-260</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>180-220</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>140-180</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>100-140</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>60-100</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Mean ± 20</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>(-20).(-60)</td>
<td>12</td>
<td>4</td>
<td>7</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>(-60).(-100)</td>
<td>3</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>(-100).(-140)</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>(-140).(-180)</td>
<td>3</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(-180).(-220)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unweighted mean</td>
<td>18.51</td>
<td>4.94</td>
<td>13.03</td>
<td>12.29</td>
<td>15.02</td>
</tr>
</tbody>
</table>

* This table is based on the unweighted average of the 50 townships.

### TABLE 7. INCOME LOSSES IN DOLLARS PER ACRE FROM CROPS. 1917-48.

<table>
<thead>
<tr>
<th>Year</th>
<th>Corn</th>
<th>Oats</th>
<th>Soybeans</th>
<th>Wheat</th>
<th>Flax</th>
</tr>
</thead>
<tbody>
<tr>
<td>1921</td>
<td>-.57</td>
<td>2.56</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1931</td>
<td>4.46</td>
<td>2.54</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1932</td>
<td>-5.90</td>
<td>3.50</td>
<td>-10</td>
<td>-1.79</td>
<td></td>
</tr>
<tr>
<td>1934</td>
<td>-1.32</td>
<td>-3.11</td>
<td>-28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1935</td>
<td>-3.57</td>
<td>2.87</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1936</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1938</td>
<td>-2.74</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1939</td>
<td>-1.83</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Soybeans, flax and wheat in order of variability are in intermediate position between oats and corn. Analysis of uncertainty aspects of variability on the basis of the measures presented in table 5 appears valid in view of the similarity of distributions of net incomes for the crops as shown in table 6. 17 Although 32 years of observations are too few to accurately describe the frequency distribution, it appears that kurtosis and skewness are much the same for all crops. However, distributions for some crops may contain more negative years than others. Table 7 presents some budgeted losses that have occurred for crops in Iowa. Oats had the most losses 9 years out of 32; corn lost money only 3 years out of 32; soybeans lost 2 years out of 20; wheat 1 year out of 32; flax had no losses. 18 Thus, the most risk attached to oats, both from the standpoint of income stability and from that of minimizing the chance of loss in a particular year. Expectation of fewest losses is offered by flax, but it has a relatively high variability of income and is not adapted to all areas. In expectation of actual losses, wheat falls between corn and flax but is more variable and less profitable in the

17 Complications that arise when distributions are different are discussed in Appendix B.

18 In budgeting, one set of given techniques was assumed over the entire period. This method does not correspond to reality. However, net incomes compared on this basis correspond more nearly to conditions as they are today and eliminate the effects of technological change which occurred.
long run than corn. Soybeans have about the same expectation of losses in particular years as corn but have greater relative variability with a lower mean income.

**RELATIVE VARIABILITY BETWEEN AREAS AND BETWEEN CROPS**

A great deal of variability exists in farming conditions within a state as large as Iowa. The average growing season ranges from under 140 days to over 170 days in different parts of the state. Rainfall varies from under 28 inches in the northwest to 36 or over in some small areas of the southeast. There are about 20 or so major soil associations in Iowa and a number of minor ones. Similarly, topography, pests, weeds, temperatures and other natural factors that affect the yields of various crops and their variability over the state differ with location. Additional figures must therefore be examined before predictions can be made of the uncertainty attached to different crops and affecting individual farms. Accordingly, the state was divided into the five areas mentioned previously to increase the homogeneity of the areas studied and more nearly describe variability as it faces farmers on particular soils and at particular locations.

**YIELD VARIABILITY BETWEEN AREAS**

Coefficients of variation were used to measure variability of crop yields within areas. Since the frequency distribution of the coefficients of variation is unknown, nonparametric tests were used to test for significant differences in variability between areas. The differences in variability of yields between areas for oats, corn and soybeans were significant at the 5 percent level.

As indicated in table 8, Areas I and II (western and southern Iowa) have greater variability of corn, oats and soybean yields than do Areas III, IV and V (central and eastern Iowa). This was expected since western and southern Iowa are more subject to drought. Northwestern Iowa has less rainfall than the rest of the state, and unless it comes at the right time, crops suffer. Similarly, southern and southwestern Iowa need rainfall at properly spaced intervals because of a number of soil types which do not store much moisture. Less difference between the absolute variabilities than between the relative variabilities suggests that weather, climate and other factors have greater effect on mean yields than upon absolute variation of yields about the mean.

Wheat might be expected to follow the same pattern as the above crops, but in practice it is grown to a large extent in the Missouri bottom lands of Areas I and II where the effects of drought are less noticeable. Wheat yields were most variable in the Clarion-Webster area of central Iowa and least variable on Tama-Muscatine soils in southeastern Iowa. Other areas had approximately the same relative variability for wheat.

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Nonparametric tests are distribution-free tests and do not depend upon a known distribution but rather upon “order statistics” to determine the probability with which various combinations are likely to occur. An ordered sample is one in which the largest observation is first, the next largest second and so on to the smallest. The distribution of area under the density function between any two ordered observations is independent of the form of the density function. See Mood, A. M. Introduction to the theory of statistics. McGraw-Hill. 1950.

Flax and wheat were not included in the tests. These crops were not grown in all sampled townships and often occurred in small acreages in those areas where they were grown.
TABLE 8. AVERAGE YIELD VARIABILITY FOR CROPS WITHIN AREAS.
1917-48.*

<table>
<thead>
<tr>
<th>Areas</th>
<th>Mean square deviation**</th>
<th>Root mean square deviation**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Corn</td>
<td>151.4</td>
<td>110.5</td>
</tr>
<tr>
<td>Oats</td>
<td>68.0</td>
<td>82.0</td>
</tr>
<tr>
<td>Soybeans</td>
<td>27.8</td>
<td>20.0</td>
</tr>
<tr>
<td>Wheat</td>
<td>26.2</td>
<td>18.6</td>
</tr>
<tr>
<td>Flax***</td>
<td>25.5</td>
<td>—</td>
</tr>
</tbody>
</table>

Coefficient of variation

<table>
<thead>
<tr>
<th>Areas</th>
<th>Mean yield**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>30.9%</td>
</tr>
<tr>
<td>Oats</td>
<td>27.9</td>
</tr>
<tr>
<td>Soybeans</td>
<td>30.4</td>
</tr>
<tr>
<td>Wheat</td>
<td>28.4</td>
</tr>
<tr>
<td>Flax</td>
<td>42.4</td>
</tr>
</tbody>
</table>

* Data on soybeans cover the period 1927-48.
** These figures are averages of the township measures expressed in bushels per acre.
*** Not all areas raised flax, and in those where it was raised, only some townships had it.

Flax followed a variability pattern similar to that of corn, oats and soybeans. Area I in eastern Iowa was most variable, but Area II did not raise any in the townships sampled. Area V (Carrington-Clyde soils) had considerably less relative variability of flax yield than the other areas and was followed by Areas IV and III in order of least variability. These differences between areas are important for farm decisions relative to opportunities involving both level and variability of income.

YIELD VARIABILITY BETWEEN CROPS WITHIN AREAS

Within-area yield variability data have greater application to individual farms than estimates of variability on a state-wide basis. Differences in variability between crops within areas were not significant at the 5 percent level when nonparametric tests were made. The coefficients of variation within areas presented in table 8 differ by less than 15 percent. Weather, pests and other natural factors within homogeneous areas evidently affect the relative variability of crop yields for all crops to about the same extent. (Flax and wheat are excepted, since sufficient data were not available.) Thus, within a homogeneous area, crop yield variability would introduce about the same amount of relative variation into gross and net income variability for all crops.

GROSS INCOME VARIABILITY BETWEEN CROPS AND BETWEEN AREAS

From table 9, it is apparent that little difference in relative variability of gross income exists between areas and that there are only slightly greater differences between crops within areas. Nonparametric tests support the conclusion of no significant differences. The differences in yield variability between areas is offset somewhat by price

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20 The probability of obtaining a between-crops ordered combination equally as likely or less likely by chance was .136. In the case of between-area differences, the probability of equally likely or less likely cases was .225.
TABLE 9. AVERAGE GROSS INCOME VARIABILITY FOR CROPS WITHIN AREAS. 1917-48.*

<table>
<thead>
<tr>
<th>Areas</th>
<th>Mean square deviation</th>
<th>Root mean square deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Corn</td>
<td>$359.2</td>
<td>$181.6</td>
</tr>
<tr>
<td>Oats</td>
<td>53.8</td>
<td>74.0</td>
</tr>
<tr>
<td>Soybeans</td>
<td>251.6</td>
<td>175.5</td>
</tr>
<tr>
<td>Wheat</td>
<td>155.6</td>
<td>118.7</td>
</tr>
<tr>
<td>Flax</td>
<td>381.1</td>
<td>—</td>
</tr>
</tbody>
</table>

Coefficient of variation

<table>
<thead>
<tr>
<th>Areas</th>
<th>Coefficient of variation</th>
<th>Unweighted mean gross income per acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>62.4%</td>
<td>$30.0</td>
</tr>
<tr>
<td>Oats</td>
<td>58.1</td>
<td>12.4</td>
</tr>
<tr>
<td>Soybeans</td>
<td>70.6</td>
<td>22.5</td>
</tr>
<tr>
<td>Wheat</td>
<td>56.9</td>
<td>21.5</td>
</tr>
<tr>
<td>Flax</td>
<td>70.1</td>
<td>27.9</td>
</tr>
</tbody>
</table>

* Soybean data cover the period 1927-48.

variability, while the difference between crops is increased but not significantly when prices and yield effects are combined in gross income. However, the producer is most interested in the variability and magnitude of net incomes. Therefore cost variability, another source of net income variability, is taken up next.

COST VARIABILITY

There is less difference in variability of costs between areas than for price and yield variability. A large portion of the costs of production and their variability is approximately the same in all areas for the same crop; regardless of the amount of crop harvested, the same amount of plowing, disking and cultivating usually goes into the raising of the crop. There are some local differences introduced because of transportation costs and taxes, but these differences are small. Harvesting costs such as corn picking, baling and combining tend to vary with yield, but the variability introduced by such costs is not enough to cause any great differences between areas. In table 10, only

TABLE 10. AVERAGE COST VARIABILITY FOR CROPS WITHIN AREAS. 1917-48.*

<table>
<thead>
<tr>
<th>Areas</th>
<th>Mean square deviation</th>
<th>Root mean square deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Corn</td>
<td>3.8</td>
<td>3.4</td>
</tr>
<tr>
<td>Oats</td>
<td>2.9</td>
<td>2.7</td>
</tr>
<tr>
<td>Soybeans</td>
<td>7.4</td>
<td>7.1</td>
</tr>
<tr>
<td>Wheat</td>
<td>3.8</td>
<td>3.6</td>
</tr>
<tr>
<td>Flax</td>
<td>5.3</td>
<td>—</td>
</tr>
</tbody>
</table>

Coefficient of variation

<table>
<thead>
<tr>
<th>Areas</th>
<th>Coefficient of variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>15.4%</td>
</tr>
<tr>
<td>Oats</td>
<td>18.1</td>
</tr>
<tr>
<td>Soybeans</td>
<td>25.4</td>
</tr>
<tr>
<td>Wheat</td>
<td>19.2</td>
</tr>
<tr>
<td>Flax</td>
<td>24.9</td>
</tr>
</tbody>
</table>

* Soybean data cover the period 1927-48.
<table>
<thead>
<tr>
<th>Areas</th>
<th>Mean square deviation</th>
<th>Root mean square deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Corn</td>
<td>307.0</td>
<td>146.1</td>
</tr>
<tr>
<td>Oats</td>
<td>38.7</td>
<td>55.3</td>
</tr>
<tr>
<td>Soybeans</td>
<td>158.1</td>
<td>123.3</td>
</tr>
<tr>
<td>Wheat</td>
<td>116.6</td>
<td>87.1</td>
</tr>
<tr>
<td>Flax</td>
<td>311.3</td>
<td></td>
</tr>
</tbody>
</table>

Coefficient of variation

<table>
<thead>
<tr>
<th>Areas</th>
<th>Corn</th>
<th>Oats</th>
<th>Soybeans</th>
<th>Wheat</th>
<th>Flax</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100.4%</td>
<td>160.6%</td>
<td>92.6%</td>
<td>84.8%</td>
<td>82.9%</td>
<td>17.22%</td>
</tr>
<tr>
<td></td>
<td>128.6</td>
<td>253.1</td>
<td>130.4</td>
<td>126.4</td>
<td>140.2</td>
<td>3.05%</td>
</tr>
<tr>
<td></td>
<td>121.3</td>
<td>106.2</td>
<td>96.7</td>
<td>91.4</td>
<td>95.3</td>
<td>11.82%</td>
</tr>
<tr>
<td></td>
<td>94.7</td>
<td>106.2</td>
<td>94.6</td>
<td>82.8</td>
<td>84.5</td>
<td>11.36%</td>
</tr>
<tr>
<td></td>
<td>95.2</td>
<td></td>
<td>96.2</td>
<td>101.7</td>
<td>91.3</td>
<td>18.71%</td>
</tr>
<tr>
<td></td>
<td>110.1</td>
<td>141.6</td>
<td>102.1</td>
<td>97.4</td>
<td>98.8</td>
<td></td>
</tr>
</tbody>
</table>

Unweighted area means

* Soybean data cover the period 1927-48.

A slight difference is apparent in cost variability between the central and eastern areas (III, IV and V) with their more stable yields and between the western and southern areas (I and II) with their more variable yields. The differences did not prove significant at the 5 percent level when nonparametric tests of the coefficient of variation were made. However, crops involve different techniques of production and therefore different cost structures; fixed cost combinations as well as variable cost combinations differ between crops. The differences in cost variability between crops within areas which nonparametric tests confirmed as significant at the 5 percent level may be noted in table 10.

**NET INCOME VARIABILITY**

If costs were to vary in the same direction and to the same extent as gross income, net income could be relatively stable even though costs, yields and prices each varied considerably. In reality, as shown in tables 9 and 10, costs tend to vary less than gross incomes for the five major crops under consideration. Net income variability is, therefore, relatively large even where costs and gross incomes do vary in the same direction since the cost variations are not large enough to offset gross income variations. Table 11 shows noticeable differences in income variability between areas and between crops within areas. (Costs and gross returns are not positively correlated to the same degree in all areas and for all crops, although negative correlation is unlikely.) Nonparametric tests indicate that these differences are significant at the 5 percent level both between areas and between crops within areas. Variability of income figures for individual areas therefore is more important than yields, costs and gross returns variability in making recommendations to individuals. Also, the larger the differences between crops with respect to income variability, the more important is the selection of uncertainty-reducing crops or combinations in order to achieve income stability.

In making comparisons of net income variability between crops within areas which gives rise to uncertainty, one may compare the coefficients of variation in table 11 directly. For farmers choosing to avoid risk of bankruptcy or for those interested in the possibility of very high incomes, the average ranges representing the lowest and

---

21 The average ranges were calculated by taking the average of the end points of the individual township ranges within each area.
TABLE 12. AVERAGE RANGES* OF NET RETURNS PER ACRE FROM VARIOUS CROPS. 1917-48.**

<table>
<thead>
<tr>
<th>Areas</th>
<th>Corn</th>
<th>Oats</th>
<th>Soybeans</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>$ -6.20 to $68.00</td>
<td>$ -4.68 to $17.32</td>
<td>$ -3.78 to $40.64</td>
</tr>
<tr>
<td>II</td>
<td>-5.77 to 45.31</td>
<td>-5.09 to 26.00</td>
<td>-3.80 to 35.31</td>
</tr>
<tr>
<td>III</td>
<td>-6.78 to 63.93</td>
<td>-4.28 to 21.09</td>
<td>-3.31 to 42.24</td>
</tr>
<tr>
<td>IV</td>
<td>-4.88 to 76.22</td>
<td>-4.04 to 24.11</td>
<td>-3.31 to 44.04</td>
</tr>
<tr>
<td>V</td>
<td>-3.55 to 53.36</td>
<td>-3.99 to 22.97</td>
<td>-2.73 to 30.96</td>
</tr>
</tbody>
</table>

Areas of Wheat Flax

I $ -3.17 to $39.30 $ 4.82 to $74.50
II -3.42 to 35.47
III -3.56 to 38.34 - .91 to 72.14
IV -2.65 to 44.94 -1.60 to 52.78
V -3.99 to 47.16 - .69 to 32.02

* End points of the above ranges are averages of the end points of the individual township ranges.
** Soybean data cover the period 1927-48.

The highest net returns that have occurred in the past are presented in table 12. Except in Areas I and IV the order of crops having the highest minimum income was as follows: flax, wheat, soybeans, oats, and corn. In the two exceptions, wheat and soybeans were interchanged. (Area II did not report flax but the order was otherwise as indicated.)

However, the range also has limitations of interpretation. While the range suggests that wheat losses per acre will be small, it gives no information as to the relative frequency of losses. The average number of years in which actual losses or negative returns per acre occurred are tabulated in table 13. Although corn has shown some relatively large losses, these have occurred infrequently. Oats have had the most years of negative income. Soybeans, flax and wheat as shown in the table have varied somewhat with areas in their ranking. However, all crops were more variable in Areas I and II (western and southern Iowa) where the drouth hazard is greater than in the other areas.

TABLE 13. AVERAGE NUMBER OF YEARS IN WHICH LOSSES OCCURRED IN THE PRODUCTION OF VARIOUS CROPS BY AREAS. 1917-48.**

<table>
<thead>
<tr>
<th>Area</th>
<th>Corn years</th>
<th>Oats years</th>
<th>Soybeans years</th>
<th>Wheat years</th>
<th>Flax years</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>3.8</td>
<td>11.6</td>
<td>4.4</td>
<td>4.2</td>
<td>2.5</td>
</tr>
<tr>
<td>II</td>
<td>4.6</td>
<td>15.8</td>
<td>4.2</td>
<td>4.8</td>
<td>1.0</td>
</tr>
<tr>
<td>III</td>
<td>2.6</td>
<td>7.9</td>
<td>2.7</td>
<td>4.0</td>
<td>1.0</td>
</tr>
<tr>
<td>IV</td>
<td>1.8</td>
<td>7.1</td>
<td>3.1</td>
<td>1.0</td>
<td>2.3</td>
</tr>
<tr>
<td>V</td>
<td>2.8</td>
<td>8.0</td>
<td>2.8</td>
<td>2.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>

* Years of negative income are the average number of years in which losses occurred. (Average of the number of years losses occurred in each township, i.e., the average number of years losses occurred in the townships of each area.)
** Soybean data cover the period 1927-48.

Some crops such as flax and wheat were grown in only a few of the townships sampled in each area. Table 14 indicates the number of townships sampled and the number of townships which reported each of the crops. Where crops were grown in only one or two townships in an area for the 32-year period, the acreages reported were usually small.

32 years for corn, oats, flax and wheat; 22 years for soybeans.
The difference in number of years of losses could be the result of kurtosis or skewness of the income frequency distribution. It is quite possible for two crops with the same coefficients of variation to be skewed in different directions. However, from table 15 it appears that all of the five crops have similar net income distributions, i.e., they tend to have more high incomes than low incomes (skewed to the right).

All of the crops are probably enough alike in this respect so that a direct comparison of their dispersions and ranges will give satisfactory information about their variability as it affects uncertainty, although 32 observations are not enough to describe the true distribution with very great precision. Some indication of the relative peakedness of the net income distributions for the various crops in the different areas is also presented in table 15. The interval having the most observations contains the peak; the relative number of observations indicates its relative height. No great differences between crops are present.

**REDUCTION OF VARIABILITY IN CROP COMBINATIONS**

Where only one crop is raised, the crop with the least variable income could be chosen to obtain the most stable income as previously discussed. However, while single-crop farming is practiced in some areas, most farms raise two or more products. By producing some legume forage along with corn, the corn yields are increased. Up to some point, increasing the legume acreage increases total crop production because the increased yield per acre due to added nitrogen, soil tilth, disease control, etc., more than offsets the reduction caused by withdrawing acreage from corn. Until the point is reached where increased yield per acre no longer compensates for the acreage withdrawn, it pays to raise the two crops together even if the forage has no other value than as a green manure crop. On the other hand, given a specified farm and equipment setup, it is often convenient to produce two or more crops which make use of the resources of production at different times. For example, a livestock enterprise such as cattle feeding may make use of available labor and equipment during the months when they are not needed for corn production.

Diversification also serves to reduce variability of income; should one crop fail, another may still be profitable. Thus, when farmers decide upon enterprise combinations (products) for the farm, stabilizing income as well as maximizing income is important. It is not enough to choose just any two crops for this purpose even though they may meet the conditions of complementarity and supplementarity; should one crop fail the other must not. Crops are chosen which will not be affected adversely by the same conditions. Even better results (from a stabilization viewpoint) would be obtained if those conditions which adversely

---

**Soybeans tended to be bimodal in distribution of net incomes, but this may be a property of the shorter period for which the data were available.**
TABLE 15. DISTRIBUTION OF NET RETURNS* FROM CROPS WITHIN AREAS, 1917-48.**

<table>
<thead>
<tr>
<th>Area I</th>
<th>Area II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>Oats</td>
</tr>
<tr>
<td>Corn</td>
<td>Oats</td>
</tr>
<tr>
<td>over 380%</td>
<td>340-380</td>
</tr>
<tr>
<td>340-380</td>
<td>1</td>
</tr>
<tr>
<td>300-340</td>
<td>1</td>
</tr>
<tr>
<td>260-300</td>
<td>1</td>
</tr>
<tr>
<td>220-260</td>
<td>2</td>
</tr>
<tr>
<td>180-220</td>
<td>3</td>
</tr>
<tr>
<td>140-180</td>
<td>4</td>
</tr>
<tr>
<td>100-140</td>
<td>5</td>
</tr>
<tr>
<td>60-100</td>
<td>6</td>
</tr>
<tr>
<td>20-60</td>
<td>7</td>
</tr>
<tr>
<td>Mean ± 20%</td>
<td>6</td>
</tr>
<tr>
<td>-20 to -60</td>
<td>7</td>
</tr>
<tr>
<td>-60 to -100</td>
<td>6</td>
</tr>
<tr>
<td>-100 to -180</td>
<td>4</td>
</tr>
<tr>
<td>-180 to -220</td>
<td>5</td>
</tr>
<tr>
<td>-220 to -260</td>
<td>3</td>
</tr>
<tr>
<td>Over -260</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Area III</th>
<th>Area IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>Oats</td>
</tr>
<tr>
<td>Corn</td>
<td>Oats</td>
</tr>
<tr>
<td>340-380%</td>
<td>300-340</td>
</tr>
<tr>
<td>340-380%</td>
<td>1</td>
</tr>
<tr>
<td>300-340</td>
<td>2</td>
</tr>
<tr>
<td>260-300</td>
<td>3</td>
</tr>
<tr>
<td>220-260</td>
<td>4</td>
</tr>
<tr>
<td>180-220</td>
<td>5</td>
</tr>
<tr>
<td>140-180</td>
<td>6</td>
</tr>
<tr>
<td>100-140</td>
<td>7</td>
</tr>
<tr>
<td>60-100</td>
<td>8</td>
</tr>
<tr>
<td>20-60</td>
<td>9</td>
</tr>
<tr>
<td>Mean ± 20%</td>
<td>5</td>
</tr>
<tr>
<td>-20 to -60</td>
<td>6</td>
</tr>
<tr>
<td>-60 to -100</td>
<td>5</td>
</tr>
<tr>
<td>-100 to -140</td>
<td>3</td>
</tr>
<tr>
<td>-140 to -180</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Area V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
</tr>
<tr>
<td>Corn</td>
</tr>
<tr>
<td>340-380%</td>
</tr>
<tr>
<td>340-380%</td>
</tr>
<tr>
<td>300-340</td>
</tr>
<tr>
<td>260-300</td>
</tr>
<tr>
<td>220-260</td>
</tr>
<tr>
<td>180-220</td>
</tr>
<tr>
<td>140-180</td>
</tr>
<tr>
<td>100-140</td>
</tr>
<tr>
<td>60-100</td>
</tr>
<tr>
<td>20-60</td>
</tr>
<tr>
<td>Mean ± 20%</td>
</tr>
<tr>
<td>-20 to -60</td>
</tr>
<tr>
<td>-60 to -100</td>
</tr>
<tr>
<td>-100 to -140</td>
</tr>
<tr>
<td>-140 to -180</td>
</tr>
</tbody>
</table>

* Operator's labor has not been included as an expense in the computation of net incomes.
** Soybean data cover the period 1927-48.
affect one crop would produce a bumper crop of the other product. Such negative correlations would insure stable yields although any correlation algebraically less than 1 has an advantage. Similarly, if it were possible to combine crops in such a manner that those crops which show a loss or low income in a particular year could be offset by crops returning a relatively high income, a step toward stability would be achieved. The serial correlation coefficient may be used as an indicator of this situation. Two crops tending to have high incomes during the same seasons would have a correlation coefficient approaching a positive 1. Those tending to vary in opposite directions would have a coefficient approaching a negative 1. The closer the approach to positive 1, the more confidence we may place in simultaneous occurrence of the high (low) income from both crops. On the other hand, the closer the approach to a negative 1, the greater the probability of a low income from one crop being offset by a high income from the other.

Correlation coefficients of yields between some of the crops are listed in table 16. Corn and soybeans have the highest correlation and are therefore not good crops to raise together from the standpoint of reducing yield variability. Flax and corn have a very small positive correlation or a slightly negative correlation in the different areas and produce the most stable yield combination.

Prices may also be serially correlated, and the indication of this phenomenon appears in table 17. All of the grain crops prices are highly correlated. Less correlation appears between grain crops and hay. Corn and hay have the lowest correlation insofar as prices are concerned, and that combination therefore introduces less variability from prices.

When net income correlation (table 18) between grain crops is taken into account, that of corn and wheat seems to be lower than that of any other combination shown. Corn and soybeans have the highest correlation of net income. Corn and soybeans would not, therefore, be grown together to reduce variability. Similarly, other combinations may be considered from the correlation coefficients. For more information on the effects on variability of combining crops, see the section on diversification.

LIMITATIONS OF ANALYSIS

One obvious limitation of the analysis results from the fact that farming in Iowa consists of raising more than field crops. Combinations of livestock enterprises and combinations of livestock and field crop enterprises are made. To be complete, our analysis should be extended to cover these combinations. Tables similar to the ones set forth for major field crops could be drawn up for the major livestock enterprises and also between livestock and crop enterprises. These might be useful in selecting enterprises necessary for income stability. It may well be that a low income in any particular season caused by failure of one crop could be offset by success in a particular livestock enterprise. The amount of income given up to attain stability is not indicated though. (The following section on diversification will cover that point.) In view of these limitations, our study may be considered only a beginning. Where guesses as to the variability of crop returns based on a few years’ experience and

24 See section on Methodological Problems in Measurement.
25 Other than the methodological problems already presented.
TABLE 16. CORRELATION BETWEEN YIELDS OF DIFFERENT CROPS.

<table>
<thead>
<tr>
<th></th>
<th>Area I</th>
<th>Area II</th>
<th>Area III</th>
<th>Area IV</th>
<th>Area V</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Corn</td>
<td>Oats</td>
<td>Corn</td>
<td>Oats</td>
<td>Corn</td>
</tr>
<tr>
<td>Corn</td>
<td>1</td>
<td>.44</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Oats</td>
<td>1</td>
<td>.46</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Soybeans</td>
<td>.55</td>
<td>.70</td>
<td>.31</td>
<td>.32</td>
<td>.34</td>
</tr>
<tr>
<td>Wheat</td>
<td>.21</td>
<td>.34</td>
<td>.55</td>
<td>.34</td>
<td>.65</td>
</tr>
<tr>
<td>Flax</td>
<td>.16</td>
<td>.35</td>
<td>.35</td>
<td>.35</td>
<td>.20</td>
</tr>
</tbody>
</table>

memory have been the basis for estimating relative uncertainty of crops, the variability estimates presented may be used to eliminate the guess work and memory bias regarding the past.

TABLE 17. CORRELATION COEFFICIENTS OF PRICES FOR IOWA BETWEEN CROPS.

<table>
<thead>
<tr>
<th></th>
<th>Corn</th>
<th>Oats</th>
<th>Soybeans</th>
<th>Wheat</th>
<th>Flax</th>
<th>Hay*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>1</td>
<td>.87</td>
<td>.79</td>
<td>.78</td>
<td>.84</td>
<td>.17</td>
</tr>
<tr>
<td>Oats</td>
<td></td>
<td>1</td>
<td>.86</td>
<td>.91</td>
<td>.87</td>
<td>.37</td>
</tr>
<tr>
<td>Soybeans</td>
<td>1</td>
<td></td>
<td>.36</td>
<td>.81</td>
<td>.86</td>
<td>.52</td>
</tr>
<tr>
<td>Wheat</td>
<td></td>
<td></td>
<td>1</td>
<td>.86</td>
<td>.86</td>
<td>.54</td>
</tr>
<tr>
<td>Flax</td>
<td></td>
<td></td>
<td></td>
<td>.37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hay*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

* Mixed clover and timothy.

TABLE 18. CORRELATION COEFFICIENTS BETWEEN NET RETURNS PER ACRE OF DIFFERENT CROPS (BY AREAS).

<table>
<thead>
<tr>
<th></th>
<th>Corn</th>
<th>Oats</th>
<th>Soybeans</th>
<th>Wheat</th>
<th>Flax</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area I</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>1</td>
<td>.71</td>
<td>.75</td>
<td>.63</td>
<td>.68</td>
</tr>
<tr>
<td>Oats</td>
<td>1</td>
<td></td>
<td>.69</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Area II|
| Corn  | 1    | .57  | .83      | .61   | —    |
| Oats  | 1    |     | .74      |       |      |

| Area III|
| Corn  | 1    | .78  | .78      | .56   | .74  |
| Oats  | 1    |     | .82      |       |      |

| Area IV|
| Corn  | 1    | .68  | .80      | .56   | .58  |
| Oats  | 1    |     | .78      |       |      |

| Area V|
| Corn  | 1    | .74  | .78      | .51   | .30  |
| Oats  | 1    |     | .78      |       |      |
### TABLE 19. VARIABILITY OF YIELDS* IN 14 SELECTED TOWNSHIPS, 1917-48.**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Crop</th>
<th>Reading Twp. Sioux County</th>
<th>Sheridan Twp. Scott County</th>
<th>Lincoln Twp. Polk County</th>
<th>Lincoln Twp. Montgomery County</th>
<th>Jordan Twp. Monona County</th>
<th>Logan Twp. Lyon County</th>
<th>Oakland Twp. Louisa County</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean square deviation</strong></td>
<td>Corn</td>
<td>162.8</td>
<td>66.4</td>
<td>136.3</td>
<td>124.9</td>
<td>100.9</td>
<td>162.9</td>
<td>77.0</td>
</tr>
<tr>
<td></td>
<td>Oats</td>
<td>99.3</td>
<td>60.2</td>
<td>52.2</td>
<td>49.5</td>
<td>45.4</td>
<td>99.0</td>
<td>18.6</td>
</tr>
<tr>
<td></td>
<td>Soybeans</td>
<td>27.3</td>
<td>29.5</td>
<td>24.2</td>
<td>30.6</td>
<td>31.7</td>
<td>19.5</td>
<td>10.8</td>
</tr>
<tr>
<td></td>
<td>Flax</td>
<td>29.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Root mean square deviation</strong></td>
<td>Corn</td>
<td>12.8</td>
<td>8.2</td>
<td>11.7</td>
<td>11.2</td>
<td>10.0</td>
<td>12.8</td>
<td>8.8</td>
</tr>
<tr>
<td></td>
<td>Oats</td>
<td>10.0</td>
<td>7.8</td>
<td>7.2</td>
<td>7.0</td>
<td>6.7</td>
<td>10.0</td>
<td>7.9</td>
</tr>
<tr>
<td></td>
<td>Soybeans</td>
<td>5.2</td>
<td>5.4</td>
<td>4.9</td>
<td>5.5</td>
<td>5.6</td>
<td>4.3</td>
<td>4.4</td>
</tr>
<tr>
<td></td>
<td>Flax</td>
<td>5.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Coefficient of variation</strong></td>
<td>Corn</td>
<td>29.7</td>
<td>12.0</td>
<td>18.5</td>
<td>23.7</td>
<td>25.3</td>
<td>32.2</td>
<td>19.3</td>
</tr>
<tr>
<td></td>
<td>Oats</td>
<td>28.4</td>
<td>17.4</td>
<td>19.9</td>
<td>25.6</td>
<td>30.2</td>
<td>25.9</td>
<td>28.7</td>
</tr>
<tr>
<td></td>
<td>Soybeans</td>
<td>29.7</td>
<td>24.6</td>
<td>24.7</td>
<td>40.0</td>
<td>32.9</td>
<td>32.1</td>
<td>30.4</td>
</tr>
<tr>
<td></td>
<td>Flax</td>
<td>59.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mean yield per acre</strong></td>
<td>Corn</td>
<td>41.6</td>
<td>67.8</td>
<td>63.1</td>
<td>47.1</td>
<td>39.7</td>
<td>39.7</td>
<td>45.4</td>
</tr>
<tr>
<td></td>
<td>Oats</td>
<td>35.1</td>
<td>43.7</td>
<td>36.2</td>
<td>27.4</td>
<td>22.3</td>
<td>35.4</td>
<td>27.5</td>
</tr>
<tr>
<td></td>
<td>Soybeans</td>
<td>17.5</td>
<td>22.0</td>
<td>19.9</td>
<td>13.8</td>
<td>13.4</td>
<td>14.5</td>
<td>14.5</td>
</tr>
<tr>
<td></td>
<td>Flax</td>
<td>9.0</td>
<td></td>
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- Units of measure are in bushels.
- Soybean data cover the period 1927-48.
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<td>Corn</td>
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<td>24.4</td>
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<td>34.1</td>
<td>22.8</td>
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<td>38.4</td>
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<td>37.1</td>
<td>61.3</td>
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<td>36.2</td>
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<td>CW</td>
<td>CC</td>
<td>TD</td>
<td>GHS</td>
<td>Sandy</td>
<td>Sh. Sey. Ed.</td>
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VARIABILITY OF CROP PRODUCTION IN SPECIFIC TOWNSHIPS
REPRESENTATIVE OF SOIL TYPES

Since crop yields are affected by fertility, permeability, depth, slope and other soil characteristics, farms located on the same soil associations will have similar yield variability. Rotations and cultivation procedures are also determined to a large extent by the soil types and slopes. Thus, differences in variability that might result from cropping practices are less on a particular soil association than for the state as a whole. The selection of 14 townships, each judged to be the representative of a specific soil association, was used to estimate variability of yields and incomes on particular soil types. The specific soil types are listed in tables 1 and 21. Analysis of the variability was then made in the same manner as for the 50-township sample.

YIELD VARIATION BETWEEN THE 14 TOWNSHIPS

If the soil experts' opinion, that each of the townships is representative of a specified soil association, is correct, the differences in yield, cost and income variability may be caused partly by weather and soil conditions at different locations. Measures of yield variability (mean square deviation, root mean square and coefficient of variation) are presented in table 19. The range of yield variability over the 14 townships is shown in table 20.

TABLE 20. RANGE OF CROP YIELD VARIABILITY OVER 14 SELECTED TOWNSHIPS.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Mean square deviation low</th>
<th>Mean square deviation av.</th>
<th>Mean square deviation high</th>
<th>Coefficient of variation low</th>
<th>Coefficient of variation av.</th>
<th>Coefficient of variation high</th>
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</thead>
<tbody>
<tr>
<td>Corn</td>
<td>60.2</td>
<td>169.7</td>
<td>162.9</td>
<td>7.8</td>
<td>23.4</td>
<td>23.0</td>
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<tr>
<td>Oats</td>
<td>45.4</td>
<td>78.4</td>
<td>153.3</td>
<td>6.7</td>
<td>27.2</td>
<td>39.6</td>
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<td>Soybeans</td>
<td>7.4</td>
<td>20.1</td>
<td>30.6</td>
<td>2.7</td>
<td>21.6</td>
<td>40.0</td>
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<tr>
<td>Wheat**</td>
<td>31.7</td>
<td>46.6</td>
<td>49.5</td>
<td>5.6</td>
<td>29.2</td>
<td>32.9</td>
</tr>
<tr>
<td>Flax***</td>
<td>6.1</td>
<td>13.4</td>
<td>29.0</td>
<td>2.6</td>
<td>38.8</td>
<td>52.5</td>
</tr>
</tbody>
</table>

* 13 townships reported soybeans.
** 2 townships reported wheat.
*** 4 townships reported flax.

TABLE 21. DIFFERENCES IN RELATIVE VARIABILITY OF CROP YIELDS ON DIFFERENT SOIL TYPES.

<table>
<thead>
<tr>
<th>No.</th>
<th>Township</th>
<th>Soils</th>
<th>Corn*</th>
<th>Oats*</th>
<th>Beans*</th>
<th>Wheat*</th>
<th>Flax*</th>
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<tbody>
<tr>
<td>1</td>
<td>Sheridan</td>
<td>Tama-Muscatine-Garwin</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Lincoln, P</td>
<td>Clarion-Webster-Nicollet</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Harrison, K</td>
<td>Clarion-Webster-Nicollet</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
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<tr>
<td>4</td>
<td>Harrison, B</td>
<td>Sandy loam</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
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<td>5</td>
<td>Grand Meadow</td>
<td>Tama-Downs</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
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<td>6</td>
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<td>River bottom soils</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Cedar</td>
<td>Grundy-Haig</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>Saratoga</td>
<td>Carrington-Clyde (plastic)</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
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<tr>
<td>9</td>
<td>Reading</td>
<td>Galva-Primagh-Sac</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
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<td>10</td>
<td>Lincoln, M</td>
<td>Marshall</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
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<tr>
<td>11</td>
<td>Logan</td>
<td>Moody</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>Jordan</td>
<td>Ida-Monona-Napler</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>13</td>
<td>Washington</td>
<td>Shelby-Seymour-Edina</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>14</td>
<td>Troy</td>
<td>Grundy-Haig-Shelby</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

* 1 represents a yield coefficient of variation under 20%.
2 represents a yield coefficient of variation of 20%-30%.
3 represents a yield coefficient of variation of over 30%.
Fig. 3. Fourteen townships on specified soil associations.

**PRINCIPAL SOIL ASSOCIATIONS**

**CW**: Clarion and Webster  
**CC**: Carrington and Clyde  
**CpC**: Carrington and Clyde, plastic till phase*  
**TM**: Tama and Muscatine  
**B**: Soils of Bottomlands  
**TD**: Tama and Dewns*  
**MT**: Mahaska* and Taintor*  
**CL**: Clinton and Lindley

**SSW**: Shelby, Sharpsburg* and Winterset*  
**P**: Fayette  
**PDS**: Fayette, Dubuque and Stony Land  
**GPS**: Galva*, Primghar* and Sac*  
**GH**: Grundy and Haig*  
**M**: Marshall*  
**Mo**: Moody*  
**MIH**: Monona*, Ida* and Hamburg*  

*New names not on county soil maps
The data in these tables indicate that variability of crop yields differs with location. Soils and weather evidently affect the yield variability of crops enough to necessitate measuring variability for each area separately where estimates of uncertainty are to be made for particular areas. The rank of the crops according to yield variability measured by mean square of deviations does not change greatly from township to township. Except for two townships, corn has the greatest yield variability followed by oats, wheat, soybeans and flax in order. The rank of crops with respect to relative variability varies throughout the townships, however. Obviously, where ranking crops in order of relative variability of yields is of primary interest, measures of relative variability for each soil area are important.

Table 21 shows a ranking of relative yield variability for the 14 townships. Crops have been ranked on each soil association as 1, 2 or 3, according to whether their coefficients of variation were less than 20 percent, 20–30 percent, or over 30 percent, respectively. The relative variability tends to be lowest in those areas having the highest mean yields; the three townships with least variable yields have the highest means. (The townships in the table are in order of least variable to most variable yields, and their locations on the soil map, fig. 3, are numbered to correspond to the township numbers used in table 21.) Soils with least variable crop yields (Tama-Muscatine-Garwin, Clarion-Webster-Nicollet, and the sandy loam soils of Harrison Township in Benton County) are level to rolling prairie soils of medium permeability located in areas of 28 to 32 inches of rainfall. Grundy-Haig soils form an exception in the case of soybeans, probably because the soybeans can be planted late in the season after spring rains have had a chance to dry up. Not all of the differences between yield variability on different soils should be attributed to soil types per se. Such factors as rainfall, hail and frost dates also affect variability. Thus Reading and Logan townships in the northwestern part of the state have less than 28 inches of rainfall, causing a part of the yield variability on Moody and Galva-Pringles-Sac soils especially when the rain does not come at just the right time. Jordan Township in Monona County (Ida-Monona-Napier soils) has quite a bit of land with steep slopes. Also drouth has struck the western and southern portions of the state hardest and most frequently. This phenomenon accounts for a great deal of the variability in these areas. Other soils with high relative variability are relatively impermeable; yields are reduced in wet years when standing water does not drain away.

There was some tendency for corn to be least variable on all soils, followed in order by oats and then soybeans. (Not enough of the townships raised the other crops continuously for classification purposes.)

**GROSS INCOME VARIABILITY IN THE 14 TOWNSHIPS**

There are greater differences in gross income variability (table 22) between the 14 townships representing soil types than between the five areas of the previous sample analyzed. The five areas within the sample of 50 townships were larger, hence not as uniform. More of the total variability is within and less between areas than in the areas represented by the 14 townships. Various gradations of each soil association as well as more soil types were included in the larger areas with a shading of one into another, while in each of the 14 townships only one distinct soil association was represented. There appear to be differences in the mean square deviation between areas
for all crops. The number of observations for wheat and flax (two townships raised wheat and four raised flax) was limited, and no great differences were apparent between the few townships growing these crops. The evidence of differences is sufficient, however, to warrant measures of variability for soil areas where the measures are to be used to make recommendations to farmers. The coefficients of variation in table 22 may be used to find the crop in each area with the least gross income variability and hence the least uncertainty. For example, in Sioux County, Reading Township, coefficients of variation indicate the crop with least variability of gross income per acre to be oats followed by soybeans, corn and flax in order.

VARIABILITY OF COSTS FOR CROPS IN THE 14 TOWNSHIPS

As before, in the process of arriving at net income variability, the costs of production are taken into account. Differences between soil areas with respect to cost variability are small. The slightly greater differences of cost variability between crops than between areas in table 23 is in line with the previous analysis of the 50-township sample.

Where one is interested in comparing the variability of costs between crops within a township, the coefficient of variation may be examined in table 23. For example, in Sioux County, Reading Township, the least variable (relative to the mean cost) crop is corn followed by oats, flax and soybeans. Similarly one may examine the indexes of variability in the other townships.

NET INCOME VARIABILITY FROM CROPS IN THE 14 TOWNSHIPS

It is possible for costs and gross incomes to be positively correlated to an extent causing a relatively constant net return from a crop. However, from table 24, which presents estimates of net income variability from crops in the 14 townships, it is obvious that this does not occur to any great extent. Not only is the income from particular crops variable, but considerable differences in variability exist between townships as well as between crops. Similarly, the dispersion of incomes relative to the mean differs from area to area. Table 25 illustrates differences between areas in relative income variability of crops. Townships are ordered according to their corn income variability, i.e., the township with the least variable corn returns heads the list. Corn not only has the least variability of income (relative) in all areas but also presents the smallest differences between areas. Those soil areas having greatest variability again lie in the western or southern part of the state. The higher variability of weather and hence yields in those areas contributes greatly to income variation.

In general the differences between soils in income variability of oats tend to follow the same pattern as for corn except that the range of differences is greater. Tama-Muscatine-Garwin and Clarion-Webster-Nicollet soils have least variability, while variable incomes result on western and southern soils, the areas most affected by drought. The relative variability of oats returns on the river bottom soils of Oakland Township is also high, not so much as the result of high absolute variability but because of a low mean income. Average oats yields, and, hence, incomes are low where land is often flooded or too wet in the spring.

Beans also follow the general pattern of being most variable with respect to income in western and southern Iowa and least variable on the Tama-Muscatine-Garwin and Clarion-Webster-Nicollet associations.
<table>
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<th>Measure</th>
<th>Crop</th>
<th>Reading Twp. Sioux County</th>
<th>Sheridan Twp. Scott County</th>
<th>Lincoln Twp. Polk County</th>
<th>Lincoln Twp. Montgomery County</th>
<th>Jordan Twp. Monona County</th>
<th>Logan Twp. Lyon County</th>
<th>Oakland Twp. Louisa County</th>
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<tbody>
<tr>
<td>Mean square deviation</td>
<td>Corn</td>
<td>451.1</td>
<td>797.4</td>
<td>495.4</td>
<td>374.4</td>
<td>276.9</td>
<td>402.5</td>
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<td>Oats</td>
<td>69.5</td>
<td>132.1</td>
<td>56.5</td>
<td>35.5</td>
<td>36.4</td>
<td>87.6</td>
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<td>52.5</td>
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### TABLE 23. VARIABILITY OF CROP COSTS IN 14 SELECTED TOWNSHIPS. 1917-48.*

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1917-48.

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<tr>
<td></td>
<td>GHS</td>
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<td></td>
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<tr>
<td></td>
<td>Sandy</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Sh. Sev. Ed.</td>
<td></td>
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</tr>
</tbody>
</table>
TABLE 25. DIFFERENCES IN NET INCOME VARIABILITY BETWEEN SOIL AREAS.

<table>
<thead>
<tr>
<th>Township</th>
<th>Soil area</th>
<th>Corn</th>
<th>Oats</th>
<th>Beans</th>
<th>Wheat</th>
<th>Flax</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grand Meadow</td>
<td>Tama-Downs</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Lincoln, P.</td>
<td>Clarion-Webster-Nicollet</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Harrison, B.</td>
<td>Sandy loam</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Sheridan</td>
<td>Tama-Muscatine-Garwin</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Cedar</td>
<td>Grundy-Haig</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Harrison, K.</td>
<td>Clarion-Webster-Nicollet</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Oakland</td>
<td>River-bottom</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Lincoln, M.</td>
<td>Marshall</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Saratoga</td>
<td>Carrington-Clyde</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Reading</td>
<td>Galva-Primghar-Sac</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Jordan</td>
<td>Ida-Monona-Napier</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Troy</td>
<td>Grundy-Haig-Shelby</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Logan</td>
<td>Moody</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Washington</td>
<td>Shelby-Seymour-Edina</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Code: Variability is indicated by numbers representing the coefficients of variation as listed below:

- 1 = less than 70%
- 2 = 70 - 90%
- 3 = 90 - 110%
- 4 = 110 - 130%
- 5 = 130 - 150%
- 6 = 150 - 170%
- 7 = 170 - 190%
- 8 = 190 - 210%
- 9 = 210 - 220%
- 10 = greater than 220%

Cedar Township with its Grundy-Haig soils might be considered an exception; it has least variable soybean returns, which is in line with its low variability of soybean yields. Yield variability also influences the returns from Oakland Township river bottom soils but in the direction of greater variability.

While differences in variability between areas are important from the viewpoint of directing research, making policy and selecting farms to buy, the operator of a particular farm is more interested in the difference in variability between crops within his own area. An examination of table 25 indicates that corn has least relative variability of income in all areas followed by soybeans and oats. However, most farmers will want to raise a combination of crops either to maximize level of income, to minimize variability or to attain some compromise of the two. Hence later sections take up the problem of diversification.
PART II.
DIVERSIFICATION AND CROP COMBINATIONS WHICH MINIMIZE INCOME VARIANCE

The second major portion of this study deals with the manner in which income variability can be lessened through diversification or selection of alternative crop combinations. More specifically, the analysis which follows attempts to set forth the nature of choices open to farmers in selecting or comparing level of income and variance of income. It illustrates the amount of variability which accompanies each level of income and predicts the amount by which income must be sacrificed for a given reduction in income variance through alternative combinations of crops. It also specifies the combination of crops for selected townships which will minimize income variability.

PROCEDURE AND DATA

The logic and data of the following pages represent an innovation of considerations relating to enterprise and crop selection. The empirical statistics presented have required a large amount of computation. Accordingly, the following procedures have been followed: First, the pure logic of diversification and minimizing income variance is set out in the next section. These details are included not only to provide the basic principles and methods used in this area of economic analysis but also to provide information which can be used as a guide to other scientists who wish to make further studies. Second, the numerical results presented are restricted to the 14-township sample mentioned earlier. This procedure was followed because computational costs precluded presentation of data for the entire sample of 50 townships. Hence the purposive or judgment sample was employed to illustrate the nature of variability for crop combinations on "typical" associations and types of soils.

DIVERSIFICATION AND CROP COMBINATIONS

Data of preceding sections have shown the degree of variability attached to single crops. Typically, however, crops are grown in combinations; income variability may be considerably less for combinations of crops than for crops grown singly. The analysis which follows serves to indicate the variance in income associated with different combinations of crops. Results have also been derived to show the possible choices which can be made between level of income and variability. From the data available, it is also possible to specify the crop combinations which will minimize income variance and to illustrate the gains or sacrifices in income which attend this condition.

FUNDAMENTAL PRINCIPLES OF DIVERSIFICATION

Diversification is one of the precautions which farmers can use in adjusting to an uncertainty situation. There are two different aspects of diversification. One is a problem of planning under perfect knowledge or certainty. The task here for an individual farmer who wishes to maximize profits is to equate the marginal rate of substitution between crop products with the price ratio of the products. The optimum degree of diversification or specialization is then dependent, to a large degree,
on the technical relationships between input and output yield ratios for each product and any technical conditions of complementary or supplementary rotation effects for the products when they are produced in combination. The other aspect of diversification is that of minimizing the variance of outcome or of attempting to put a floor under the level of income or in preventing the occurrence of undesirable outcomes. The farm manager, unable to predict price and yield outcomes, may wish to select a combination of enterprises which gives a steady year-to-year flow of income. He may also attempt to combine enterprises in a manner to minimize the probability that income will drop below levels required to meet family living expenses, farm costs and principal payments; or he may simply attempt to minimize the probability that his business will become bankrupt in any specified period. Although one aspect of diversification deals with minimizing variance of returns (or the probability of undesirable outcomes), the two are highly related. Minimization of income variance is a short-run production pattern which prevents bankruptcy; the farmer is able to "stay in the game" so that he has opportunity to maximize returns in the long run. Our interest in this study is in the latter aspect of diversification as a planning procedure to meet uncertainty.

**SYSTEMS OF DIVERSIFICATION**

Diversification can be accomplished by two quite different methods: (1) Resources can be increased. Under this system a farmer producing corn on 100 acres might diversify by adding another 100 acres and produce both corn and soybeans. (2) Resources can be held constant while part of them are shifted to other products: If the farmer has 100 acres and is producing corn, he can shift 50 acres to oats and produce both crops. The second system has a more widespread application since most farmers have limited capital because of their aversion to risk or because of other restrictions. Too, once the added resources have been taken on under the first system, the logic and principles are exactly the same as for the second system. Therefore, the discussion which follows refers mainly to diversification with given resources (acreage limited in this case).

Diversification may be employed as a method of handling two aspects of income variability. First, the operator may think in terms of the variability of income over his entire operating career. In this case, the number of years involved becomes a series of production periods for which he may wish to minimize income variability. Second, the operator may think in terms of possible large profits or possible large losses in a single year. In the latter case, he may attempt to organize his resources to minimize the chance of a large loss in that particular year. While similar, the two considerations are not identical and need not lead to the same course of action. A system of farming may allow low variability of income over the farmer's career, but it also may allow infrequent large losses. We shall discuss both cases, but first we consider diversification as an attempt to minimize income variability over the entire population of years in which the farmer operates. Here, since we are examining purely formal considerations, we shall use variance, defined as an expected value for our measure of variability.

Aside from the "sampling considerations" outlined below and considering that different income populations are represented by different enterprises, the first system of diversification outlined above, adding

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27 Farmers, of course, are not interested directly in the variance figure per se since its computational details are not directly related to the variability which they experience. See footnote 10, p. 630. Note that our symbols here all refer to unknown population quantities, e.g., $r = \frac{\text{variance}}{\text{variance}}$ with $\rho = E(\text{a} - \text{b}) (n-b)$. 
an enterprise through additional resources, can either increase or decrease income variance. When two enterprises, A and B, with income variances $\sigma_A^2$ and $\sigma_B^2$ respectively are combined, the variance for the total operation, $\sigma_T^2$, becomes $\sigma_T^2 = \sigma_A^2 + \sigma_B^2 + 2\rho\sigma_A\sigma_B$. This equation states that the variance for the combined operation is equal to $\sigma_A^2$, the variance for enterprise A, plus $\sigma_B^2$, the variance for enterprise B, plus twice the covariance which is defined as $\rho\sigma_A\sigma_B$ where $\rho$ is the correlation coefficient for the two enterprises and $\sigma_A$ and $\sigma_B$ represent the standard deviations (the square roots of the variances) for the income of each respective enterprise. Now if incomes from the two enterprises have a zero correlation coefficient ($\rho$ is zero) the equation becomes $\sigma_T^2 = \sigma_A^2 + \sigma_B^2$. Hence the addition of enterprise B to enterprise A will always increase variance (for the combined operation as compared to specialization in A alone) regardless of the relative variance for enterprise B. If $\rho$, the correlation coefficient, is $+1.0$ the equation becomes $\sigma_T^2 = \sigma_A^2 + \sigma_B^2 + 2\sigma_A\sigma_B$. The variance under the combined operation can now be less than for A alone; addition of enterprise B will reduce the total variance if the quantity $2\sigma_A\sigma_B$ is greater than $\sigma_B^2$, the variance for B alone. That is to say, total variance ($\sigma_T^2$) will remain unchanged if the ratio $2\rho\sigma_A\sigma_B/\sigma_B^2$ is equal to 1.0, decrease if it is greater than 1.0 and increase if it is less than 1.0. Since this ratio reduces to $2\rho\sigma_A/\sigma_B$, the quantity becomes $2\sigma_A/\sigma_B$ when $\rho$ is equal to $-1.0$ and total variance will be reduced as long as the standard deviation (the square root of the variance) for B is less than twice as great as the standard deviation of A. If $\rho$ is equal to $-0.5$, the term becomes $\sigma_A\sigma_B$ and total variance is reduced if the standard deviation of B is less than the standard deviation of A.

If $\sigma_A$ and $\sigma_B$ are equal, the total variance equation can be transformed to $\sigma_T^2 = \sigma_A^2 + \sigma_B^2 + 2\rho\sigma_A\sigma_A$ or to $\sigma_T^2 = 2\sigma_A^2 + 2\rho\sigma_A^2$. With equal standard deviation and a correlation coefficient of $-1.0$, diversification will reduce income variance to zero; if the correlation coefficient is $-0.25$ diversification (e.g., production of two crops in combination as compared to production of A alone) will increase income variance from $\sigma_A^2$ to an amount equal to $1.5\sigma_A^2$, or by 50 percent.

**DIVERSIFICATION WITH LIMITED RESOURCES**

The outcome can be quite different under the second method of diversification, diversion of part of the resources from one enterprise to another. Let us examine the case where the nature of returns to scale need not be considered. We have a given quantity X of resources which has been used for enterprise A. We now decide to use only one-half of this for A and to use the remainder for B. (A quantity of resources equal to .5X is now used for either enterprise while $\sigma_A^2$ and $\sigma_B^2$ are each based on X quantity of resources.) The equation for the total variance now becomes $\sigma_T^2 = .25\sigma_A^2 + .25\sigma_B^2 + \frac{\rho\sigma_A\sigma_B}{2}$

Total combined variance may now be decreased even if the variance of B, the added enterprise, is greater than the variance of A, the original enterprise. When $\rho$ (the correlation coefficient) is zero, the equation reduces to $\sigma_T^2 = .25\sigma_A^2 + .25\sigma_B^2$; total variance will be decreased if $.25\sigma_B^2$ is less than $.75\sigma_A^2$, the amount by which variance for enterprise A is reduced. In other words, total variance decreases if the ratio $.75\sigma_A^2/.25\sigma_B^2$ is greater than 1.0. Since the ratio reduces to $3\sigma_A^2/\sigma_B^2$, total variance will decrease as long as for enterprise B is not three times greater than the variance for enterprise A. When $\rho$ is $+1.0$ the equation reduces to $\sigma_T^2 = .25\sigma_A^2 + .25\sigma_B^2 + \frac{\rho\sigma_A\sigma_B}{2}$ and the combined
variance will be increased if the sum \( .25\sigma_A^2 + \frac{\sigma_A\sigma_B}{2} \) is greater than \( .75\sigma_A^2 \), the reduction in variance of A. When \( \rho \) is equal to \(-1.0\) the equation reduces to \( \sigma_T^2 = .25\sigma_A^2 + .25\sigma_B^2 - \frac{\sigma_A\sigma_B}{2} \) and diversification leads in the direction of a lowered variance; diversion of one-half the resources from A to B will increase variance only if \( .25\sigma_B^2 \) is greater than the sum, \( .75\sigma_A^2 + \frac{\sigma_A\sigma_B}{2} \).

Again, the realistic situation is that of a positive correlation coefficient. Positive correlation coefficients prevail generally over periods of any length for agricultural products. This situation holds true because the major variable in agricultural income is the exogenous, business cycle phenomenon, and major product swings are always in the same direction. Even over a period of any length, crop yields are also positively correlated. While the forces causing variations in livestock yields are less closely related to weather, the writers have been unable to find correlation coefficients that are less than zero. Accordingly, let us examine the situation wherein the correlation coefficient between income for two enterprises is positive and the variances for enterprises A and B are equal. With a correlation coefficient of +.6, the total variance under diversification then becomes \( \sigma_T^2 = .25\sigma_A^2 + .25\sigma_B^2 + .6\sigma_A\sigma_B \) or \( .8\sigma_A^2 \) and income variance is less than \( \sigma_A^2 \), that realized when the entire quantity of resources is devoted to enterprise A. If the correlation coefficient is +.3, variance under diversification is only \( .65\sigma_A^2 \). If the correlation coefficient is +1.0, the total variance is equal to \( .25\sigma_A^2 + .25\sigma_B^2 + 0.5\rho\sigma_A\sigma_B \) or \( \sigma_A^2 \); diversification, in this case of equal variances, gives the same total variance as production of either crop by itself.

**REDUCTION IN VARIANCE**

If we have knowledge of the variance for individual crop enterprises we can also make quantitative statements about the reduction in income variability as different combinations of crops are produced with given resources. Again suppose that we have a quantity of resources equal to \( X \) and that this amount can be divided between A and B in any manner we select. If \( \sigma_A^2 \) and \( \sigma_B^2 \) refer to the income variance of the two enterprises respectively when \( X \) quantity of resources is used for either, and if the proportion of the total resources used for A is denoted as \( q \), the total variance then can be denoted as below:

\[
\sigma_T^2 = q^2\sigma_A^2 + (1-q)^2\sigma_B^2 + 2\rho q(1-q)\sigma_A\sigma_B
\]

Total variance is now a function of \( q \), the proportion of resources allocated to either enterprise. We can compute the change in total variance as \( q \), the proportion of resources devoted to enterprise A, takes on different magnitudes. This change in total variance, \( d\sigma_T^2 \), can now be expressed as a derivative:

\[
\frac{d\sigma_T^2}{dq} = 2q\sigma_A^2 - 2(1-q)\sigma_B^2 + 2\rho(1-2q)\sigma_A\sigma_B
\]

We shall make use of this equation in a later section where we measure the reduction in variance associated with shifting different quantities of land between crops.
MINIMIZING THE PROBABILITY OF BANKRUPTCY

We now turn to diversification as a "safeguard" for a single year or two. The analysis above supposed that the operator was interested in minimizing the variance of income over some period, perhaps his operating career. Since unfavorable outcomes in a single year may bankrupt the operator with little capital or a low equity, he may diversify in order to increase the chance that high income as well as low income may be realized.

CROP PATTERNS WHICH MINIMIZE VARIANCE

From equation II, above, it is possible to specify crop patterns which minimize the absolute variability of income. This is accomplished by setting equation II equal to zero and solving for \( q \). Thus, a crop pattern is indicated which results in no change in total variability as an infinitesimally small amount of land is shifted between a pair of products. By setting equation II equal to zero, it is possible to derive equation III which specifies \( q \), the proportion of land which should be allocated to crop A if income variance is to be minimized. (The proportion \( 1-q \), the amount to be allocated to crop B, is determined simultaneously.)

\[
q = \frac{\sigma_A^2 - \rho \sigma_A \sigma_B}{\sigma_A^2 + \sigma_B^2 - 2 \rho \sigma_A \sigma_B} \tag{III}
\]

This equation will be used in later sections in specifying crop combinations which result in minimum variance for different soil types. By computing minimum variance, we can compare the level of income which accompanies this cropping pattern and therefore suggest whether the pattern of diversification or land use is desirable in terms of the sacrifice in returns which it necessitates.

RELATIVE VARIABILITY

While variance serves satisfactorily for many purposes as a measure of absolute income variability, the concept of relative variability likely is more useful in decision-making; some enterprise or crop combinations may give a low absolute variability, but income variation may be great relative to the level of income itself. For example, a crop such as oats may have a low variance of income but, since the level of income from oats is low, the absolute variability may be great relative to the size of the income itself. Therefore, to measure relative variability under diversification we can again employ a coefficient of variation which is defined below.

One step in computing a coefficient of relative variability is that of computing the standard deviation of income. Since the value of \( q \), which minimizes variance, is identical with that which minimizes the standard deviation, the details will not be outlined; the standard deviation of income under diversification is simply the square root of equation I. From this we can express the coefficient of variation in appropriate terms and examine the relative variability of income under different allocative patterns. For example, one combination of resources may give a low absolute variance but variability may be high relative to the level of income. Equation IV below defines the coefficient of variation, CV, in the conventional manner wherein the standard deviation is divided by the "mean" income. Here \( I_A \) and \( I_B \) refer to income from enterprises A and B, respectively, while \( I_T \) is the total farm income and \( \sigma_T \) is the standard deviation of farm income.

\[
\frac{\sigma_T}{I_T} = \sqrt{q \sigma_A^2 + (1-q) \sigma_B^2 + 2pq (1-q) \sigma_A \sigma_B} \frac{1}{q I_A + (1-q) I_B} \tag{IV}
\]
If we now use the square of the coefficient of variation as our measure of relative variability, we obtain equation V which can be manipulated with greater facility.

\[(CV)^2 = \frac{q^2 \sigma_A^2 + (1-q) \sigma_B^2 + 2 \rho q (1-q) \sigma_A \sigma_B}{(qI_A + (1-q)I_B)^2}\]

From this equation it is possible to derive VI below which specifies the marginal \((CV)^2\) and therefore indicates the change in level of relative variability for each change in \(q\), the proportion of resources allocated to enterprise A. This equation can be simplified and the right side equated to zero in order to specify the value of \(q\) which minimizes the square of the coefficient of variation and which also will minimize the magnitude of the coefficient of variation (the relative variability of income) as is illustrated in equation VII.

\[\frac{d(CV)^2}{dq} = (qI_A + (1-q)I_B) \left(2q \sigma_A^2 - 2(1-q) \sigma_B^2 + 2 \rho (1-2q) \sigma_A \sigma_B\right)\]

MAGNITUDE OF CORRELATION COEFFICIENT TO LESSEN VARIANCE

From previous equations we can specify, for certain conditions, the value of the correlation coefficient which will allow diversification to lower income variance. From equation I, the value of \(\rho\), the correlation coefficient, can be stated in the manner of VIII.

\[\rho = \frac{\sigma_A^2}{2q(1-q) \sigma_A \sigma_B} - \frac{q \sigma_A^2}{2(1-q) \sigma_B^2} - \frac{(1-q) \sigma_B^2}{2q \sigma_A^2}\]

For different values of variance for either product we can now state the magnitude of the correlation coefficient necessary before diversification will lessen variability for the farm as a whole. Let us suppose that the variances are equal for the two enterprises and therefore that \(\sigma_A^2 = \sigma_B^2\). Equation VIII then reduces to IX which can in turn be expressed in the manner of X. From the last, it is evident that total variance, \(\sigma_T^2\), will be reduced only if the right-hand side of the equation is less than 1.0 (i.e., the ratio \(\sigma_T^2/\sigma_A^2\) is less than 1.0); in other words the condition of equation XI must hold true. From equation XI, it is possible to derive XII indicating that, given equal variances for the two enterprises, variability will be reduced for any correlation coefficient less than 1.0.

\[\rho = \frac{\sigma_T^2}{2q(1-q) \sigma_A^2} - \frac{q}{2(1-q)} - \frac{1-q}{2q}\]

\[\sigma_T^2 = \left[\rho + \frac{q}{2(1-q)} + \frac{1-q}{2q}\right] \left[2q(1-q)\right]\]

Under the first system of diversification, doubling of resources and addition of a second enterprise, the value of \(\rho\) can be specified in the manner of XIII. If the variances for the two enterprises are equal, the equation in turn gives rise to equations XIV and XV and finally XVI and XVII stating that income variance for the total farm business will be reduced only if the correlation coefficient is less than 1.0.

\[2q \sigma_A^2 (1-q) + 1 - 2q(1-q) < 1.0\]

\[\rho < \frac{2q(1-q)}{2q(1-q)} \text{ or } 1.0\]
The value of \( \rho \) necessary to lower income variance can also be specified from equations VIII and XIII.

\[
\rho = \frac{\sigma_T^2 - \sigma_A^2 - \sigma_B^2}{2\sigma_A \sigma_B}
\]

(\text{Equation VIII})

\[
\rho = \frac{\sigma_T^2 - \sigma_A^2}{2\sigma_A^2} - 1
\]

(\text{Equation XIII})

\[
\frac{\sigma_T^2}{\sigma_A^2} = 2(\rho + 1)
\]

(\text{Equation XIV})

\[
2(\rho + 1) < 1.0
\]

(\text{Equation XV})

\[
\rho < -0.5
\]

(\text{Equation XVI})

Knowledge of variances and correlation coefficients also allows us to make statements about the effectiveness of numbers of enterprises in reducing income variance. While predictions can be made for variances and correlation coefficients of any magnitude, let us examine the possibilities of combining enterprises with equal variances where each pair has a correlation coefficient of .6. If \( \sigma_A^2 \) is the variance for one enterprise produced alone, then variance for two enterprises produced in combination will be \( .8\sigma_A^2 \) while (on the basis of calculations from a formula such as I above expanded to include covariance terms for each pair) it will be \( .72\sigma_A^2 \) for three enterprises and \( .70\sigma_A^2 \) for four enterprises. In other words, added enterprises reduce farm income variance by smaller and smaller amounts as equations XVII, XVIII and XIX show.

(2 crops \( \sigma_A^2 = \sigma_B^2 \); \( \sigma_T^2 = (.5)^2\sigma_A^2 + (.5)^2\sigma_B^2 + (2)(.6)(.5)\sigma_A\sigma_B = .8\sigma_A^2 \)

(3 crops \( \sigma_A^2 = \sigma_B^2 = \sigma_C^2 \); \( \sigma_T^2 = (.33)^2\sigma_A^2 + (.33)^2\sigma_B^2 + (.33)^2\sigma_C^2 + (2)(.6)(.33)\sigma_A\sigma_B + (2)(.6)(.33)\sigma_B\sigma_C + .72\sigma_A^2 \)

(4 crops \( \sigma_A^2 = \sigma_B^2 = \sigma_C^2 = \sigma_D^2 \); \( \sigma_T^2 = .25\sigma_A^2 + .25\sigma_B^2 + .25\sigma_C^2 + .25\sigma_D^2 + (2)(.6)(.25)\sigma_A\sigma_B + (2)(.6)(.25)\sigma_A\sigma_C + (2)(.6)(.25)\sigma_A\sigma_D + (2)(.6)(.25)\sigma_B\sigma_C + (2)(.6)(.25)\sigma_B\sigma_D + (2)(.6)(.25)\sigma_C\sigma_D = .70\sigma_A^2 \)

ANALYSIS OF VARIANCE AND INCOME FOR DIVERSIFIED CROPPING PATTERNS

The data presented previously and the logic of models outlined above can now be used to calculate the income variance for all possible combinations of any two crops with the land area given. Our estimates are in terms of 60 acres for each soil or location. Although an acreage of any magnitude could be used as a basis of deriving variance figures for diversified cropping patterns, we use this figure because it is easily reduced to fractions or multiples which apply to any farm. In addition to the variability statistics presented in an earlier section, serial correlation coefficients are needed for using the equations outlined above. The observed serial correlations for our data are presented in table 26 which follows and like those of the following tables, refer to net income excluding labor as a cash cost.

These observed serial correlation coefficients (table 26) are of interest in themselves. While major economic fluctuations and drouths tend to cause incomes of individual crops to move in the same direction, the serial correlation coefficients are surprisingly low for particular crop combinations and for particular locations. Correlation coefficients tend to be highest in all locations for corn paired with oats and other small
TABLE 26. CORRELATION COEFFICIENTS FOR NET INCOME BETWEEN PAIRS OF CROPS.*

<table>
<thead>
<tr>
<th>Crop combination</th>
<th>Troy</th>
<th>Grand M.</th>
<th>Stratocca</th>
<th>Harrison, K.</th>
<th>Cedar</th>
<th>Logan</th>
<th>Jordan</th>
<th>Lincoln, M.</th>
<th>Lincoln, P</th>
<th>Sheridan</th>
<th>Reading</th>
<th>Harrison, E</th>
<th>Oakland</th>
<th>Washington</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn-oats</td>
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* We have already pointed out in the section, "Methodological Problems in Measurement," that observed serial correlations such as we present here may be poor estimators of true serial correlations. In this section, however, we use these correlations to illustrate the application of the various results just derived for combinations of enterprises.

** Data are for the full 32 years except for the pairs including soybeans. These generally include only the most recent 22 years.

grains; they tend to be relatively high between hay and grains. They generally are lowest for hay and flax paired with grain crops. Similarly, the coefficients are lowest for most crops in those townships located in southern Iowa and other locations with variable weather and reoccurring pests such as grasshoppers.

Although these observed correlation coefficients do not alone specify optimum diversification pairs (variances must also be known for individual crops), they do suggest some optimum pairs. Since all of the coefficients are positive, it is apparent immediately that from the criterion of minimizing income variance alone, wheat and hay make a better pair for diversification in Jordan Township, Monona County than do corn and oats; wheat and flax represent a better diversification pair than corn and flax in Harrison Township, Kossuth County. Similarly, diversification through use of almost any pair indicated will reduce income variance to a greater extent in Troy Township, Clarke County than in Harrison Township, Kossuth County. Since correlation coefficients are lower at the former location, diversification is a more effective means of reducing variability than at the latter location. Similar comparisons can be made between other soils and locations.

VARIABILITY UNDER DIVERSIFICATION

We now combine the data from table 26 with the variability measures from a previous section to estimate income variability under
various patterns of diversification. Variance, standard deviation and coefficient of variation figures are presented along with income data in tables 27-40 inclusive. The value of \( q \) indicates the proportion of 60 acres devoted to the first-mentioned crop of each pair; a \( q \) value of .6 for corn-oats refers to 36 acres in corn and 14 acres in oats.

These data indicate (tables 27-40) that absolute variability declines throughout as land is shifted from corn to oats for all soil types and locations studied. In Troy Township, the crop pairs corn-hay, soybeans-hay, oats-hay, and corn-soybeans-hay never allow minimum variance with resources devoted to one of the crops alone. Only a small amount of soybeans is required in combination with corn to minimize income variability; hay and soybeans are mainly the “stability crops” at this location. In Grand Meadow Township, minimum variance for the crop pairs hay-soybeans, soybeans-oats and hay-oats comes with some combination of the two; corn always increases variance as compared to soybeans, oats and hay.

Diversification reduces variance in Harrison Township, Kossuth County for the crop pairs corn-flax, hay-oats, hay-soybeans, hay-flax and flax-soybeans; only a small acreage of hay is required to minimize variance in the hay-soybean pair, and a greater acreage of beans adds only slightly to income but adds a large amount to variance. As in the case of all other townships, corn grown alone has a much greater variance than most other crops but also has a much higher level of income as an average over the period of years. Only the pairs soybeans-hay and hay-oats result in a smaller variance when grown alone in Cedar Township. In contrast to the Kossuth County soils and location, addition of soybeans at the expense of hay (beyond the point of minimum income variance) augments income relatively more for each addition to variance. Four crop pairs in Logan Township give a lower variance under some pattern of diversification than for single crops. Only flax added to corn minimizes variance with some acreage devoted to both crops; absolute variance is less for any other crop pair when single crops are selected over corn. Hay-wheat, corn-wheat and corn-hay are pairs which cause income variance to be less under some pattern of diversification than under specialties alone in Jordan Township. In contrast, all crop pairs except corn-oats have a lower variance under some combination than under specialization on Marshall soils of Lincoln Township, Montgomery County; lower rainfall, more frequent attacks from grasshoppers and other pests cause this to be true.

Two out of five crops have minimum variance under diversification on Clarion-Webster soils in Polk County. Weather is less variable from short growing seasons here as compared to the same soils in Kossuth County. In Sheridan Township of Scott County, the more stable rainfall causes all crops except hay to give a lower variance if they are grown alone rather than in combination with corn. Greater variability in climate for Sioux County causes diversification to be more important in lessening variance for crop pairs in Reading Township. It is interesting to note that a large gain in stability (reduction in variance) can be attained in company with a small gain in income by shifting completely from flax to soybeans. At the Benton County location, a cropping pattern including 20 percent beans and 80 percent hay gives a lower variance than if either crop is grown alone; for soybeans-oats,

Note that the mathematical results just obtained for a combination of enterprises are based on knowledge of certain parameters, variances and serial correlations. Here we use our observed measures to illustrate the empirical consequences of various enterprise combinations. Since our mathematical results are in terms of the parameters, we refer from here on to our observed measures by the same names although the reader should be aware of the methodological problems in this transition.
TABLE 27. LEVEL OF INCOME, VARIANCE, STANDARD DEVIATION AND COEFFICIENT OF VARIATION.
SHELBY-GRUNDY-HAIG SOILS, TROY TOWNSHIP, CLARKE COUNTY.*

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* Variance in thousands. The value of q refers to the proportion of 60 acres devoted to the first mentioned crop of each pair.
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* Variance in thousands. The value of q refers to the proportion of 60 acres devoted to the first mentioned crop of each pair.
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### TABLE 31. LEVEL OF INCOME, VARIANCE, STANDARD DEVIATION AND COEFFICIENT OF VARIATION.

**GRUNDY-HAIG SOILS, CEDAR TOWNSHIP, LEE COUNTY.***

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* Variance in thousands. The value of $q$ refers to the proportion of 60 acres devoted to the first mentioned crop of each pair.
TABLE 32. LEVEL OF INCOME, VARIANCE, STANDARD DEVIATION AND COEFFICIENT OF VARIATION.  
MOODY SOILS, LOGAN TOWNSHIP, LYON COUNTY.*

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* Variance in thousands. The value of q refers to the proportion of 60 acres devoted to the first mentioned crop of each pair.
TABLE 36. LEVEL OF INCOME, VARIANCE, STANDARD DEVIATION AND COEFFICIENT OF VARIATION.
TAMA-MUSCATINE-GARWIN SOILS, SHERIDAN TOWNSHIP, SCOTT COUNTY.

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- Variance in thousands. The value of \( q \) refers to the proportion of 60 acres devoted to the first mentioned crop of each pair.
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### Table 38: Level of Income, Variance, Standard Deviation and Coefficient of Variation.

#### Sandy Loam Soils, Harrison Township, Benton County.

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* Variance in thousands. The value of \( q \) refers to the proportion of 60 acres devoted to the first mentioned crop of each pair.
TABLE 39. LEVEL OF INCOME, VARIANCE, STANDARD DEVIATION AND COEFFICIENT OF VARIATION.
RIVER-BOTTOM SOILS, OAKLAND TOWNSHIP, LOUISA COUNTY.*

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* Variance in thousands. The value of \( q \) refers to the proportion of 60 acres devoted to the first mentioned crop of each pair.
TABLE 40. LEVEL OF INCOME, VARIANCE, STANDARD DEVIATION AND COEFFICIENT OF VARIATION.
SHELBY-SEYMOUR-EDINA SOILS, WASHINGTON TOWNSHIP, APPANOOSE COUNTY.

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<th>Standard deviation</th>
<th>Coefficient of variation</th>
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<th>Variance</th>
<th>Standard deviation</th>
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* Variance in thousands. The value of \( q \) refers to the proportion of 60 acres devoted to the first mentioned crop of each pair.
the proportions are 50-50. In Oakland Township of Louisa County, another stable rainfall area, 90 percent of the land in hay and 10 percent in soybeans results in a minimum variance. In Washington Township, Appanoose County, four out of six crops can be combined to reduce income variance. As in all other townships, corn grown alone not only has a large variance but also has a higher level of income than other crops.

Since crops are normally grown in combination, the data of the previous tables are important in illustrating the nature of income variability when crops can be combined in various proportions. Diversification or enterprise combination is the chief policy which the farmer can initiate on his own farm to increase stability of income. While this study deals only with primary crop production, a wide range of opportunities exists for reducing variability through diversified production patterns which include livestock. Most livestock enterprises, while subject to the same major price forces, involve less output or yield variability than Iowa crops. (A subsequent publication dealing with livestock income and variance will illustrate the nature of these relationships.) The effect of crop diversification at the various locations is illustrated clearly in the data, however. With few exceptions, crop combinations reduce variance below that for the crop of the pair with the greatest variance when grown alone.

PARTICULAR COMBINATIONS AND LOCATIONS

Oats and hay have the effect of reducing variance for many crops on the various soil associations. They are effective in this sense because of their low absolute variance. The low absolute variance for oats grows out of the fact that income for the crop is low; deviations of 10 percent in yield have much less effect in the total variance component than a similar percentage variation in yield or price for a higher return crop such as corn or soybeans. While addition of oats to a combination is highly effective in reducing income variance, the reduction comes with a relatively high sacrifice in income.

Other interesting and useful interpretations of income variance under diversification also can be made. On Shelby-Grundy-Haig soils in Troy Township, Clarke County, soybeans added to corn have the effect of reducing variance within a limited range. As table 27 shows, variance declines until .8 of the acreage is devoted to corn and .2 is devoted to beans; addition of more beans at the expense of corn acreage has the effect of increasing variance. With .6 of the acreage in corn and .4 in beans, variance is approximately as great as it is with the entire acreage devoted to corn. With the entire acreage devoted to beans, variance is approximately 13 percent greater than for corn alone. In contrast, on Carrington-Clyde soils of Saratoga Township, Clarke County, variance declines as acreage is shifted to beans until all of the land is in beans. Similar contrasts exist between beans and corn in other townships. It should be pointed out, however, that soybeans do not have the universal effect of adding stability to income, a belief held by many people. The soybean is one of the best crops for diversification on many soils of Iowa, however. With the exceptions which can be noted in the tables, some acreage of soybeans has the effect of reducing income variance without reducing income itself to the levels brought about by hay or oats as diversification crops.

When combined with corn, hay also serves to reduce income variance for numerous locations. In contrast to oats, however, minimum variance is not so often attained when the entire acreage is devoted to hay. In Troy Township, Clarke County, income variance declines until 20 percent of a given acreage is in corn and 80 percent is in hay; in Saratoga Township of Howard County the parallel figures are 30
percent in corn and 70 percent in hay, while the figures are 11 and 99 for Jordan Township of Monona County. Like oats, hay is not a good crop for reducing income variance in many counties because the level of income itself is low. There are, however, exceptions such as Appanoose Township in Washington County.

Oats and hay can be combined to effectively reduce income variability; variance of income is less under some combination of the two than for either alone on 60 acres. Because the income of both is low, however, neither crop is highly desirable from the standpoint of diversification. Oats will continue to be grown on most Iowa farms over the range in which they serve as a supplementary and complementary crop in aiding the catch of seedings and the production of hay. Hay should be grown on most soils through the range in which it is complementary to corn and allows a greater production from the same acreage through its ability to control erosion and where it adds organic matter and nitrogen to the soil at a lower cost than other sources. On some soils hay does substitute at a rate high enough to allow it to partially replace corn and soybeans in the competitive range.
of crops.\textsuperscript{29} In Troy Township of Clarke County, income declines until 60 percent of the given land acreage is in oats and 40 percent is in hay. For Saratoga Township, Howard County, the figures are 70 percent and 30 percent, respectively; they are 95 and 59 for Appanoose Township, Washington County.

Since returns from flax are highly variable, the addition of most crops with flax results in a reduction of income variance. In the Carrington-Clyde soils of Saratoga Township, Howard County, the crop pair which includes flax and soybeans results in reduction of variance.

income as compared to other crops. This choice is an important one to farmers. Each operator is individually faced with making the optimum choice between alternative (and likely competing) goals of income maximization and variability reduction.

He often must select level of income at the expense of stability of income and vice versa; in some instances the two go hand in hand. The extent to which the operator should select the possibility of higher income while sacrificing possible stability of income or, conversely, select greater stability at a sacrifice in income depends on many factors including his own preference or dislike for risk, his capital and equity position, the scale of his operations and his family responsibilities. A young farmer possessing little capital and a low equity particularly may prefer stability to magnitude of income. He may feel fairly certain in his own mind that an enterprise combination which has low income variability will give smaller returns than one with greater variability. Yet his choice is entirely rational in the
sense that the great variability under the high income system may cause him to go bankrupt in a year of great losses. On the other hand, an established operator with large capital and equity may select the "prospectively high" return enterprise even if the probability is great for large losses in single years. His capital position makes possible business survival over one or a few years of loss and the capture of extremely high, offsetting profits in other years. While low income variability is a short-run goal of many farmers, it also is a means to greater or maximum profits in the long run; by selecting "more dependable" crop or livestock combinations during his beginning and low-capital phases of farming, the younger operator may then build his equity to a level where continuance of operation is secured and invest-
Fig. 8. Production possibilities showing relationship between level of income and variance of income: Grundy and Haig soils; Cedar Township, Lee County.

Fig. 9. Production possibilities showing relationship between level of income and variance of income: Moody and associated soils; Logan Township, Logan County.

ment can be made in these enterprises which average high returns over time but are also accompanied with great variability of income.

However, efficient choices between competing goals of higher income or greater stability can be made by few farmers unless they know the nature of the production possibilities involved, i.e., the amount of variability that attaches to each level of income and vice versa. In order to provide a better picture of these possibilities figs. 4-17 inclusive have been constructed from columns 2 and 3 for each crop combination in tables 27-40. The possibility curves of these figures show the relationship of level of income and variance of income.
Fig. 10. Production possibilities showing relationship between level of income and variance of income; Ida, Monona and Napier soils; Jordan Township, Monona County.

These figures give a vivid illustration of alternative choices between level of income and stability of income. If we use magnitude of income variance to reflect income stability (the lower the variance, the greater is the stability, while the higher the variance, the lower the stability), then it can be said that the possibilities indicated include both competitive and complementary ranges in choice. By complementary we mean income can be increased at the same time stability of income is increased (i.e., income variance is lessened); by competitive we mean choice of either level of income or stability of income must be made at the expense of the other. These distinctions are illustrated respectively by the negative and positive sloped portions of the curve in the figures. For example, in fig. 4 for the Shelby-Grundy-Haig soil situation, corn and oats involve competition alone between level and stability of income since the curve is positively sloped only. A cropping system representing corn alone is represented by the uppermost point of the curve while a cropping system representing oats alone is represented by the lowermost point. Starting with oats alone (the lowest point on the curve), points higher and higher on the curve...
Fig. 11. Production possibilities showing relationship between level of income and variance of income; Marshall and associated soils; Lincoln Township, Montgomery County.

are attained through a greater shift in the use of capital, land and labor resources from oats to corn until corn alone is represented (the highest point on the curve). Similar statements apply to other curves. The highest or end point of each curve represents a use of resources where only the first-mentioned crop of each pair is grown; the lower point represents production of the second-mentioned crop. Other points on the curve represent combinations of the two crops; the value of \( q \), the proportion of resources devoted to either crop, can be determined from tables 27-40 for any point on the curve since these "possibility curves"
are graphed from the income and variance columns of the table.

For corn and soybeans on the Shelby-Grundy-Haig soil situation for fig. 4, the range of complementarity is great starting from soybeans alone and moving to more corn; the curve has a long negatively-sloped portion indicating that a shift of resources from beans to corn has the effect of both increasing income and increasing stability (reducing variance). Eventually, however, the curve takes on a positive slope denoting that if greater income is selected as the paramount goal, it can be attained only at a sacrifice in stability (i.e., through an increase in variance of income).

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Fig. 12. Production possibilities showing relationship between level of income and variance of income; Clarion, Nicollet and Webster soils; Lincoln Township, Polk County.

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Fig. 13. Production possibilities showing relationship between level of income and variance of income; Tama, Muscatine and Garwin soils; Sheridan Township, Scott County.
Or starting from corn alone, shifting some acreage to beans results in a reduction in variance (an increase in stability of income). The choice to be made between level of income and stability of income, again, is one which the individual farmer alone can make and the decision should turn on his capital position, his like or dislike for risk and his family position. However, he has no reason to shift further from corn to beans over the negatively-sloped or complementary range of the curve; the shift not only lowers the level of income but re-

Fig. 14. Production possibilities showing relationship between level of income and variance of income; Galva and Primghar soils; Reading Township, Sioux County.

Fig. 15. Production possibilities showing relationship between level of income and variance of income; sandy loam soils; Harrison Township, Benton County.
Fig. 16. Production possibilities showing relationship between level of income and variance of income; river bottom soils; Oakland Township, Louisa County.

...duces stability of income. Other crop pairs for the Clarke County situation which include complementarity as well as competition in choice are soybeans-hay, corn-hay and oats-hay; the complementary range of the curve is relatively long for oats-hay, and while all combinations of the two crops result in a low absolute variance, income is also low as is denoted by the position of the oats-hay curve in the graph.


Fig. 17. Production possibilities showing relationship between level of income and variance of income; Seymour, Edina and Shelby soils; Washington Township, Appanoose County.
<table>
<thead>
<tr>
<th>Value</th>
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Soybeans and Oats

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<th>Cedar</th>
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Wheat and Hay

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*The value of \( q \) refers to the proportion of resources devoted to the first mentioned crop of each pair. Variance figures are in thousands.
and hay-oats. Washington: corn-soybeans, corn-hay, soybeans-hay, and hay-oats. In Saratoga Township, Howard County, soybeans with corn present competitive choices throughout, and the farmer is faced entirely with the question of whether to grow more corn and increase income or to grow more soybeans and increase stability of income. The complementary range between corn and hay is short in this township, while it is quite long for corn and flax and hay and flax. Similar relationships can be noted for other soils and locations although the details are not discussed in the text. Oats with corn presents competitive relationships in all townships with the question always being one of selecting between absolute variance and income.

The data of previous tables and the nature of the curves presented include characteristics which are worthy of further analysis. These points are brought out more vividly in the data of table 41 which indicate the rate of change in variance which accompanies each unit change in $q$, the proportion of resources allocated to one of a pair of crops. The data have been derived by equation II of a previous section. In economics, this quantity or amount of change can be termed the marginal variance. As the data show, each successive unit-increase in $q$ for the corn-oats combinations results in a greater and greater addition to variance. Starting from a $q$ of .1 (10 percent of the entire acreage devoted to oats) for Lincoln Township, Montgomery County, a unit change in $q$ causes variance to be increased by 289,000; at a $q$ of .2, 400,000 is added to total variance, while at .3, 512,000 is added. In this case, as was mentioned earlier, each successive increase in income is accompanied by a greater addition to variance than in the previous instance.

Where income is complementary with stability, each increase in $q$, starting from zero, results in a decrease in total variance (the sign of the marginal quantity is negative). However, a point is eventually reached where further increases in $q$ are accompanied by a more-than-proportional increase in variance and the variance figure becomes positive.

**VALUE OF $q$ FOR MINIMUM VARIANCE**

The analysis above leads directly to specification of the crop combinations, the values of $q$, which result in a minimum variability of income. These values of $q$ are computed from equation III above and presented in table 42. The average income over time for this crop combination which minimizes income variance is given in the lower one-half of the table.

For combinations including corn and oats, variance is at a minimum when $q$ is zero, i.e., with the entire acreage allowed to oats except for Lincoln Township, Montgomery County: 20 percent of given resources devoted to corn and 80 percent devoted to oats minimizes variance for this location. As suggested previously, variance is at a minimum with the full acreage allotted to oats because the level of income for this crop is low and even large percentage fluctuations in income add a small amount to absolute variance as compared to corn. As the income figures show, extreme sacrifices in income would be necessary if corn-oats combinations which minimize variance of income were employed. Income per acre of oats is only $.12 at the Monona County location which includes Ida-Monona soils. While it is $11.44 at the Scott County location including Tama-Muscatine soils, it is less than one-third the $38.44 net income for corn, as a mean of the period. For these reasons, few farmers are likely to choose corn-oats combinations which minimize variance of income. Other crops are better adapted to this choice pattern. Consequently the major acreage of oats grown in Iowa,
### TABLE 42. VALUE OF $q$ OR CROP COMBINATION AND LAND USE PATTERN TO MINIMIZE VARIANCE OF INCOME.*

<table>
<thead>
<tr>
<th>Crop pair</th>
<th>Troy</th>
<th>Grand M</th>
<th>Saratoga</th>
<th>Harrison, K</th>
<th>Adair</th>
<th>Logan</th>
<th>Jordan</th>
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Level of income when $q$ is at level to minimize income variance (dollars)

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</table>

* $q$ refers to the portion of 60 acres devoted to the first mentioned crop of each pair while the portion devoted to the second crop is $1 - q$. 


whether with high or low returns, will be grown for rotational purposes and not because of their contribution to income and income stability.\textsuperscript{30} Except for a soybean-oats combination where most townships have a minimum variance with a zero bean acreage, the pattern is quite different for other crop pairs. In Saratoga Township, Howard County, \( q \) is at a minimum for corn-flax when a .4 portion of the land is devoted to corn; income is \$645 for this combination but does not compare favorably to the \$1975 for 60 acres of corn alone. In Grand Meadow Township, Clayton County, the value of \( q \) denoting minimum income variance for the soybeans-hay pair is .5 and the corresponding income of \$674 is only slightly less than for the \$719 for 60 acres of beans and slightly more than the \$629 for 60 acres of hay. Pairs such as this serve optimally from the single standpoint of minimizing income variability; variance reduction can be obtained with little sacrifice in net income for the particular pair. Important income sacrifices are necessary, however, if the comparison is between corn and such crops as wheat or flax. While the variance of 60 acres of corn grown alone on this township of Galva-Priminghar-Sac soils is 1,400 thousand, income from 60 acres of corn averaged \$1144 over the 32-year period.

The minimum value of \( q \) in table 42 corresponds to the vertical or “turning point” on curves such as those presented in figs. 4-17; the rate of change in the curve is zero at the point where the curve “turns” and thus denotes a marginal variance of zero. In combinations where competition alone exists, as in the case of corn-oats in Troy Township of fig. 4, variance is always minimum at the lowest point on the curve. The allocative or cropping pattern which results in minimum variance differs between soils for similar crop pairs. For example, as is evident in table 42, income variance is at a minimum for corn and soybeans in Troy Township, Clarke County with 80 percent of the land devoted to soybeans; in Saratoga Township, Howard County, the proportions are .96 and .04 percent, respectively, while in Lincoln Township, Montgomery County, they are .3 and 0.1 percent. For soybeans-hay in Saratoga Township and Cedar Township, they are 70 and 30 percent and 20 and 80 percent, respectively. In other words, soybeans are a crop with more stable yields and income in Howard County than in Lee County and if the farmer goal were alone one of minimizing income variance, altogether different proportions of soybeans and hay would be grown in the two areas. In Troy Township, Clarke County the minimum variance is denoted for oats-soybean combinations with a \( q \) value of .141 for oats while it is .682 in Saratoga Township. Hay yields are enough more stable than corn yields in Clarke County that only 13.7 percent of the land devoted to corn for corn-hay combinations will minimize variance; with corn yields relatively more stable as compared to hay in Howard County, 27.3 percent can be devoted to corn for minimum variance.

**RELATIVE VARIABILITY OF INCOME**

Farmers perhaps are more interested in the relative variability of income than in absolute variance. The reason for this interest has been explained partially in a previous section: A crop such as oats can be employed in the cropping system to reduce income variance but it also reduces income as compared with almost any other crop. Since both income and absolute variance are low for such crops as these, the possibility that the relative variability of income (magnitude of variance relative to magnitude of income) is still great. This is the case with crops such as oats, and for the townships and soils represented

\textsuperscript{30} For details on this aspect of rotation economics, see Heady and Jensen. op. cit.
in tables 27-40, relative variability of income as expressed by the coefficient of variation is less for corn grown alone than for oats grown alone. In other words when the choice is between level of income and relative variability of income, all combinations of corn and oats, for the soil situations and locations studied, result in an increase in relative stability of income and an increase in level of income as resources are shifted from oats to corn.

These statements are illustrated in figs. 18-31 where income is indicated on the vertical axis and the coefficient of variation in percent (as an index of relative variability computed by dividing the standard deviation by the income) is indicated on the horizontal axis. In this case, the choices between income and relative variability which denote competition (one must be selected at the expense of the other) are represented by the negatively-sloped portion of the curves while complementarity (both level of income and relative variability of income are increased or decreased at the same time) is denoted by the positively-sloped portion of the curves. In fig. 18, for example, choices involving cropping patterns which include corn and oats involve only complementarity; as resources are shifted from oats to corn, both level of income and relative stability of income are increased (i.e., the coefficient of variation declines as resources are shifted from oats to corn as income is increased). On the other hand, a shift of resources from corn to oats results in a reduction of both level of income and relative stability (income decreases and the coefficient of variation increases). Accordingly, the farmer interested in relative stability of income as

As in the case of figs. 4-17, the uppermost point on each curve in figs. 18-31 represent production alone of the first-mentioned crop in each pair while the lowest point represents production alone of the second-mentioned crop. In-between points on the curves represent proportions of the crops denoted by the value of \( q \) for the crop pairs indicated in tables 27-40. The curves in figs. 18-31 have been drawn from the second and fifth columns for each crop pair indicated in tables 27-40.
Fig. 19. Production possibilities showing relationship between level of income and relative variability of income; Tama, Down and Muscatine soils; Grand Meadow Township, Clayton County.

well as level of income would be acting irrationally if he did not shift from oats or any combination of oats and corn to corn alone over the range in which the two crops serve as competitors in respect to total output. He would sacrifice in both level of income and relative stability of income if he shifted from corn to any combination of corn and oats. These statements apply equally to all townships since corn and oats provide sets of complementary choices alone for all of the townships studied (figs. 17-31, inclusive).

Crop pairs which display complementarity between income and variance of income do not always display complementarity between income and relative variability of income. In Troy Township, Clarke County, corn and soybeans have a short range of complementarity between income and stability when the latter is expressed in variance. (See fig. 4.) However, the two crops are competitive alone when choice is between level of income and relative stability of income as reflected by the coefficient of variation. (See fig. 18.) In fig. 18, a shift from corn to soybeans results in a decrease in income and an increase in relative variability, starting from the highest point on the curve, which refers to corn alone, and ending with the lowest point on the curve, which refers to soybeans alone. In other words, the corn-soybean curve in fig. 4 has both a positive and negative sloped portion while the curve of 18 has only a negative slope. Similar differences also exist for other crops and other soil situations.

Where crop combinations include both competitive and complementary ranges, the value of \( q \) (the portion of resources devoted to either one of two crops) which minimizes relative variability of income also differs from the value of \( q \) which minimizes variance of income.

By the competitive range we refer to combinations of the two crops where an increase in total output of one necessitates a decrease in total output of the other. This statement does not refer to possible combinations of the two crops where they are supplementary in the use of resources and an increase in one does not reduce total output of the other or where they are complementary and an increase in total output of one also increases the total output of the other. Indirectly, oats may serve as a complement to corn as they are used with legumes to increase forage stands and thus add nitrogen and organic matter to the soil.
These contrasts are evident through comparisons of the curves in figs. 18-31 with those of 4-17; in both cases the “turning point” on the curves (i.e., the vertical point separating negative from positive slope) is defined by the cropping pattern which minimizes variability of income. In fig. 4, the variance of the corn-hay combinations for Troy Township is at a minimum when income is approximately $350; in fig. 18, the coefficient of variation is at a minimum when income is approximately $630. In terms of acreage combinations (see table 27), variance for corn-hay is at a minimum in the same township with 20 percent of the land in corn while relative variability is at a minimum with 70 percent of the land in corn. In comparing figs. 20 and 6, we see that for Saratoga Township, income variance is at a minimum for corn-soybeans when income is at a level of $371, but relative variability is at a minimum when income is at a level of $684; in table 29, minimum variance is realized with zero portion of resources devoted to corn while relative variability is minimized with 60 percent of the resources devoted to corn. In the case of corn and flax at this same location, the acreage pattern which minimizes variance does not differ so greatly from the one which minimizes relative variability of income. Similar comparisons and contrasts can be made for other crop pairs and other soil types or locations.

The production possibility curves expressing alternative choices between level of income and stability of income (as measured by relative variability) present some contrasts with the previous curves expressed in terms of variances. In Troy Township, oats and hay have a long range of complementarity; as resources are shifted from oats (the bottom point of the curve) to hay, large reductions can be made in relative variability while a small gain can be made in income. However, as the “turning point” of the curve denoting a minimum coefficient of variation is attained, further shifts in resource use allow only slight gains in level of income as a large addition is made in relative variability.

The exact values of $q$ (the proportion of acreage devoted to specified crops) to minimize the coefficient of variation have not been computed in the manner of table 42 for income variance. However, a rough indication of the cropping pattern which gives a minimum coefficient of variation can be obtained for each crop pair in tables 27-39.
Fig. 21. Production possibilities showing relationship between level of income and relative variability of income; Clarion, Nicollet and Webster soils; Harrison Township, Kossuth County.

hay-flax, hay-soybeans, soybeans-oats, hay-flax, hay-soybeans and corn-soybeans are pairs with lower coefficients of variation when grown in combination than when grown alone, i.e., the curves always have a positive slope as well as a negative slope. Statements similar to those above can be made about the Clarion-Webster soil location in Kossuth County. Too, a cropping pattern including soybeans alone results in a much greater coefficient of variation and only slightly more income than an allocative pattern including mainly hay and a small amount of soybeans. In Cedar Township of Lee County, only the three pairs corn-hay, soybeans-hay and hay-oats have ranges in which it is possible both to increase income and to reduce the relative variability of income by shifting to a combination of the crops (in contrast to producing the low-income choice alone). In Logan Township as an average over time, returns and relative variability have been low for flax and the flax-hay curve has both a positive and a negative slope.

In Jordan Township of Monona County, wheat income has been relatively high compared with corn income, and a combination of the two crops allows a lower relative variability than if each is grown alone. Also, hay and wheat fit well together from the standpoint of relative variability. The fact that the three curves corn-hay, corn-wheat and wheat-hay are curved indicating a gain in stability through diversification while all three give relatively high incomes suggests that
the three can be fashioned into a profitable rotation for the soil studied. The choices open to farmers in respect to level of income and relative variability of income are similar in the Marshall soils of Montgomery County to those of other locations; starting with a low-income crop such as oats, level of income and relative variability of income both can be increased by shifting to any other one of the crops mentioned. (This fact can be denoted by the negative sloping curves in all cases.) Starting from hay alone, income can be increased and the coefficient of variation reduced by shifting some resources to soybeans; at some point, however, the choice must include a higher level of income at the expense of relative stability of income. (The curve "bends" and takes on a positive slope.) The same statement applies to the hay-wheat pair. The curves for the remaining townships can be interpreted similarly. In most cases corn gives relatively high income and relatively great stability in income. In many cases, greater income can always be obtained at the same time as greater stability of income. For other crop pairs, however, choice must be made between level of income and relative stability of income, and the optimum selection will depend on the capital, equity and other resources and abilities possessed by the individual operator.

Again it can be said that few farmers are interested in selecting level of income or relative variability of income at the expense of each other. Generally the problem is one of selecting the optimum combination of the two with the exact pattern depending on the operator's capital and equity position and his preference for and ability to withstand risk-taking. Specialists in agriculture have little basis for specifying, in terms of soil conservation or income considerations alone, a particular rotation or cropping system for the farmer without considering the degree of risk or income variability involved. The more nearly correct procedure should be one of outlining the choices open which relate level of conservation and income to variability of income and letting the farmer select the combination which fits the combinations peculiar to himself. The data presented above can serve this purpose for the "typical situations" selected to represent par-

Fig. 22. Production possibilities showing relationship between level of income and relative variability of income; Grundy and Hald soil; Cedar Township, Lee County.
ticular soil and climatic situations. While both sets of variability data have a place in these comparisons and choices the relative variability measures are of greater use than those on absolute variance. The implications of this statement are partially apparent from the comparisons above which show that a minimum coefficient of variation allows a greater acreage of high-income crops and a higher level of income than minimum variance.

Fig. 23. Production possibilities showing relationship between level of income and relative variability of income; Moody and associated soils; Logan Township, Lyon County.

Fig. 24. Production possibilities showing relationship between level of income and relative variability of income; Ida, Monona and Napier soils; Jordan Township, Monona County.
The analysis of the preceding section dealt with diversification or cropping patterns which minimize the variance of income. Diversification may also be practiced to minimize the probability of losses, bankruptcy or income below family-living and debt retirement levels in individual years. This is the notion expressed by farmers and agriculturists when they suggest that "one should not put all his eggs in one basket." The farmer can view incomes from distinct enterprises as different observations drawn from a single population of possible incomes. By increasing the number of observations or income-enterprises even though these are highly correlated on prices and also on yields, he will reduce to some extent the chance of a major loss from only one or a few enterprises. While the combination which results in a minimum variance of income may also be the one which has the lowest minimum income in any one year, the two need not be coincident.

Tables 43 and 44 have been prepared to show the effect of crop combinations on averting low incomes in single years. Table 43 shows the lowest income in any one year of the 32-year period for the single crops and pairs of crops at the locations included. Combinations include 30 acres of each crop. In the case of corn-oats combinations, the minimum income of any one year is greater than that for either crop taken alone for all but six locations. For other scattered combinations, minimum income of any one year is increased, as compared to either crop alone, for the soil locations of Troy and Grand Meadow townships; it is decreased materially for such townships as Harrison in Kossuth County and Harrison in Benton County. A corn-flax combination lowers the minimum income of any one year to $0.02 in Logan Township as compared to $6.92 for corn alone and $3.18 for flax alone. Hay, more than any other crop, has the effect of lowering minimum incomes because of the relatively low correlation of incomes between hay and other products.

Fig. 25. Production possibilities showing relationship between level of income and relative variability of income; Marshall and associated soils; Lincoln Township, Montgomery County.
## TABLE 43. MINIMUM INCOME PER ACRE IN ANY ONE YEAR, SINGLE CROPS AND CROP PAIRS. *

<table>
<thead>
<tr>
<th>Crop or combination</th>
<th>Troy</th>
<th>Grand Meadow</th>
<th>Saratoga</th>
<th>Harrison Kossuth</th>
<th>Cedar</th>
<th>Logan</th>
<th>Jordan</th>
<th>Lincoln Montgomery</th>
<th>Lincoln Polk</th>
<th>Sheridan</th>
<th>Reading</th>
<th>Harrison Benton</th>
<th>Oakland</th>
<th>Appanoose</th>
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<td>Corn</td>
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<td>-4.30</td>
<td>-5.77</td>
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<td>-2.99</td>
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</tr>
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<td>-7.37</td>
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<td>-4.58</td>
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<td>-4.84</td>
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<td>XX</td>
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<td>XX</td>
<td>XX</td>
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* Based on 1/2 acre devoted to each crop for crop pairs and 1 acre for single crops. The figures indicate the lowest net income in any single year of the period included.
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<tr>
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<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>xx</td>
<td>-1.39</td>
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<td>1.83</td>
<td>-0.84</td>
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<tr>
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<td>xx</td>
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<td>xx</td>
<td>xx</td>
<td>-2.56</td>
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<tr>
<td>Oats-soybeans-flax</td>
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<td>-4.10</td>
<td>-1.93</td>
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<td>xx</td>
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<tr>
<td>Oats-soybeans-hay</td>
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<td>-5.66</td>
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<td>-2.03</td>
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<td>0.34</td>
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</tbody>
</table>
Three-crop combinations are slightly more effective in putting a floor under income than are two-crop combinations as can be illustrated in table 44. For example, in Sheridan Township, the pairs corn-soybeans, corn-hay and soybeans-hay have minimum incomes of $2.49, $1.32 and $1.20; under the three-crop combination, minimum income of any one year is $1.15. Even then it can be pointed out that in many cases, three-crop combinations do not lessen the loss over single crops. This aspect of diversification is likely less important than many farmers think it to be.

INTRA-ROTATIONAL EFFECTS ON VARIANCE

The nature of the data presented above does not fully account for intra-rotational effects of crop combinations on income variance. This is true since the data are not drawn from distinct rotations. Crops grown in rotation, as compared to those grown alone, may not only result in lower income variance because of the tendency of random yield and price fluctuations of single crops to offset each other when grown in combination but also because one crop may contribute a factor which helps stabilize the yield of another. Hay, for example, is important from the first standpoint because its income variability is not so closely correlated with that of most other crops. It can also be important
from the second standpoint since the nitrogen and organic matter which it furnishes to subsequent grain crops grown in rotation may reduce yield variability of the latter.

The analysis of previous pages shows the effect of crop combinations on income variance when they might be grown on the same farm but not necessarily in rotation with one following the other. We now examine the effects of combinations when the crops are grown together in rotation. Only scattered data are available for these comparisons since they must be drawn from long-time rotations. The only rotation data in Iowa meeting these requirements are those on Clarion-Webster soils at Ames for a period beginning in 1915 and those on Marshall soils at
Clarinda for a period beginning in 1933. Interpretation of these results follows:

The main effects of rotations on income variability come through yield variability. Some rotations may cause more variable yields of the individual crops than other rotations as well as affecting income variability through crop combinations. At these locations the introduction of meadow into the rotations increased the variability of corn and oats yields. Variability of hay yields on the agronomy plots was much the same for all rotations containing hay. Available information indicates that data from actual rotations would lead to more accurate measures of variability by the mean square deviation for crops in rotation.

However, grain yields were also greater when hay was included in the rotation. Therefore, variability of yields relative to the mean yield need not be affected in the same way. Estimates of the crop yield variability relative to the mean yield are presented in table 45. Differences are probably no greater than are to be expected as chance variation between plots. Also, some local soil differences between rotations are confounded with rotation effects.

Thus, while more data, when it becomes available, might bring out other variability differences caused by rotations, present information is inconclusive.

![Graph showing production possibilities](image)

Fig. 29. Production possibilities showing relationship between level of income and relative variability of income; sandy loam soils; Harrison Township, Benton County.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Corn</th>
<th>Oats</th>
<th>Meadow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotation Coef. of var.</td>
<td>c-o</td>
<td>c-o-m</td>
<td>c-c-o-m</td>
</tr>
<tr>
<td>c</td>
<td>24.0</td>
<td>31.0</td>
<td>22.6</td>
</tr>
</tbody>
</table>
| Source: Jensen. (See footnote 34, below.)

POLICIES AND ALTERNATIVES IN REDUCING INCOME VARIABILITY

As the early sections of this report indicate, the primary production of Iowa agriculture is subject to important net income instability. While the degree of variability differs between primary crops and locations, income variance is still great for those with the smallest relative variability. While this report does not deal with livestock, instability in primary production also gives rise to instability in secondary production in a livestock economy such as Iowa where livestock output is highly dependent on crop output.

This study has related to only one individual farm policy or precaution to uncertainty, namely, diversification. It is apparent that attainment of income stability through this avenue involves a less efficient use of resources than would otherwise be necessary. Inefficiency is reflected to the individual farmer through the profit which he must sacrifice as he substitutes a low-return crop for a high-return crop in order to lessen variability of income; while there are crops which result both in greater income and less variance of income as they are substituted for others, these crops are not commonly the ones which bring maximum returns from given cost or resource outlays. Society also sacrifices in total welfare since wherever the farmer must sacrifice value of product to attain stability of returns, the community of consumers is, as reflected through the lower value product, obtaining less of those products to which they attach greatest esteem and values.

GOALS IN FARMER EDUCATION

Mankind can do little to eliminate those major variations in production and, hence, in income that stem directly from predictable and unpredictable variations in weather and other acts of nature. Society can exercise some precautions which offset the income effects of major fluctuations in yield and production. Steps may also be taken which lessen the impacts of major economic variables on farm income. Currently, it does

Fig. 30. Production possibilities showing relationship between level of income and relative variability of income; river bottom soils; Oakland Township, Louisa County.
not appear that the adverse effects of those instability forces which are both endogenous and exogenous to agriculture will be eliminated in the near future. Thus, given the great degree of income variability involved in a state such as Iowa, stable farming patterns become an intermediate goal of farming which should be recognized in the educational efforts of land-grant colleges. Since farmers must select between competing alternatives which involve more income or greater stability of income, educational efforts need to be directed along lines which help farmers make efficient choices. Cropping patterns which maximize yields per acre, or even those which maximize farm income over time, are unlikely the immediate goal of many farmers. Instead, they wish to seek out cropping patterns which allow efficient combinations of level of income and stability of income. Additional resources in both research and education should be devoted to this aspect of choice.

NATIONAL POLICIES

While only one farmer-policy has been examined in this study, the use of diversification in crop production as a means of reducing income variability, it has been shown that the alternatives here often are attained only with great sacrifices in income or are attained only in small degree. Some of the greatest opportunities for handling the variability problem fall at the national level and require economic policies of a large scale. A later empirical study will show how these can be interrelated with the aspects of income variability outlined earlier in this study.
APPENDIX A.
TOWNSHIPS IN THE 50-TOWNSHIP SAMPLE

<table>
<thead>
<tr>
<th>Area I Township</th>
<th>Area I County</th>
<th>Area II Township</th>
<th>Area II County</th>
</tr>
</thead>
<tbody>
<tr>
<td>Richland</td>
<td>Lyon</td>
<td>Ward</td>
<td>Clarke</td>
</tr>
<tr>
<td>Marcus</td>
<td>Cherokee</td>
<td>Guilford</td>
<td>Monroe</td>
</tr>
<tr>
<td>Willow</td>
<td>Monona</td>
<td>Jackson</td>
<td>Wayne</td>
</tr>
<tr>
<td>Battle</td>
<td>Ida</td>
<td>Wyacohadah</td>
<td>Davis</td>
</tr>
<tr>
<td>Harrison</td>
<td>Harrison</td>
<td>Center</td>
<td>Wapello</td>
</tr>
<tr>
<td>Cass</td>
<td>Shelby</td>
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<td></td>
</tr>
<tr>
<td>Grant</td>
<td>Cass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ingraham</td>
<td>Mills</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red Oak</td>
<td>Montgomery</td>
<td></td>
<td></td>
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<tr>
<td>Lincoln</td>
<td>Adams</td>
<td></td>
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<tr>
<td>Douglass</td>
<td>Union</td>
<td></td>
<td></td>
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<tr>
<td>Linn</td>
<td>Warren</td>
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</tr>
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</table>

<table>
<thead>
<tr>
<th>Area III Township</th>
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</tr>
</thead>
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<tr>
<td>Bristol</td>
<td>Greene</td>
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<td>Dodge</td>
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<td>Hudland</td>
<td>Clay</td>
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<td>Garfield</td>
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<tr>
<td>Ell</td>
<td>Hancock</td>
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<tr>
<td>Logan</td>
<td>Calhoun</td>
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<tr>
<td>Vernon</td>
<td>Humboldt</td>
</tr>
<tr>
<td>Clear Lake</td>
<td>Hamilton</td>
</tr>
<tr>
<td>Sherman</td>
<td>Hardin</td>
</tr>
<tr>
<td>Grant</td>
<td>Story</td>
</tr>
<tr>
<td>Delaware</td>
<td>Polk</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Area V Township</th>
<th>Area V County</th>
</tr>
</thead>
<tbody>
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<td>Chickasaw</td>
<td>Chickasaw</td>
</tr>
<tr>
<td>Niles</td>
<td>Floyd</td>
</tr>
<tr>
<td>Hartland</td>
<td>Worth</td>
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<tr>
<td>Bennezette</td>
<td>Butler</td>
</tr>
<tr>
<td>Adams</td>
<td>Delaware</td>
</tr>
</tbody>
</table>

APPENDIX B.
LIMITATIONS IN THE USE OF THE COEFFICIENT OF VARIATION

While the coefficient of variation as a measure of variability (dispersion relative to the mean) is useful to indicate the degree of uncertainty attached to various crops, it has certain limitations which should be mentioned. Three cases of variability or "expected outcomes" (i.e., in the subjective sense of anticipation) are presented to illustrate this point: In case I (fig. a) no particular limitations are involved in the use of the coefficient of variation as a measure of variability and "degree of risk." (The distributions are symmetrical.) The crop represented by frequency distribution B would be chosen even though the absolute dispersion is the same as that of A.\(^1\) Since the

\(^1\) Costs are an exception since the farmer is interested in minimizing cost per given output.
lowest observation in B lies above the highest in A, higher yields, prices or income (whichever the distribution represented) would always be expected even if planning were in terms of the lowest possible outcome. The symmetrical distribution with the greater mean presents, in this case, relatively less "risk," i.e., the average or most probable event may be discounted relatively more and still permit a more favorable expectation than in the case of the product with the lower mean.

Case II, a situation where the means are the same but the absolute dispersion differs, also allows use of the coefficient of variation as an indicator of uncertainty of particular outcomes. With symmetrical distributions the smaller coefficient of variation (dispersion relative to the mean) indicates a range of outcomes more closely distributed about the mean and therefore involves less uncertainty in predicting expected outcomes.

Case III (fig. a), where neither the means nor the absolute dispersions (variances) are the same, presents additional possibilities in measurement: (1) B's variance may be smaller than A's but its mean may be larger; (2) both the mean and dispersion of crop B may be larger than for crop A. The first situation (case III a) offers no difficulties. Crop B would have a greater mean, smaller coefficient of variation and less absolute dispersion than crop A. The second situation is shown in case III b where the variance and the mean of crop B are both larger than for crop A. This situation causes greater difficulty of interpretation of variability than previous cases; although the coefficients of variation are the same, crop B presents less risk in the sense of loss possibilities since a greater profit can be expected with certainty even though the variance is larger than for A. Case III c presents a still more difficult case because of the "overlapping" of the distributions. In the classical concepts of uncertainty crop A involves less uncertainty in the sense that the range and variance are smaller. However, again the farmer's capital position may affect his decision; he may wish to raise crop B even though its coefficient of variation may be the same as A's because it offers greater possibilities of higher returns with only a small probability of lower returns. On the other hand, a man with a very low equity may choose A; although the probability of a relatively high return is small, there is little chance of ex-
tremely low returns. Where the farmer wishes to exercise great precaution in planning (i.e., wishes to select crops with low probabilities of losses or small returns even though the possibility of very high returns is excluded) the coefficient of variation does not serve efficiently in aiding his choice if the situation is that of case III. The distributions must be examined in light of the degree of overlapping.

For nonsymmetrical distributions, additional complications arise in interpretation of the variance and even the coefficient of variation as reflections of the uncertainty involved. If the frequency distributions of incomes differ between crops (some skewed to the right, some to the left and/or some bi-modal) the coefficients of variation are not comparable since the direction and amount of skewness may differ between crops. On the other hand, if all the distributions are of the same type, e.g., skewed to the right in approximately the same magnitude, the comparisons discussed above for symmetrical distributions still have application. For identical distributions, probabilities are equal for outcomes falling in an interval of a standard deviation about the mean; since they are distributed in a similar manner, the dispersion relative to the mean (coefficient of variation) still serves as a meaningful estimate of variability. These and other qualifications should be kept in mind when using the statistics representing variance and other measures of dispersion in the text to suggest "degree of risk" involved in different crops.

APPENDIX C

Since crop combinations in the text include pairs only, the statistics of table 1 have been provided for three crops. The three crops included are corn, oats and hay since these are the chief rotational crops on all arable soils of Iowa. In constructing these figures from previous equations, \( q \) refers to the proportion of land in corn while the proportion in oats and hay is \( .5(1-q) \) for each. Hence, the acreage of hay and oats is always the same for the figures shown in table 1. With 60 percent of the resources used for corn, for example, 20 percent is used for oats and 20 percent is used for hay. Most of these data show that a combination of oats and hay with corn would have minimized relative variance of income in the past. Also, except in Troy Township, a reduction in the coefficient of variation is always associated with a reduction in level of income. In most townships, a 4-year rotation of C-C-O-M with 50 percent of the land in corn, more nearly than other "standard rotations," would minimize relative income variance. Of other standard rotations (those most commonly recommended to farmers) a C-O-M rotation with about one-third the land for each crop would seem in about second place for minimizing income variability.
### Table 1: Level of Income and Coefficient of Variation for Income with Specified Combinations of Corn, Oats, and Hay

<table>
<thead>
<tr>
<th>Township</th>
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<th>C.V.</th>
<th>Income</th>
<th>C.V.</th>
<th>Income</th>
<th>C.V.</th>
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*APPENDIX C*
TABLE 1. (Cont'd.)

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