ADAPTATION OF THE FARM FIRM IN WESTERN KANSAS TO CONDITIONS OF UNCERTAINTY

by

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INTRODUCTION

This thesis is an attempt to apply the principles of economic logic and statistical analysis to a problem existing in society. Economic theory is used to suggest testable hypotheses, to guide researchers in their search for "facts" and to supply the logic necessary for conclusions which must be reached in the absence of experience or data. When this situation occurs, the scientific method cannot be applied in its entirety[1]. Decisions must be made, but the observations necessary for the adequate testing of a hypothesis are not available. The logic is also used as a basis for obtaining the necessary data whenever available.

The above proposition contains a controversial point. One frequently hears the statement, "Don't come to me with recommendations until you have the facts." Frequently research people concur in such a belief. Many of these people believe that a simple observation of the facts will yield acceptable conclusions. The use of economic theory or logic in suggesting testable hypotheses to indicate which facts to

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[1]As used here the complete scientific method involves the following: problem formulation, hypothesis formulation, design of empirical procedures, data analysis, and interpretation. (Heady, 9)

observe and how to observe them is not realized. However, the research worker in putting forth recommendations need not include with those recommendations the entire process by which they were obtained. He can present the "facts" that he used to test his hypothesis and have acceptable material for extension purposes. But what is the correct procedure when we have no data? Can the research worker make a contribution? If he cannot apply the entire scientific method, must he remain silent? Since economics is an empirical science, one may answer the above by indicating that in the absence of experience or experimentation the economist must have nothing to say. The economist would surely be right a greater percentage of the time if he were to confine his answers to those questions where he has complete and accurate information. However our economic theory would tell us that it is not necessarily the average product that we should maximize. To be of the greatest use to society, the scientist should make recommendations in accordance with the principles of marginality. The writer holds that this point is beyond the maximum average product. It would seem that with years of work behind him on the development of economic logic by such minds as Marshall, Hicks, Smith, Mill, Keynes, and Knight that the economist should not apologize for his recommendations that are made in the absence of a hypothesis rejected or accepted at a high level of probability or when the information is not available for verification. If the problem is important, a decision will be made by the practical man. This decision will also be made in the absence of data and will be based upon certain assumptions implicit though they may be. It is submitted that the economist has the advantage for he has economic logic as a tool of analysis. The assumptions behind his analysis and recommendations should be explicitly stated and well known. This thesis is written in the belief that the economist may make a contribution even though he does not at the present have all of the necessary data to test all his hypotheses. The formulation of a hypothesis even though it is never tested may be of value since such a formulation may treat in an orderly manner the relevant variables bearing on a question.

It should be recognized, however, that the above thesis holds only if the data or the statistical devices are not available with which to analyze the data. The scientific method in its entirety implies verification or rejection of hypotheses. When observations are available or can be made, the proper procedure is to analyze those observations with the appropriate statistical methods. No doubt it was this point that lead Phelps Brown (3, p.208) to observe that the future of economics was closely connected with the progress of the econometricians. Tintner (30, p. 4) makes a useful distinction between the econometrician and the statistical economist. The former uses his knowledge of economic theory to suggest hypotheses for testing while the latter is engaged in the manipulation of data in the hope that the data will show principles or laws of economic behavior.

Certainly much of the work in agricultural economics could be classified as either econometrics or statistical economics. Agricultural economists have traditionally been concerned with observations of various kinds. Following Tintner, the bulk would be classified as statistical economics with work in econometrics being in the minority. At the present, however, there seems to be an increase in the work that might be classified as econometrics. Economic theory is being emphasized to a considerable extent on the graduate level in many institutions. At the same time statistical methods are also being stressed. This is evidence that a relationship is thought to exist between the disciplines.

The above does not mean that all the work in agricultural economics has been of a statistical or empirical nature. Agricultural policy is an example of a division of agricultural economics where economic logic or theory has played an important part. Much of the subject matter of agricultural policy has been developed by deductive methods. An example of this is the volume Readings in Agricultural

Policy, parts 2 and 3 (Jesness, 12). Here policy implications and recommendations are derived from theoretical background and are based on little empirical data.

In farm management and production economics, however, the work has been many sided. Traditionally much of the work has been of an empirical nature. Cost accounting routes and the Farm Management Associations are examples of the emphasis which was placed upon the collection of data. This procedure would more nearly fit the function of the statistical economist than it would the econometrician.

The farm budget is an example of a combination of both the deductive and inductive approach. Farm plans are drawn by the use of data or standards collected from actual farm organizations. This is a process where specific information is collected, then combined as dictated by economic logic, and the results applied to a particular farm or region. This has been the traditional use of the farm budget. The budget may also be used as a tool in relating variables so that hypotheses which have been suggested by economic theory may be tested.

Surveys have also been a source of information for research workers in farm management. Such data may be collected either with the object of testing certain hypotheses or in the hope that manipulation and observation of the data will show economic principles and laws. Inherent in survey data, however, is the question of the validity of inferring to a particular farm on the basis of interfirm data. Modern statistical methods of sampling and analysis of variance can reduce the magnitude of this problem but cannot eliminate it completely.

Farm management has not been without work of a deductive nature, however. Many of the texts in farm management are primarily of a deductive nature setting forth economic principles and specifying general relationships. They are devoted largely to setting forth the logic of management without an appeal to actual farm organizations for verification. The difficulties involved in verification will be treated later. Many questions can be raised concerning the validity of much of the data that is included as well as the theory that is used in the deductive part.

The foregoing discussion places this thesis in its proper setting among other works in farm management and establishes the case upon which the particular approach rests. The method of procedure of this thesis is to use economic logic or theory to set forth hypotheses for empirical verification. Some hypotheses will be formulated even though only meager data are available for rejection or acceptance of the inherent hypothesis. The justification for this procedure lies in the fact that economic logic is of value in isolating relevant variables even in the absence of data. The decisions must be made and the economist should be able to aid the entrepreneur in making an economic decision.

Research of any kind must be useful to the people who are supporting that research if it is to be given continued support; therefore, the researcher is justified in giving some attention to extension methods and techniques. This point is emphasized since the problems expressed at the extension level can influence research in the inception stage. If research has no use or if it brings to light facts that command the interest of no one other than the researcher, then the wisdom of undertaking such research may be questioned. Such a decision, however, must rest upon the assumption that the ends of society are known. In the absence of any such assumption the researcher will be completely at a loss unless he makes certain assumptions regarding society's ends. The author recently heard the statement made by an enumerator of a group of low income farm families, "These people are happy as they are, why are we trying to change their lives?" It is submitted that such a statement misses the function of both research and extension. One possible reason for the investigation might be that the remainder of society is interested in the facts which the investigator was trying to ascertain. In addition to that, however, the investigator may be trying to describe reality and how to attain certain ends. There is nothing in such a concept that would indicate that the lives of people <u>should</u> be changed. Results of research when presented properly will increase the recipient's information. If certain ends are assumed, the assumption should be made clear. The point is that research and extension should use society's ends as guides for their work. Ends or value systems are not properly the target which the researcher or the educator should aim although the educator may call attention to possible inconsistencies.

Non-economists frequently object to the work of economists in the belief that economists operate on the assumption that profit maximization is the only human motivation. It is true that this assumption does underlie much economic work. The point made here, however, is that the value of the work by the economist does not depend upon such an assumption. Economic theory provides the framework for relating various ends and showing the conditions under which those ends can be maximized. It is in this vein that the results of economic research should be made known. There is no reason to assume that society has only one end. It is only necessary to recognize that there are indifference curves or preference functions relating different ends. Perhaps a simple but desirable goal in extension education would be to inform people they have such indifference curves. It is believed the above points are not universally accepted and realized, but it is also maintained that it is the only position consistent with the fundamental tenets of a science.

THE PROBLEM

The isolation of a meaningful problem is an important step in the research process. One method of problem recognition is the existence of doubt or uncertainty in the minds of members of society. If the members of society feel they have a problem, they may call upon a researcher to investigate. The researcher may either show that no problem exists or he may indicate how the problem may be solved. In either case the "felt" difficulty must be checked against some established criteria to see if a problem really exists.

Problems may also be indicated and isolated solely by the research worker since an individual may not always recognize or identify a problem when he confronts it. He may check an existing situation against some ideal or preestablished set of criteria. The distinction then really lies in where the question originates. It may start with members of society other than the research worker or it may originate in the mind of the scientist. The means of problem isolation then is the comparison of the existing situation with that of an ideal. In economic investigations this ideal is that which is specified by economic logic or theory. Obviously the isolation of a relevant problem is essential to worthwhile research. An attempt will be made below to indicate that the question to be treated in this thesis may be classified under either heading.

The problem tentatively stated is the concern which exists concerning the high variability of agricultural income in a part of the Great Plains due to unstable weather conditions and changing product and factor prices. When poor yields coincide with poor prices and this condition persists for a period of years, many farmers suffer acute financial distress (Table 1). Historically this condition of high variability of rainfall has caused the area to be known successively as the Great American Desert and the Dust Bowl. Reference to Tables 2 and 3 will indicate the variability of both prices and yields of wheat, the principal crop of the area. In addition, the poor and good years tend to occur in cycles. These cycles are not predictable or of a regular duration, and it is difficult to establish statistically that they do occur. However, observation of Table 2 would indicate that yields have not occurred as might be expected if they were drawn at random from a normal distribution.

Static economic theory would tell us that an entrepreneur with a profit motive would equate marginal cost and marginal revenue. The introduction of time would merely indicate the entrepreneur should discount the marginal revenue for waiting, and this would limit the application of inputs.

Table 1

The Estimated Average Annual Effect of Drouth on Kansas Income, 1936-39[a]

(Million dollars)

Source of income	Annual income from farm marketings		Reduction due to drouth
	Actual	Estimated without drouth	
Agricultural income:			
Wheat	88.1	110.8	22.7
Corn	2.6	5.2	2.6
Other crops	12.2	15.8	3.6
Total crops	102.9	131.8	28.9
Meat animals	105.9	148.0	42.1
Dairy products	29.2	36.2	7.0
Chickens & eggs	20.4	36.1	15.7
Other livestock & livestock products	5.7	6.3	.6
Total livestock & livestock products	161.2	226.6	65.4
Total crops & livestock	264.1	358.4	94.3
Government payments	25.0	22.5	(-)2.5
Total	289.1	380.9	91.8
Income payments to individuals	721.8	876.3	154.5

[a]Laude and Hodges (19, p. 43)

Table 2

The Yield of Wheat at the Colby Kansas Experiment Station for Continuously Cropped and Summer Fallowed Wheat 1915-1949

Year	Continuously cropped Yield in bushels per acre	Summer fallow Yield in bushels per acre
1915	18.7	25.4
1916	18.5	22.6
1917	0	0
1918	9.7	19.0
1919	11.4	32.8
1920	15.2	39.3
1921	12.6	28.8
1922	15.4	26.4
1923	7.9	35.3
1924	12.2	28.0
1925	6.6	22.2
1926	2.1	18.3
1927	1.0	2.9
1928	16.5	34.2
1929	8.2	16.2
1930	22.1	37.2
1931	11.2	25.6
1932	1.5	31.8
1933	0	0
1934	0.1	10.0
1935	0	0
1936	0	0
1937	1.6	3.9
1938	5.5	9.2
1939	2.4	6.0
1940	0	6.5
1941	11.3	22.3
1942	21.5	25.2
1943	10.9	27.6
1944	20.5	33.2

continued

Table 2 continued

Year	Continuously cropped Yield in bushels per acre	Summer fallow Yield in bushels per acre
1945	17.0	38.7
1946	11.3	24.8
1947	23.2	36.5
1948	6.4	19.4
1949	7.0	20.0
Coefficient of variation	75.4	59.9
Mean	9.7	21.4

Table 3

The Average Price of Wheat at Kansas City[a]
1926-1949

Year	Price per bushel
1926	1.53
1927	1.46
1928	1.46
1929	1.22
1930	.93
1931	.65
1932	.55
1933	.75
1934	.95
1935	1.09
1936	1.15
1937	1.23
1938	.84
1939	.82
1940	.89
1941	1.01
1942	1.21
1943	1.45
1944	1.64
1945	1.72
1946	1.97
1947	2.68
1948	2.47
1949	2.32
Coefficient of variation	42.75

[a]Kelley, Gerber, and Foster (16, p. 84-85)

In the situation just presented, however, the entrepreneur may be able to forecast in a fairly accurate fashion the costs that are to be incurred in production, but the production function in any one year is highly erratic and historically yields have varied from nothing to nearly two and one-half times the average (Table 2). To convert the expected production function into an expected revenue function, expected yields must be multiplied by expected prices. Reference to Table 3 will indicate the difficulty of forecasting prices. There is also imperfect knowledge concerning the cost of inputs that will be applied; and, since considerable time must elapse in agriculture between the application of the input and the harvesting of the results, this lack of knowledge may intensify the problem.

The uncertainty referred to previously is serious both for the long and the short planning period. The yield, prices, and costs are not known for the year ahead, but for the period beyond the next year the information is even more scarce. It is sometimes recommended that a farmer plan on the average. It is not very helpful to plan on averages when the average is always changing and when it may take a lifetime or longer to secure the average.

Economic logic and simple arithmetic would tell us that the highly variable production function together with con-

Table 4

Gross Income per Acre for Wheat at the Colby Kansas Experiment Station on Summer Fallowed Land 1926-1949

Year	Dollars per acre
1926	28.00
1927	4.23
1928	49.86
1929	19.73
1930	34.60
1931	16.59
1932	17.55
1933	0
1934	9.48
1935	0
1936	0
1937	4.80
1938	7.73
1939	4.93
1940	5.77
1941	22.48
1942	30.54
1943	40.08
1944	54.38
1945	66.64
1946	48.81
1947	97.89
1948	47.96
1949	46.44
Coefficient of variation	89.7

siderable variation in prices would tend to cause extreme variation in gross income. Historically this variability has been accentuated by the fact that low prices and low yields and high prices and high yields have tended to coincide. Reference to Table 4 will establish this point. It would be possible for the variation in prices and yields to counteract or cancel each other with the result that the variation in gross income would be less than the variation of either prices or yields. Historically this has not been the case. In checking the situation against the "ideal" or the allocation of resources under conditions of certainty, a problem is definitely established. Analytically a problem is posed from the standpoint of not only the individual manager but also society. The problem becomes one of decision and choice-making with imperfect knowledge.

The problem would also be a relevant one in terms of a felt difficulty. The extreme hardship suffered by farmers in the area in question during the 1930's is well known. Reference to Table 1 will indicate why this is so.

THE ADAPTATION OF THE FARM FIRM TO CONDITIONS OF UNCERTAINTY

The purpose of this chapter is to examine the goals of the entrepreneur who operates under conditions of uncertainty and to present alternative lines of action which hold promise of permitting him to attain those goals. The effect on the entrepreneur of the proximity of the household and the firm will be examined. The way various individuals react to lack of knowledge concerning the future will be treated. Application will be made of the theory of uncertainty to Great Plains agricultural conditions. This step must be taken prior to empirical work in this or any problem area if research is to prove systematic and most fruitful.

Knight's (17) Risk, Uncertainty and Profit was the original work on the theory of the firm when the assumption of perfect knowledge was relaxed. His approach was on the probability basis. He defined three types of probability - a priori, statistical, and subjective. He pointed out that events that fall into the first two categories could be classified as risk and would then become insurable or costs of production. Events falling in the last category he designated as uncertain and went on to point out that adjustment to uncertain events was the function that was unique with the entrepreneur. The payment, according to Knight, that this function commanded was profit.

Writers since Knight have generally agreed that there are losses which the entrepreneur may suffer which do not become a cost of production and which cannot be insured. There has been some disagreement as to his explanation of profit. In addition, certain refinements have been made in the broad classification of events which Knight calls uncertainty. Tintner (31, p. 645-648) has broken Knight's classification of uncertainty into subjective risk and subjective uncertainty. He designates the first as being a single subjective probability distribution. Subjective uncertainty is then defined as a situation where the entrepreneur has a subjective probability distribution of probability distributions. The two positions do not necessarily conflict; one is a refinement of the other.

The problem facing the farmer in Western Kansas seems to fall largely in the general area of Knight's uncertainty. Uncertainty would be characteristic of both technical and market conditions. It is true that part of the price uncertainty can be insured against by hedging on the futures market. However, a futures market does not exist for all commodities. Even if a futures market does exist, the uncertainty may be increased by yield uncertainty. A farmer cannot sell futures unless he can deliver actual wheat at a certain time or buy back the contract prior to the due date. This means that the futures market has limited application for planning which must be made prior to the inception of the production process.

Yield fluctuations also can be classified as being uncertain (following Knight). Crop insurance is made available to a certain extent by both private and governmental agencies. Here again the insurance is not complete. Even though the mean expectancy can be established, the yield of any one year is still uncertain. The entire value of the crop is not covered, and all crops are not insured. The result is that there is a considerable area in which the entrepreneur must make adjustment regarding the uncertainty of future events.

Factor costs are probably more nearly known than either yields or prices, but even here the knowledge is not complete. As the planning process becomes shorter and shorter, it is evident that the knowledge becomes greater. For the year ahead costs may be estimated with considerable accuracy, but for the long run considerable uncertainty undoubtedly prevails. In the acquisition of capital the uncertainty may take two forms. In the first case the price may be relatively stable but the supply of capital may be unpredictable. In periods of general prosperity capital may be available, but in times of depression (or) pessimism, rationing may become severe both of an internal and external nature. In the second case the actual cost of capital may be uncertain.

Firm-Household Interrelations

In much of the literature of economics the assumption of profit maximization on the part of the entrepreneur is made. Under dynamic conditions this assumption takes the form: the maximization of the present discounted value of his expectation of net receipts (Hart [7], p. 89). Hart established this objective in the absence of uncertainty and capital rationing. The problem then becomes one of selecting the production plan which will best meet this objective. Under conditions of uncertainty and capital rationing the attitude of the entrepreneur is important. Individuals vary in their reaction to danger or chance. If external capital rationing is a factor, the production plan must meet the approval of lenders. In addition, the entrepreneur as a decision maker is also a member of a household which has as its objective the maximization of utility. The objective stated by Hart may be modified when it conflicts with the maximization of utility over time which is the objective of the household. The purpose of this chapter is to treat these possible modifications.

Hart (7, p. 89) has shown that the maximization of the present discounted value of expected net receipts is identical with the maximum discounted value of expectations of withdrawals or maximum present net worth. This identity would hold in the absence of capital rationing and under conditions of subjective risk where the entrepreneur thinks he knows what is going to happen.

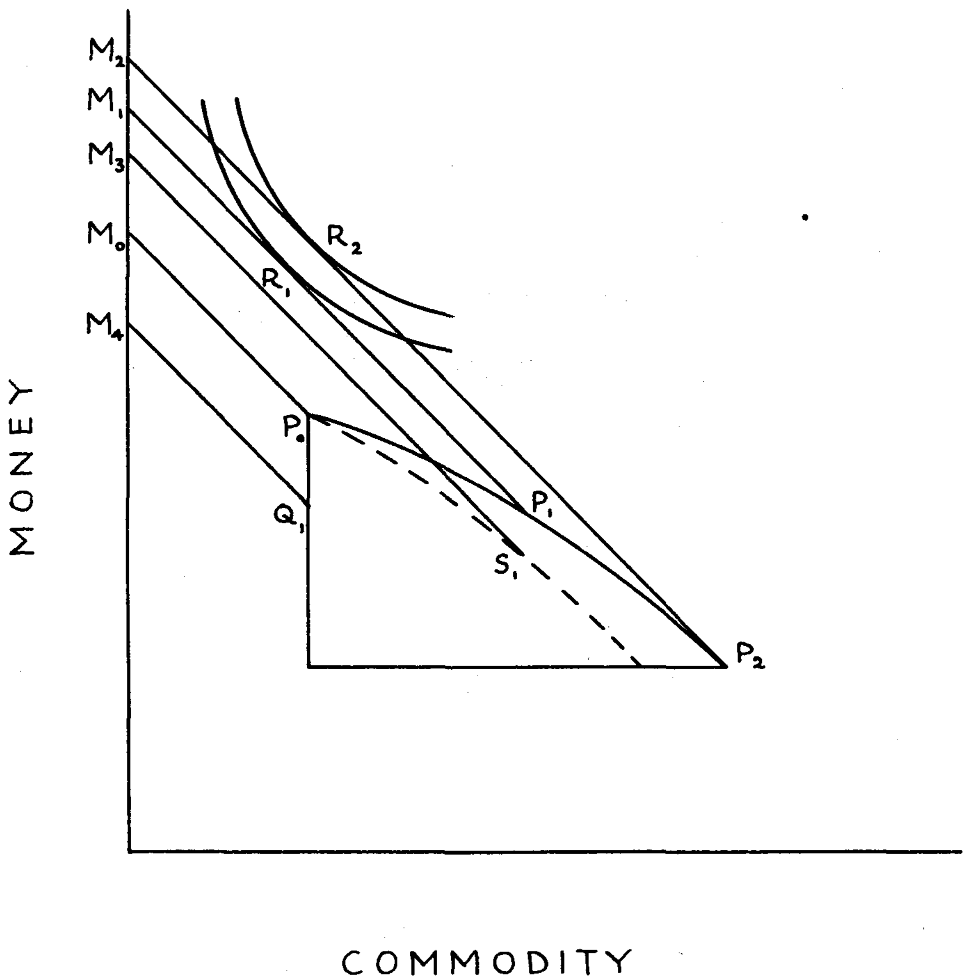
Under such conditions there may be no conflict between the firm and the household. If the household places a high value on withdrawals in the present, receipts from the production plan for the future will be discounted heavily. If the decision maker for the firm is the same as for the household, and if the maximization of utility in the household is taken as the ultimate end, the production plan will be selected with this end in mind; and all conflicts will be resolved in favor of the household. On the other hand the success of a firm may be looked upon as an ultimate end. In this case the household will be organized not as a consuming but as a producing unit designed to contribute to the production of the firm. Any conflict which might arise will be decided in favor of the firm. Some combinations of ends would appear to be more realistic than the selection of either end as the ultimate one. To a certain point the two would appear to be complementary; they then would become competitive. The chosen point in the competitive range will be the point that maximizes the utility of the decision maker. For this reason the production plan may differ among entrepreneurs with identical physical resources. Future returns will be discounted differently, and the combination of expected withdrawls and expected net worth that return the greatest satisfaction probably will not be the same for different individuals.

Boulding (2, p. 96) has constructed a model which isolates certain variables in relation to this problem. (See Figure 1.) Suppose P_0P_2 are points on a transformation curve between money and the commodity to be produced. The producer has the opportunity of converting his money into the commodity to be produced to point P_2. Let us assume that he moves to P_1. Now he can move to any point on P_1M_1 by exchange. This line will be tangent to some indifference curve (say) at R_1. In this example, however, it is possible for the firm to produce more and reach a higher indifference curve. Thus it can produce to P_2 and reach a point on a higher indifference curve R_2.

It may be, however, that time must elapse before a firm can produce P_2. If the household wishes to make withdrawals during the process of production, P_2 may never be reached. If M_0M_1 is the profit produced, all or part of this amount

Figure 1. Production in Perfect Markets.

Boulding (1, p. 96)



M_2
M_1
M_3
M_0
M_4
R_2
R_1
P_0
Q_1
P_1
S_1
P_2
MONEY
COMMODITY

may be withdrawn and M_0 would be the money net worth of the firm indefinitely. If something less than M_0M_1 were withdrawn, the firm would gradually work toward P_2 and the maximization of profit. In the absence of uncertainty and capital rationing, P_2 would be produced since money could be borrowed for consumption purposes and there would need be no premium on withdrawals from the firm until it reached P_2.

It is realistic to suppose, however, that uncertainty actually does exist. Because of this uncertainty it is unlikely that there will be a rapid movement to the profit maximization point. Credit probably is not always available for consumption purposes. It may also be that the higher exchange path does not always place an entrepreneur on a higher indifference curve. The greater production probably would also call forth greater effort on the part of the entrepreneur. This may be an exertion that he does not wish to make. For these reasons the maximization of profit may not be the appropriate end, and in reality resources may be allocated differently than this end would imply.

This model may also be used to illustrate the effect of minimum withdrawals on the size of the firm if a surplus is not produced equal to the withdrawal. Suppose that due to unfavorable transformation conditions (a poor crop year) that S_1 rather than P_1 would be produced. Let us suppose that an amount equal to M_0M_1 is the minimum withdrawal of the firm. Then this amount is subtracted from M_3. This would place the money net worth at M_4; and a new transformation curve, lower in the plane, would result.

Households vary, of course, in their reaction to a highly variable income. At one extreme the household would attempt to determine what the average withdrawals from the firm should be and then attempt to save any excess of this amount in "good" years to be spent in "poor" years. At the other extreme the household might spend just as they withdraw. The former might budget their expenditures as they would if they were paid a salary. One would not expect the percentage to vary greatly from one year to the next among clothing, food, housing, entertainment, etc. On the other hand the household that spent as the withdrawals occurred probably would buy relatively more housing, automobiles, and fine clothes during the good years. In actuality it is probable that a large portion of families are not at either extreme. However, due to the low propensity to save of many people it would be expected that the spending plans of the household would follow quite closely the income return of the production plan. Again the subjective determination of the relative importance of money spent for consumption and the future success of the firm would be an important factor.

The household may also have an influence on the production plan regarding the distribution of income within the year. Straight wheat production would probably cause withdrawals to be made from the business infrequently during the year. This might be contrasted to dairy production where withdrawals might be made on a weekly basis. Here again it would be expected that the expenditure plan might vary partly because the desires of the household had influenced the production plan and partly because of the propensity to spend and save. In most instances the future will be discounted. The result is that spending when infrequent withdrawals are made may follow a different pattern than when withdrawals are made on a regular, frequent basis.

The close connection between the firm and household suggests various influences on the production plan of the firm and the spending policies of the household. Unless a reserve exists or unless external capital is available, there will be a minimum below which withdrawals cannot fall. It was mentioned above that under conditions of uncertainty capital rationing both of an internal and external nature are likely to occur. Capital rationing occurs when the lender is willing to lend more than will be taken at the going rate of interest (internal capital rationing) or when the borrower is willing to borrow more than is available at the going interest rate (external capital rationing). Internal capital rationing is a psychological phenomenon about which little is known, and careful investigation of this phenomenon needs to be made. If the reasons are economic in nature, education relating to outlook and prediction would be appropriate. External capital rationing also stems from conditions of uncertainty. Since "poor" years are usually caused by inadequate rainfall, the conditions are usually general in nature and do not apply to any particular farm. This results in inadequate funds on the part of local lending agencies during these poor years. Outlook and prediction information placed in the hands of lenders might have considerable value.

Another aspect of external capital rationing relates to the distinction frequently drawn between consumption and production loans. When the household and firm are an inseparable unit, it is doubtful if the distinction is a meaningful one. If the lender insists on a production loan, the firm may actually be applying inputs at a time when conditions are not favorable to such an activity. A consumption loan at this time may be much more meaningful since there is a possibility that it may prevent withdrawals for consumption purposes which would reduce the capital value of the firm. A comprehensive lending program which would view the firm and household as a unit would seem to be appropriate. Lending, which is made on the basis of production or for a particular enterprise, may not permit the producing and consuming unit to achieve an economic allocation of resources.

Reaction of the Entrepreneur

Up to this time the variability of the management function has not been treated explicitly as a variable. Management has been treated in general and principles of management have been developed that may apply under conditions of uncertainty.

There may be completely different reactions from two rational entrepreneurs under conditions of uncertainty when they are faced with identical situations. One may be so constituted that he may be able to make quick decisions and many of them without an adverse effect upon his mental stability. Another individual may be so constituted that he is not able to analyze current information relative to the future. He may not be able to make decisions emotionally or mentally. There is no reason to suppose that all individuals will react to decision making in the same way just as everyone will not react to other stimuli in the same way. This variability of individual reaction to uncertainty has implications in the choice of the production plan.

Some individuals may not be able to act when the appropriate time arrives. When they do act, conditions may not be as favorable as they were previously and the possible effectiveness of the action has been reduced. An example might be the choice of a feeder cattle program versus a cow herd on the basis that the former allows greater adjustment to changing conditions. Inherent in such a plan, however, is action. Considerable latitude exists in the buying and selling of the cattle. If it is thought during the summer conditions will be favorable to the buying of cattle in the fall, attention should be given to the proper time of purchase. Outlook information on the market should be utilized as well as attention given to feed conditions on the farm; then at the proper time action is required. This involves placing an order with a commission man in a livestock market or visiting such a market in person. Financing must be arranged prior to such action. All this involves an awareness of conditions and the ability to take action. Many individuals have a dislike to a change in routine. The travel or contact with the commission man involves the unusual. If it takes place every year, it may become an accepted part of the routine; but conditions may not be favorable every year. Observation would lead one to believe farmers differ greatly in their reaction to routine. To some the making of decisions, a change of scenery, and a study of economic conditions are highly desirable while the labor of farm work may be monotonous and tiresome. This would not appear to be true, however, for all farmers. Many farmers spend their entire life in a small geographic area. A trip to a large livestock market means a trip to the unknown. Certain beliefs regarding the relative desirability of urban and rural life may cause such a trip, although temporary, to be viewed with distaste. The extent to which this is true would be of value in the formulation of production plans to be offered for farmer consideration.

Farmers as a group, however, are not adverse to change. Reference to Table 5 shows that historically there have been considerable shifts by farmers nationally from the production of one commodity to another. This would indicate that plans are made on a year to year basis and that frequent and numerous decisions are made. It is doubtful, however, if adequate provision is made in long time plans to provide for such shifts in production because decisions of long run implications do have to be made.

It is also doubtful if shifts of such magnitude would have been made if they had involved greater contact with distant points as would be the case with livestock buying and selling programs. A farmer may not be adverse to making a change if it involves shifting from one enterprise to another the resources he has at his command. On the other hand if such a shift involves the acquisition of finances and contacts with a distant market, he may be reluctant to take

Table 5

Coefficient of Variation for Selected Factor Inputs and Production Units in Agriculture, United States, 1930-1947 (%)[a]

Item	Coefficient of variation
Factor inputs	
Acres land in 52 major crops	4.9
Number of workers	4.1
Capital investment in livestock	7.2
Production units	
Pork output	33.7
Spring sows farrowed	18.3
Hens and pullets	12.1
Turkeys	13.8
All cattle except dairy	15.9
Cattle on feed	19.1
Milk cows	5.1
Sheep and lambs on feed	48.2
Acres corn	21.0
Acres wheat	10.9
Acres soybeans	43.3
Acres flax	42.7
Acres cotton	28.3
Acres potatoes	13.7

[a]Heady (10, p. 242)

such a step. The desire for self-sufficiency and fear of the unknown both play a part in such a reaction. Possibly these desires and fears all stem from uncertain knowledge. When information is made available regarding the alternatives, the individuals who are fitted for entrepreneurs will accept the remaining uncertainty and adjust to it. Such individuals will be willing to accept large losses in the belief that windfall gains will also accrue. The individual who is not willing to accept such conditions may be expected to cease to be an entrepreneur or to establish an inflexible organization and will then attempt to follow the details of such a plan. This, undoubtedly, is the reasoning behind the extension recommendation "to get on a plan and stay there". The decisions of long run implications are made by extension personnel. They specify the type of organization (say) dairy cattle. The general blueprint is then established and the farmer carries out the details. He is expected to remain with this organization regardless of external conditions. Such advice may suit certain individuals. Others may not be suited to such an arrangement and may be better able to meet change by utilizing additional information. It may, therefore, be possible to rank entrepreneurship in an uncertain world. The entrepreneur who makes long run decisions in the absence of any kind of plan and then shifts from one commodity to the other without the best information available may be ranked at one extreme. A different type of entrepreneur is the one who selects a definite production plan for the future which specifies the output and product. Such an entrepreneur recognizes that change will occur but believes that the costs of shifting will out-weigh the advantages. The plan that places the greatest reliance on the management function, however, is the one which embodies long run decisions and is based upon the presupposition that change will occur. Shifts are then made from time to time as additional information becomes available. Inherent in such a plan is the assumption that the management function will be exercised frequently. It means that it is anticipated that the additional information will be utilized effectively and the costs of change will be more than offset by the additional return. People engaged in helping farmers with economic decisions should recognize that managers vary in their ability and desire to react to change. Entrepreneurs who like and insist on frequent change may be instructed in the best way to achieve flexibility. Those who dislike constant change may be made aware of the long time outlook for various commodities. The dangers of an inflexible plant should be recognized since great loss may occur if a drastic change becomes necessary. In either case long run planning is necessary. In both instances the future is recognized as being uncertain; the difference is in the way the individual reacts to this uncertainty.

The extent to which individuals vary in their reaction to uncertainty may be a partial explanation of the present allocation of resources in agriculture. The reasons for this variability are many and stem from the psychological make-up of decision makers. Some of these reasons have been enumerated in a general fashion. It may be possible, however, to formulate certain principles somewhat more precisely than has been done previously.

Kalechi (14) has established the point that the discounting of future returns may be dependent upon the proportion of borrowed capital. According to this proposition, if a firm expands with the aid of borrowed capital, the chance of losing its own capital increases. That is, if the owned capital becomes a smaller proportion of the total, a given percentage loss of the total assets would reduce the owned assets in a progressively greater fashion. This may mean that the amount of capital applied may vary according to the amount of owned capital of the entrepreneur. This may partially explain both internal and external capital rationing. A borrower may find it increasingly difficult to acquire additional funds since his equity may continuously decline. An entrepreneur may be unwilling to borrow additional funds if the chance of losing all his holdings becomes progressively greater.

The presence of uncertainty and the entrepreneur's reaction to it may partially explain the present size of farms in the United States. On the basis of static analysis constant returns to scale would be the only explanation for the fact that farms of various sizes exist side by side. Since constant returns to scale can exist only if management is not considered a variable, the explanation would be that managers of different ability must be the explanation of the variation of the size of farms. Under conditions of uncertainty entrepreneurs may differ in their uncertainty aversion. As a result inputs may vary widely from individual to individual depending upon his subjective evaluation of the unknown.

Precautions Available to the Farm Firm

It is under conditions of uncertainty that the functions of the entrepreneur become important. The making of decisions under conditions of imperfect knowledge has some of the characteristics of gambling where the willingness to take chances, a knowledge of probability, and the ability to make decisions are necessary. It has been pointed out previously that the entrepreneur is conditioned as to his ends by the household of which he is a member and by his personal characteristics relating to uncertainty and the unknown. If the entrepreneur, for whatever reason, places a high value upon stability of income, he will desire a production plan that will return him an income with relatively little variability although this may mean a lower average income over a period of years. Another individual may desire a high net income and be willing to accept considerable variability of that income. Under the highly variable weather conditions which exist in Western Kansas it is doubtful if it is possible to develop a farm organization which will insure low variability of income. Various measures exist, however, by which this variability may be reduced. On the other hand, since it is recognized that complete stability can never be achieved, an entrepreneur may desire an organization that is capable of rapid change. Such an organization may be developed on the assumption that in such an area the greatest profits are those of a windfall nature; and, therefore, it is these profits that must be pursued.

There does exist in practice and economic logic various methods which may be used to achieve these results under conditions of uncertainty; these methods may involve a choice between a level of income and variability of income. Flexibility may be a method of increasing average income, but it may also increase variability of income. Product diversification may be a method of reducing variability of income. Liquidity of assets, combining as it does some of the characteristics of both flexibility and diversification, is another precaution that may be taken. These methods of meeting uncertainty will be developed in turn.

Flexibility

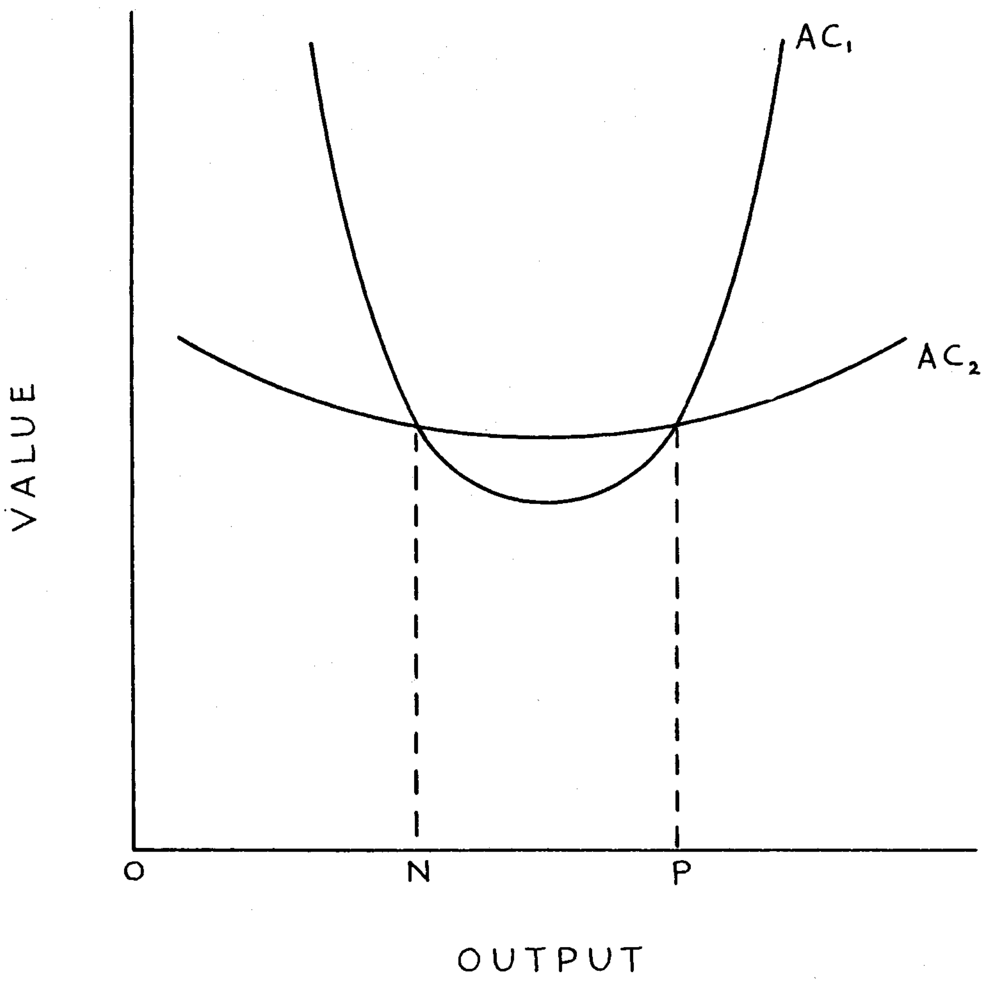
The purpose of flexibility is to organize production in such a way that decisions may be postponed until additional information is available. Such flexibility is usually available only at a cost, and to be justified it must be expected to return more than its cost. It will be noted that the definition is sufficiently general so that there may be many facets to the application of the concept.

Plant flexibility. One facet of the general concept of flexibility is plant flexibility. If there is a conflict between the flexible and non-flexible plant, the non-flexible or specialized plant will be the more efficient for a certain range of outputs. At outputs greater and less than this range the flexible plant is the more efficient. If it is known that the output will fall in the range where the specialized plant is the more efficient, then the specialized plant is the one which will be used. It may not, however, be possible to tell at the time the plant is designed just what the output will be. If it is probable that the output will frequently fall outside the range where the specialized plant is the more efficient, then there will be an issue involved. The cost of the flexible plant is the less efficient production for those outputs that a specialized plant could produce more efficiently.

The logic of plant flexibility is illustrated in Figure 2. AC_1 is the average cost curve for a specialized plant. AC_2 is the average cost curve for a non-specialized or flexible plant. For outputs ON to OP the specialized plant is the more efficient. For outputs less than ON or more than OP the flexible plant is the more efficient. If it is known that output will fall in the ON - OP interval, the specialized plant will be chosen. If the output is not known, it may be rational to choose the flexible plant. Such a decision would involve giving up the more efficient production of the specialized plant for certain outputs because of the possibility that output may be less than ON or greater than OP.

A farm organization equipped to handle 1,000 acres of wheat land will probably have a lower unit cost of production for that 1,000 acres and the forthcoming product than would an organization designed to handle an acreage ranging from 800 to 1,500 acres. In times of high prices and good crop years a farmer may desire to expand operations to 1,500 acres. If the situation is unfavorable, he may wish to contract operations to a basic unit of 800 acres. If he is a

Figure 2. Average Cost Curves for Specialized
and Non-Specialized Plants.



AC_1
AC_2
VALUE
O
N
P
OUTPUT

tenant farmer with a planning period of more than one year, annual rent payments are a variable cost. This variable cost may be lessened by reducing the number of acres farmed. This has implications regarding the equipment with which he supplies himself. If he knows that he will be harvesting 1,000 acres of wheat every year, he may decide he should purchase a combine of a certain size. If the acreage he will be farming is uncertain, he may decide to rely upon custom combining. Another example might be in the size of equipment purchased. The specialized plant would be typified by smaller machines than would the flexible plant if the entrepreneur thought the possibility of farming more than 1,000 acres was greater than that of farming less than 1,000 acres. The same analysis can be applied to the renting and owning of land. The renter may be in a better position to expand and contract than the owner. Serious financial loss may result for the large land owner who attempts to contract during depressed agricultural conditions. On the other hand, it may be difficult for the renter to expand in periods of prosperity when the competition for land is keen. On balance, however, it would seem that the renter would have greater flexibility.

If livestock is introduced into a farm organization under conditions of uncertainty, certain plant flexibility implications are present. If it is decided to produce pork, it may be that for a particular output which would be dependent upon a definite feed supply a breeding herd would be the least cost plan. However if the feed supply were smaller or greater than this amount, a feeder pig purchase program might be a more efficient method for the smaller or larger pork output as the case might be. A feeder pig purchase program would then allow for a greater flexibility in output.

The same reasoning can be applied to cattle and sheep. Feeding programs that permit the entrepreneur to wait until information regarding his feed supply is available and then to determine his output may permit lower costs for many outputs. This might not be the case if a definite feed supply were certain. In this case a breeding herd of cows or ewes might be the low cost method of production. If the feed supply fell extremely low, however, severe losses might be suffered since attention would need to be given to the maintenance of the breeding herd. It would also be difficult to expand rapidly if conditions were favorable.

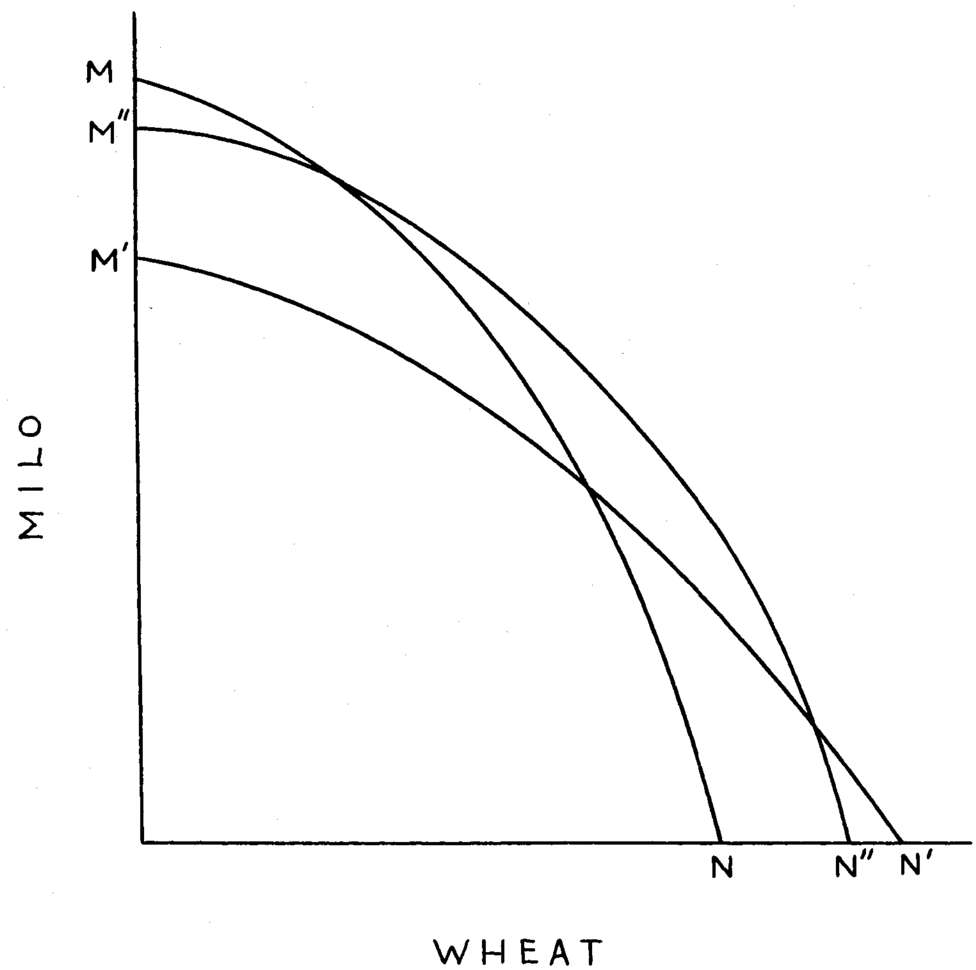
The above analysis regarding livestock is based upon a variable feed supply. The variability of the feed supply may be reduced or eliminated by storage. A knowledge of the long time average yield would be necessary to select the size of herd or flock that would utilize this feed. Certain objections may be raised to this plan. One is that an individual starting in business may not have the necessary reserve to carry his herd or flock through one or more poor years. The other objection is that it is impossible to store certain kinds of feeds such as pasture. Stored roughage supplemented with grain, either stored or purchased, probably would be an expensive substitute for pasture. In addition, if a positive time preference exists, returns for the future must be discounted for the present. The extent to which future returns are discounted will determine the costs of the storage. If these costs are not included, the resulting cost of the specialized plant may not be realistic. This has important implications where capital rationing is severe and the resulting productivity of capital is high. Budgeting procedures, which charge the capital at some fixed interest charge, may be seriously under estimating the true productivity of the capital which is rendered inactive by feed storage. This point will be considered again under the section on liquidity.

Product flexibility. Flexibility of output is one aspect of the concept of flexibility which may be extended in many directions. Product flexibility is another facet which flexible planning may take. Product flexibility may be defined as the organization of the producing plant so that when changes are made in the combinations of products, the resulting output may be produced more efficiently than if the change were made from a specialized plant designed for a particular combination of products. The logic may be demonstrated by reference to Figure 3.

Let MN be the transformation curve for wheat and milo when resources have been committed for the purpose of specialized milo production. M'N' is the transformation curve when the plant has been designed for specialized wheat production. It may, however, be possible to design a plant so that M"N" is the transformation curve. As drawn this transformation curve is the more efficient for producing many of the possible combinations of wheat and milo. Widely fluctuating price ratios may make such a plant desirable. The cost of such flexibility to the specialized milo producer is the amount MM". If this amount is small, the advantage for the dual purpose plant is greater.

The application of the above to the Western Kansas farm would probably lie in the choice of machinery and the design of buildings. General purpose tractors and all crop harvesters would be examples of equipment which would be included in the flexible plant. Machinery selected to farm both row and drilled crops are of a flexible nature. Further application might be in the design of machine sheds so that they may be adapted to the production of livestock. Electric fences are another example of a resource that may be used for various enterprises.

Figure 3. Transformation Curves for Specialized and Non-Specialized Plants.


M
M″
M′
MILO
N
N″
N′
WHEAT

<u>Contractual flexibility</u>. It is possible to acquire the factors of production in agriculture by various means. Land may be acquired either by renting or by buying. The form of rental customarily is in cash or a share of the crop. Labor may be contracted by the day, month, or year; and there is flexibility as to the length of time for which capital may be borrowed. When these arrangements are classified on the basis of flexibility, certain relationships, advantages, and disadvantages become apparent.

The renting of land has certain advantages from the standpoint of flexibility because it permits rapid contraction and expansion when desired. In addition there is the contractual advantage in length of time. Customary rental contracts are for one year. Land which is purchased with the assets of the entrepreneur has no contract attached, and the only limitation is the ease or difficulty involved in disposing of the land. However, if the land is acquired with the aid of a mortgage, the implications are quite different depending upon the length of the mortgage. Land, purchased with a mortgage on the basis of the capitalized value of the expected future stream of surpluses, may represent a rigid commitment that will be difficult to meet if either prices or yields are less than those expected when the capitalization process took place. When land is purchased with a mortgage, the buyer faces the possibility of either a lower price level or lower yields than those used in the capitalization process. The only way this could be avoided would be to go to the absolute lower extreme, and it is doubtful if a seller could be found under these circumstances. The result of the above is that the encumbered owner is more likely to reap windfall gains and losses than the renter.

Custom hiring of machine work versus ownership is of the same general nature of contractual arrangement. Owning may be the least cost method of the performance of a particular piece of work - if the work actually has to be performed. When there is no crop to harvest, the combine must still suffer depreciation and obsolescence.

If resources could be used with equal efficiency in alternative enterprises, complete flexibility would be more desirable in an area where future outcomes are uncertain. It has been pointed out in the previous section, however, that once resources are committed to some particular combination of products, it is not possible to follow the original planning curve in production. The relevant problem then becomes one of weighing the costs of flexibility against the opportunities which present themselves as more information becomes available. The issue is not one of planning. Flexible farming may embody a very high caliber of planning. It may involve the careful selection of a physical plant so that change can be made rapidly and efficiently. It requires an entrepreneur willing and able to make a considerable number of decisions. When a change is made in an organization to take advantage of additional information, it may not be a drastic change involving great cost but one the possibility of which was taken into account when the basic physical plant was designed. Foresight and planning are necessary in flexible farming, but no attempt is made to estimate the exact conditions for the distant future. It involves a recognition of the fact that knowledge concerning the distant future is inadequate. It also involves the rejection of detailed plans based upon the assumption of adequate knowledge of the future. Hart (7, p. 81) makes the point as follows:

> Two fairly general conclusions about rational planning and estimation flow from these considerations. The first is that it is likely to be irrational to have the general framework of the firm's plan continuously under revision, since to do so requires continuous attention from a number of the firm's leaders to the sacrifice of important details. Furthermore, some at least of the planning personnel are likely to be directors or consultants with outside interests which prevent their being in continuous touch. Prudence will ordinarily leave adaptations to unexpected conditions up to a certain magnitude to subordinates, without continuous co-ordination. General revision needs to be undertaken only when the drift of market conditions away from expectations has accumulated to a serious extent -- ordinarily a periodic meeting for planning will provide adequately for this -- or when a major emergency comes up.

> The second conclusion is that detailed estimation and planning for dates beyond the very nearest future is likely to be wasted effort. Even the course of events considered "most probable" will certainly diverge so from reality that all details of plans based upon it will have to be re-worked. It is better economy to lay out the broad outlines of estimates and plans for the distant future, concentrating attention on fields relating to durable equipment whose acquisition must soon be considered. Somewhat more detailed plans are appropriate for the middle future (say a year or two ahead): and full detail is appropriate only for periods so short that losses from recasting plans are likely to outweigh losses from following faulty plans.

The application of the above analysis to Western Kansas conditions would involve the sparing use of detailed plans for the distant future. Even within the year it is possible for decision making to be used to a considerable extent. The possibilities of this will be considered more fully later. The premium should be placed upon flexibility for the intermediate planning period. This is the period for which machinery must be selected and long time enterprises chosen. It is in this latter aspect of planning that the premium should be on flexibility. It is true that some one production plan needs to be chosen. There will be a difference in the organization, however, if it is thought that this production plan will be adhered to throughout the life of the business as contrasted with the realization that the plan will be modified as knowledge changes. The latter type of activity might be characterized as planning for change. The former would be planning in the belief that an organization designed to produce a specific combination of products adhered to for a long enough period would yield the most satisfactory income. Flexible farming then would be characterized by dual-purpose tractors, rented land, custom hired machines, and the presence of livestock programs, if any are included, whose inputs come late in the production process. The opposite type of activity would call for specialized machines, little hiring of the factors of production, and little if any shift in the combination of products from time to time.

Liquidity

Liquidity may be defined as the characteristic of an asset that permits it to be transformed into or exchanged easily for cash. General acceptability is a necessary characteristic of a liquid asset. Money is the most liquid of all assets followed in liquidity by those assets that can be exchanged for or transformed into money easily. One would therefore expect products to be more liquid than factors since the sale of factors would alter the operation of a plant and since the transformation into products can only take place with the passage of time. A ready market may not exist for certain specialized factors which have been adapted to a particular plant. When technical and market conditions are uncertain, considerable premium may be placed upon assets that can be characterized as liquid. If such uncertainty exists, a premium may be placed upon highly liquid assets so that they may be drawn upon for either household withdrawals or production expenses. When the market is uncertain, liquid assets may be held to permit quick transfer into cash when additional information becomes available.

Boulding (2, p. 48) has developed the preferred asset ratio which is the proportion of the value of the total assets which an individual wishes to hold in some particular form. The sum of these ratios for all assets must equal one. Suppose that an individual has two commodities X and Y. If the preferred asset ratio for X is r, then the preferred asset ratio for Y must be 1 - r. Then, if X is money

$$\frac{X}{X + PY} = r \qquad \text{or} \qquad X = \frac{Pr}{1 - r} Y$$

where P is the price of Y. These preferred asset ratios will be affected by the expectation of the holder and will change as his expectations change. Exchange is then to be viewed as a means of varying the proportion of assets with a constant total value.

Hicks (11, p. 205) has developed the elasticity of expectation as follows:

$$\frac{\text{Expected percentage change in future prices}}{\text{Expected percentage change in present prices}}$$

This ratio may be used as an index of the way the demand for various kinds of assets may change. If the ratio is less than 1, it would mean that future prices are expected to change less than present prices. Under such circumstances an entrepreneur would not change his asset preference ratios. If the ratio is greater than 1, asset preference ratios would change. If future prices are expected to decline more than present prices, the preferred asset ratio for cash balances and bonds would increase. Cash would be expected to have a greater purchasing power in the future. This would also hold for the fixed yields of bonds. If future prices are expected to rise more than present prices, the preferred asset ratio for cash and bonds would fall since the expected purchasing power of the cash and bond yields would decline. Since the sum of the preferred asset ratios must equal one, there would be corresponding changes in the preferred asset ratios for other assets. The demand for physical commodities and stocks would change in the direction opposite to that for cash and bonds.

The carrying of feed reserves has been advocated as a means of meeting technical uncertainty in Western Kansas. The logic is that these reserves may be converted into a saleable product in the event of feed crop failures. Such a procedure would result in a more stable money income, but it may be expensive in real income. If the prices of products farmers sell fall more than the cost of factors farmers use in production, then real income will be reduced. If this were expected, real income could be raised and stabilized by selling in the period of excess feed production and holding cash reserves. If relative prices are expected to become more favorable to the producer, the holding of feed reserves may raise his real income as well as stabilize money income.

The costs of storage may be high, however, if the opportunity cost of the capital is calculated. If capital is rationed, its productivity in alternative uses will likely be high. Unless this opportunity cost is taken into consideration, the cost of storage and the effect on real income will not be realized in an ex ante sense. If the feed is in the form of grain, capital may be obtained through loans in the absence of capital rationing. If the stored feed is roughage, such a loan may not be forthcoming.

If the future were known with subjective certainty, the entrepreneur could base his decision upon expected production and the expected ratio of prices and costs. If the future is completely uncertain, there will be no basis for action unless one conceives of uncertainty as being a probability distribution of probability distributions. If the future is thought of in this fashion, a decision will be forthcoming. The procedure then would be to balance the expected gain or loss from a particular action with the degree of confidence in that particular outcome. The way the individual entrepreneur reacts to this type of situation will mean a unique solution for every individual. Hence in the real world individuals with identical physical resources may allocate them quite differently.

The above analysis indicates that either liquidity or illiquidity may be consistent with time diversification. If the desire is to stabilize income over time, this may be achieved either by holding cash or feed reserves. The particular form of the feed reserves may be either liquid or illiquid, depending upon whether it is grain or roughage.

On the other hand, one would expect a high proportion of liquid assets with a flexible organization. If the ability to move rapidly was thought to be highly desirable, a relatively high proportion of liquid assets would be necessary. If it were thought that additional land should be planted to wheat in the fall, it would be necessary to meet certain operating expenses. This would be in contrast to an inflexible system where the funds for operating expenses could be calculated with considerable accuracy well in advance.

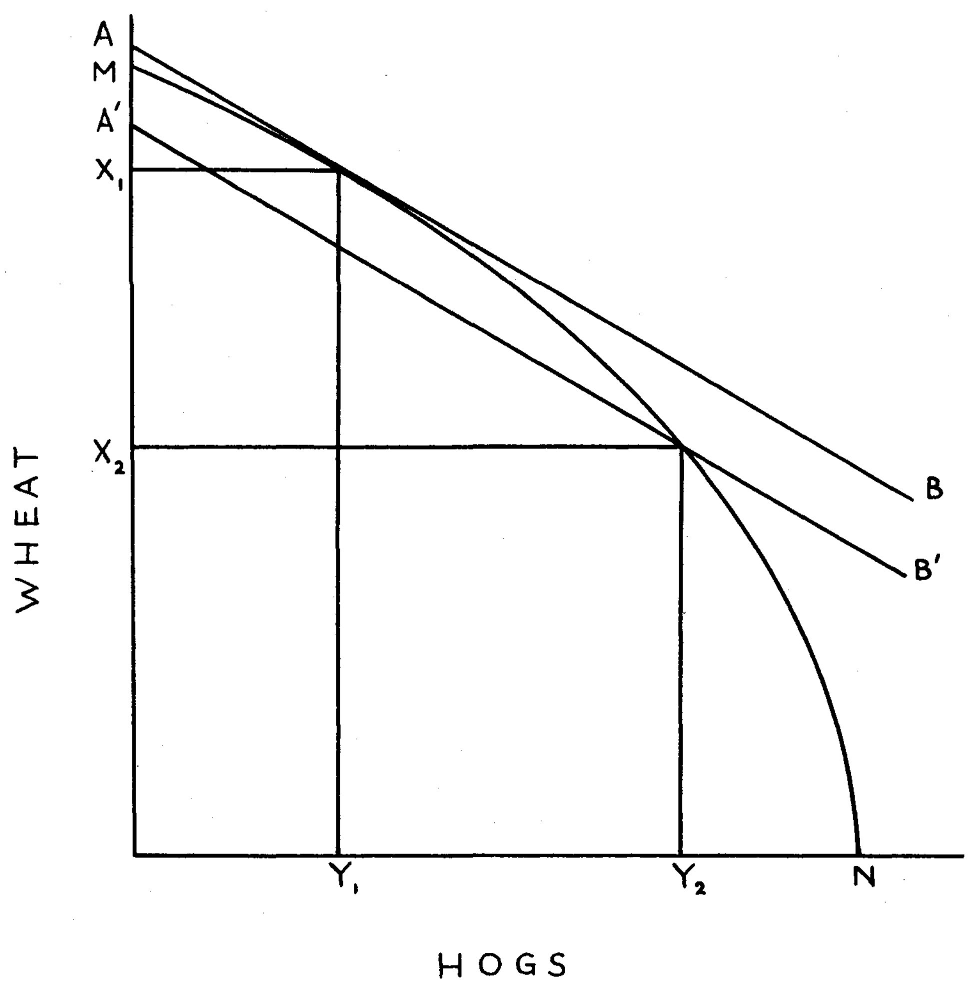
Diversification

The justification given for diversification in the Great Plains has been that such a procedure will reduce variability of income. Little attention has been paid as to whether or not such diversification will increase or decrease average income. The prevailing opinion is that wheat is the principal crop of the area and must therefore have a high comparative advantage. Even if this is so, there may be an advantage from diversification if it will reduce the variability of income.

The logic of the argument regarding the reduction of variability of income is presented in Figure 4. MN is the transformation or iso-resource curve between wheat and hogs. If AB and A'B' are iso-revenue curves reflecting the price ratio of wheat and hogs, it is apparent that the highest net income is to be realized by producing considerable wheat in relation to hogs (OX_1 of wheat, OY_1 of hogs). It may be, however, that AB has greater variability than A'B'. If this is the case, either combination may be chosen quite rationally depending upon the desires of the individual regarding variability and the level of his income.

It becomes important then in framing recommendations for farmers to know something about their reaction to uncertainty. If a farmer's indifference curve relating to this

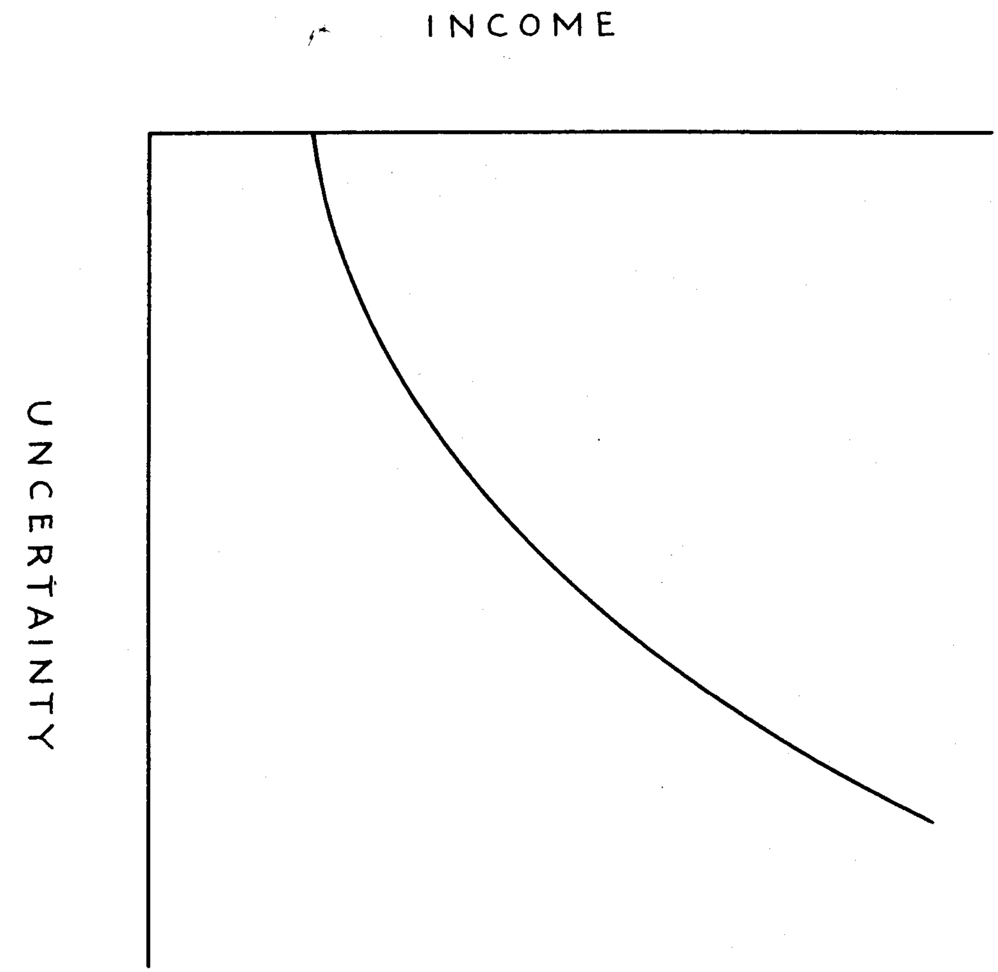
Figure 4. Production for Specialized and Diversified Plants.


A
M
A′
X₁
X₂
WHEAT
B
B′
Y₁
Y₂
N
HOGS

problem were of the nature as specified in Figure 5, a method which would insure stability at the expense of considerable income would be recommended. In this example the individual would be willing to give up considerable income if he could reduce his uncertainty by a small amount. Individuals vary, of course, in their willingness to accept uncertainty of income. It would be expected that individuals having a preference for uncertainty would tend to gravitate toward the Great Plains, and those having an aversion to such conditions would tend to leave. If it is the function of the experiment stations to frame recommendations for farmer acceptance, some knowledge of farmer ends must be known. Otherwise alternatives or cause and effect relationships are the only information that should be disseminated. It was noted earlier that individual ends may and probably do vary. If so, there would be no one recommendation that would fit all people. However, there may be people who have similar ends and would view the uncertain future in approximately the same fashion. If the frequency distribution of people in relation to their ends were known, the problem would be greatly simplified.

If the problem is viewed from the standpoint of society as a whole the indifference curve of the individual may not be given paramount importance unless such individual preferences prevented the attainment of society's ends. If the

Figure 5. Indifference Curve Relating Income and Uncertainty.


INCOME
UNCERTAINTY

farmers of the Great Plains choose to produce OX_2 of wheat and OY_2 of hogs (Figure 4) because of uncertainty aversion, then they are not producing as society would have them produce as reflected in the price ratios of the two commodities. This represents an inefficient use of resources from society's standpoint. It may be that society would be better off and the farmer as well off if he were to produce OX_1 of wheat and OY_1 of hogs with society guaranteeing a certain minimum income every year. It is in this framework that the subsidization of a crop or income insurance program might be analyzed.

The logic of the combination of enterprises for the purpose of reducing variability may be illustrated by means of the following model:

$$V_{\left(\frac{x + y}{2}\right)} = (1/2)^2 \left[V_x + V_y + 2rs_x s_y\right] \qquad (1)$$

where V = variance

X = one enterprise

Y = another enterprise

r = correlation coefficient between enterprises

s = standard deviation.

If two enterprises have equal variances and the correlation coefficient is zero, the combined variance will be one-half of either alone. If a third enterprise were added having a variance equal to each of the others and a correlation coefficient of zero with each of the others, the combined variance would be one-third of either alone. Whether or not the addition of an enterprise will reduce variability will depend upon the variance of the original enterprise as compared with the variance of the added enterprise, and upon the degree of association or correlation of the returns of the two enterprises.

The following model comes from the less general formulation presented previously:

$$V_T = V_x + V_y + 2rs_xs_y. \qquad (2)$$

This would apply if additional resources were available so that an additional enterprise could be added. Equation (1) would apply if the existing resources had to be divided equally between the existing and the added enterprise. Equation (2) simplifies to

$$r = \frac{V_T - V_x - V_y.}{2s_xs_y} \qquad (3)$$

If two enterprises have equal variances, the correlation coefficient must be less than -0.5 if the total variability is to be reduced. Since

$$V_x = V_y \qquad s_ys_x = V_x \qquad r = \frac{V_T}{2V_x} - 1. \qquad (4)$$

If $\frac{V_T}{V_x} = 1; \quad r = -0.5.$

this is not the case, however, where the resources are divided equally between the existing and the additional enterprise because equation (1) simplifies to

$$r = \frac{4V\left(\frac{x + y}{2}\right) - V_x - V_y}{2s_x s_y} \qquad (5)$$

Let $V_x = V_y$ and $s_x s_y = V_x$

$$r = \frac{2V\left(\frac{x + y}{2}\right)}{V_x} - 1. \qquad (6)$$

If $\frac{V\left(\frac{x + y}{2}\right)}{V_x} = 1; \quad r = 1.$

It may be seen from (6) that a farm organization which must divide its resources equally among enterprises will reduce the variance by adding an enterprise with a variance equal to that of the existing enterprise and there is less than perfect correlation between the enterprises. If the added enterprise has a greater variance than the original enterprise, the correlation coefficient must be correspondingly lower. Suppose the variance of the added enterprise is twice that of the original enterprise.

$$r = \frac{4V_{\left(\frac{x + y}{2}\right)} - V_x - V_y}{2s_x s_y} \qquad (7)$$

Let $V_x = 0.5V_y$ and $s_y s_x = V_x V_y$

$$r = \frac{4V_{\left(\frac{x + y}{2}\right)} - 3V_x}{2.828V_x}.$$

If $V_{\left(\frac{x + y}{2}\right)} = V_x$; $r = \frac{1}{2.828}$ or 0.3536.

Under the above conditions if the added enterprise is to decrease the variance the correlation coefficient must be less than 0.3536. It may be seen from the above examples that it is possible to reduce variability of income by a combination of enterprises depending upon the relative magnitude of the variance and the degree of association of the existing and added enterprises.

EMPIRICAL ANALYSIS OF PRECAUTIONS AVAILABLE TO THE FARM FIRM

In the absence of information regarding the ends of society, investigation of the relationships specified in Figure 4 is a relevant research problem. It has been pointed out previously that it is not known if AB is actually higher in the plane than A'B'. Neither is it known that AB has a greater variability than A'B'. The nature of the transformation curve is also unknown. It seems reasonable to believe, however, that wheat is competitive with almost all other enterprises in the Great Plains. Certain supplementary features may be mentioned such as the use of labor and machinery. In the use of land most enterprises would be competitive. An exception to this would be a livestock enterprise that utilized only wheat pasture. Within limits pasturage will not affect wheat production. It is, however, difficult to find a livestock enterprise that does not demand other resources. A small flock of chickens which would utilize feed that would otherwise go to waste might be an exception. Labor is frequently an idle resource through many of the winter months, but labor must be used in combination with other resources. If the other resources are in short supply, competition rather than supplementarity becomes the relevant relationship. Off-the-farm employment may be supplementary to wheat production. In general, however, the assumption is made that wheat, on balance, is competitive with other enterprises in the Great Plains. The testing of this assumption would not be a fruitful procedure. Budgeting would not test the assumption because similar assumptions would need to be made in the construction of budgets. The problem of the investigator at this time is to compare the historical variance of points on the iso-revenue lines AB and A'B' and the variance of points on the transformation curve MN for various enterprises that might be combined with wheat in the Great Plains. In Western Kansas it is known that yields of various crops are highly associated. Since moisture is frequently the limiting factor for all crops, they tend to succeed and fail together. Prices are highly associated, also, and it would not appear that great advantage would be obtained from the addition of another enterprise for the purpose of reducing variability. An attempt was made to test this hypothesis on the basis of historical data for both prices and yields. The effect of the addition of enterprises upon the variability of both physical production and gross income was tested.

The source of the physical data was the experiment station reports of the Colby and Garden City Stations. Data were available which indicated the yields of various crops on fallowed and continuously cropped land extending back to 1914. The Colby Station is located in the northwest part of the state of Kansas. The Garden City Station typifies the southwest part of Kansas. It is believed that historical data for this period will indicate the relative response of various crops to physical and biological conditions which have prevailed in these areas. Question can be raised, however, as to how good a sample in time the past thirty-five years have been. This period includes the drouth of the 1930's together with the good crop years of the 1940's. It seems to be the only basis for anticipating the future, however, in the absence of any meteorological theory which would explain weather cycles or which will aid in long range prediction.

Product Diversification at the Garden City Kansas Experiment Station

Reference to Table 6 indicates the degree of association of various crops for which data were available at the Garden City Station. Data were available for the Garden City Station from 1914 to 1941 for wheat, milo, and kafir. Data on kafir production was not available beyond 1941. Wheat and milo have a correlation coefficient of 0.247. If the variance of the two crops were equal, any correlation coefficient less than 1 would reduce variability. The problem is complicated by the fact that the pound production of milo is greater than that of wheat. This does not permit the direct comparison of the two variances. The coefficient of variation for wheat is 110.3 while the coefficient of variance

Table 6

Correlation Coefficients, Coefficients of Variation, Average Yield, Variance, and Standard Deviation of Various Crops at the Garden City Kansas Experiment Station for the Years 1914-1941

	Wheat	Milo	Kafir grain	Kafir forage
Wheat	1.00	0.247	0.544	0.438
Milo		1.00	0.922	0.748
Kafir grain			1.00	0.802
Kafir forage				1.00
Coefficient of variation	110.3	90.5	92.3	58.06
Average yield in pounds	616.8	1383.5	1086.8	3730
Variance in pounds	463339.9	1571529.4	1006701.9	4698064
Standard deviation in pounds	680.8	1252.8	1003.3	2166

of milo is somewhat less (90.5). The correlation coefficient between wheat and kafir grain is 0.544. Kafir grain has a coefficient of variation of 92.3. The correlation coefficient between kafir grain and milo is 0.922. Since both are sorghums and have similar growing seasons, a high correlation is to be expected. Kafir forage was more stable than the other products with a coefficient of variation of 58.6. The correlation coefficient between wheat and kafir forage was 0.438. It was more highly associated with milo since the correlation coefficient between the two was 0.748. The correlation coefficient between kafir grain and kafir forage was 0.802, indicating that in some years forage was produced when conditions were not favorable for kafir grain production.

As indicated above it is not possible to make a direct comparison of two variances of distributions which do not have equal means. If the standard deviation, the square root of the variance, is expressed as a percent of the mean, a measure in standard units is available. This will permit a comparison of two distributions with different means. This statistic, the coefficient of variation, cannot be tested for significance. This is a considerable handicap since the result cannot be stated with a probability level. The results must be interpreted subjectively. It is possible to treat this difficulty by assuming that one is not dealing with a sample in time but with a population. In this case one can state the results with a probability of one for this particular population. The purpose of research, however, is to predict the future. Therefore, a subjective interpretation must be given to the applicability of the past as a guide to the future. Whether or not society can look forward to a recurrence of the high technical variability which has existed in the Great Plains for the past three decades is a question which cannot be answered by an appeal to the facts that now exist. This is the basis upon which the empirical part of this study rests.

In Table 7 the variances were combined and the resulting coefficients of variation were calculated. The combination of wheat and milo had a smaller coefficient of variation than did either alone. This combination had a smaller coefficient of variation than did either the wheat-kafir combination or the wheat-milo-kafir combination. On the basis of physical production it does appear that the addition of milo to wheat would have the effect of decreasing the variability of the output. It does not appear that variability of physical production of this combination would be reduced by adding kafir grain. The addition of kafir forage to wheat does substantially reduce the coefficient of variation from that of wheat alone. This would suggest that a forage consuming livestock enterprise might serve to stabilize production as compared to that of wheat alone.

Table 7

Variance of Physical Production of Various Crop Combinations at the Garden City Kansas Experiment Station for the Years 1915-1948

Crop combination	Variance	Coefficient of variation
Wheat	463339.9	110.3
Milo	1571529.4	90.5
Kafir grain	1006701.9	92.3
Kafir forage	4698064.0	58.0
Wheat-milo	614094.9	78.4
Wheat-kafir grain	553277.7	87.3
Wheat-kafir forage	1611213.1	58.4
Wheat-milo-kafir grain	862.7	83.9
Wheat-milo-kafir forage	1834655.7	71.0

Price relationships were studied prior to the calculation of gross income for various enterprises. The correlation coefficients are presented in Table 8. The lowest correlation coefficient was between wheat and corn (0.636). The highest correlation coefficient was between wheat and hogs (0.975), indicating that on the basis of price there would be little reduction in variability by combining the two enterprises in relation to either alone. The significant point in regard to the correlation coefficients is the

Table 8

Correlation Coefficients, Coefficient of Variation, Average Price, Variance, and Standard Deviation of Price per Pound of Various Commodities for the Years 1926-1949[a]

	Wheat	Corn	Barley	Milo	Hogs	Cattle
Wheat	1.00	.635	.893	.794	.975	.896
Corn		1.00	.966	.972	.972	.875
Barley			1.00	.961	.831	.779
Milo				1.00	.853	.833
Hogs					1.00	.913
Cattle						1.00
Coefficient of variation	42.8	48.5	47.4	43.4	51.4	46.7
Average price per pound	.0222	.0165	.0162	.0167	.1164	.1032
Variance	.00009	.000063	.000059	.00005249	.00356722	.00232789
Standard deviation	.00949	.008	.00768	.00724	.0598	.0482

[a]Kelley, Gerber, & Foster (16, p. 84-87, 94-97)

high degree of association which exists among all prices. This would indicate that certain basic factors cause all prices to change in the same general direction.

There was a remarkable similarity of the coefficients of variation of the prices. Wheat had the lowest coefficient of variation (42.8). Hogs had the highest coefficient of variation (51.4). There does not appear to be any great advantage for any commodity on the basis of variability.

To measure the effect the addition of prices would have on variability, a similar analysis was made for the gross incomes at the Garden City Station. Hogs and cattle were brought into the analysis, and the production of livestock was made a function of kafir and milo production. The correlation coefficients are presented in Table 9. Here again the low correlation coefficient was between wheat and milo (0.526). The highest correlation coefficient was 0.930 between milo and hogs. This is to be expected in view of the fact that hogs were made a function of milo production. It is interesting to note that hogs had the highest coefficient of variation of 160.5. This was succeeded by wheat (126.0), milo (114.0), and cattle (76.9). The low variability of gross income from cattle may be explained by the fact that the output is dependent upon kafir forage. Reference to Table 7 will establish the relative stability of this crop.

Table 9

Correlation Coefficients, Coefficient of Variation, Average Gross Income, Variance, and Standard Deviation of Gross Income of Various Enterprises Based upon Yields at the Garden City Kansas Experiment Station 1925-1941

	Wheat	Milo	Hogs	Cattle
Wheat	1.00	.526	.622	.764
Milo		1.00	.930	.807
Hogs			1.00	.770
Cattle				1.00
Coefficient of variation	126.0	114.0	160.5	76.9
Average gross income	10.14	15.09	18.07	22.50
Variance	171.50	295.88	840.18	300.57
Standard deviation	13.1	17.2	29.0	17.3

In Table 10 the results of the combination of the various enterprises are presented to show the effect such combination would have upon the variability of the gross income. The addition of either milo or cattle to wheat reduced the variability of income as measured by the coefficient of variation. The wheat-milo-cattle combination had a lower coefficient of variation than did the wheat-milo-cattle-hog combination. The addition of hogs increased the coefficient of variation while

Table 10

Variance of Gross Income of Various Enterprise Combinations at the Garden City Kansas Experiment Station for the Years 1925-1941

Enterprise combination	Variance	Coefficient of variation
Wheat	161.4	126.0
Milo	278.4	114.0
Hogs	790.7	160.5
Cattle	282.8	76.9
Wheat-milo	165.7	102.0
Wheat-hogs	349.1	132.5
Wheat-cattle	192.7	85.0
Wheat-milo-hogs	307.8	121.7
Wheat-milo-cattle	171.6	87.0
Wheat-milo-cattle-hogs	285.0	103.9

the addition of cattle reduced such variation. This is to be expected in comparing the coefficient of variation of cattle (76.9) to that of hogs (160.5).

On the basis of both physical production and gross income it does appear that variability of gross returns can be reduced by the addition of enterprises to that of straight wheat production. There does not appear to be a reduction in variability by the addition of more than one enterprise to that of wheat. The greatest reduction occurs with the addition of cattle. In fact, the addition of hogs at any stage increased variability.

Implicit in the preceding analysis has been the assumption that variability is a measure of uncertainty. To the extent that this is not so, the combination of variances is not a true measure of the advantages of diversification in the reduction of uncertainty. It is possible that while total variability may not be substantially decreased by diversification, complete crop failures or disasters may be avoided. It may be that while total reduction in variability is not large, the reduction in variability that does occur is important. To test this hypothesis, a frequency distribution of crop yields was prepared. These data are presented in Table 11. Both wheat and kafir distributions were improved by the addition of other enterprises since the number of yields in the 0 - 4.9 category were reduced. Little seemed to be gained by the addition of other crops to the production of milo. Not only is milo the most stable of the grain crops (as measured by the coefficient of variation) but also it appears to have a smaller number of poor crop years that might be called complete crop failures.

Table 12 has been presented to show the effect of diversification on the distribution of gross income among

Table 11

Frequency Distribution of Yields by Years for
the Garden City Kansas Experiment Station
1914-1941

Bushels per acre	Wheat	Milo	Kafir	Wheat-milo	Wheat-kafir	Wheat-milo-kafir
			(Number of occurrences)			
0 - 4.9	12	7	10	7	8	7
5 - 9.9	4	4	1	2	2	4
10 - 14.9	2	1	1	4	5	2
15 - 19.9	3	2	3	2	3	2
20 - 24.9	3	-	3	5	5	4
25 - 29.9	1	3	2	1	1	3
30 - 34.9	3	1	2	3	1	1
35 - 39.9	-	3	1	2	3	1
40 - 44.9	-	2	1	2	-	4
45 - 49.9	-	1	2	-	-	-
50 & over	-	4	2	-	-	-
Total	28	28	28	28	28	28
			(Per cent)			
0 - 4.9	43	25	36	25	29	25
5 - 9.9	14	14	3	7	7	14
10 - 14.9	7	3	3	14	18	7
15 - 19.9	11	7	11	7	11	7
20 - 24.9	11	-	11	18	18	14
25 - 29.9	3	11	7	4	3	11
30 - 34.9	11	4	7	11	3	4
35 - 39.9	-	11	4	7	11	4
40 - 39.9	-	7	4	7	-	14
45 - 44.9	-	4	7	-	-	-
50 & over	-	14	7	-	-	-
Total	100	100	100	100	100	100

Table 12

Frequency Distribution of Gross Income
of Various Enterprise Combinations
at the Garden City Kansas Experiment Station
1925-1941

	Gross income in dollars per acre						
	0- 4.9	5- 9.9	10- 19.9	20- 29.9	30- 39.9	40- 49.9	50 & over
	(Number of occurrences)						
Wheat	11	0	2	2	2	0	0
Milo	6	2	3	3	2	0	1
Cattle	3	1	5	3	2	2	1
Hogs	6	1	4	0	0	3	3
Wheat-milo	7	2	2	4	2	0	0
Wheat-cattle	4	3	4	3	2	1	0
Wheat-hogs	6	2	2	2	1	4	0
Wheat-milo-cattle	6	0	5	3	2	1	0
Wheat-milo-hogs	6	1	3	2	3	1	1
Wheat-milo-cattle-hogs	6	0	4	2	3	2	0
	(Per cent)						
Wheat	64	0	12	12	12	0	0
Milo	35	12	18	18	12	0	0
Cattle	18	6	29	18	12	12	6
Hogs	35	6	28	0	0	18	18
Wheat-milo	41	12	12	24	12	0	0
Wheat-cattle	24	18	24	18	12	6	0
Wheat-hogs	35	12	12	12	6	24	0
Wheat-milo-cattle	35	0	29	18	12	6	0
Wheat-milo-hogs	35	6	18	12	18	6	6
Wheat-milo-cattle-hogs	35	0	24	12	18	12	0

years. It is interesting to note that wheat has the greatest number of observations in the 0 - 4.9 interval. When interpreting the data in Table 12, it must be borne in mind that the data are gross income. As a result livestock would appear in a favorable position relative to crops. Wheat and milo, however, had a smaller number in the lowest interval than did wheat alone.

Product Diversification at the Colby Kansas Experiment Station

In Table 13 the degree of association of physical production of various crops at the Colby Station is presented. Barley and kafir forage have the lowest correlation coefficient (0.397). Barley and wheat, however, had the highest correlation coefficient (0.796). The correlation coefficient of wheat and milo was 0.643. The coefficient of variation of kafir forage was the lowest (44.7). This was followed by wheat with a coefficient of variation of 59.9. The coefficients of variation for the other crops were substantially greater.

Due to this greater variability of crops other than wheat and to the high degree of association among the various crops, the addition of crops to that of straight wheat did not reduce the variability of physical production (Table 14).

Table 13

Correlation Coefficients, Coefficient of Variation, Average Yield, Variance, and Standard Deviation of Various Crops at the Colby Kansas Experiment Station for the Years 1915-1949

(Pounds per product per acre)

	Wheat	Corn	Barley	Milo	Kafir forage
Wheat	1.00	.681	.796	.643	.609
Corn		1.00	.695	.637	.552
Barley			1.00	.568	.397
Milo				1.00	.629
Kafir forage					1.00
Coefficient of variation	59.9	79.6	72.7	71.7	44.7
Average yield in pounds	1250	1207	1310	1427	5190
Variance in pounds	562409	924348	906647	1046966	5349342
Standard deviation in pounds	749.9	961.4	952.2	1023.2	2312.9

Table 14

Variance of Various Crop Combinations at the Colby Kansas Experiment Station for the Years 1916-1949

Crop combination	Variance	Coefficient of variation
Wheat	562409	59.9
Milo	1046966	71.7
Barley	906647	72.7
Corn	924348	79.6
Wheat-milo	649046	60.2
Wheat-barley	651109	63.9
Wheat-corn	615559	63.8
Wheat-milo-corn	638811	61.7
Wheat-milo-barley	591422	57.9
Wheat-milo-barley-corn	609461	60.0

This is in contrast to the Garden City data. Comparison between the two stations at this point is not accurate because of the difference in periods covered. Data at the Garden City Station were available only to 1941 while Colby data were available to 1949. This would have the effect of making the Garden City data more variable. On the basis of these data there does not appear to be any significant effect on the variability of physical production by the addition of crops to that of straight wheat production.

A similar analysis was made for gross income at the Colby Station (Table 15). The degree of association of the gross income of the various crops is made evident by observation of the correlation coefficients. The lowest correlation coefficient was between wheat and corn (0.676) while the highest correlation coefficient was between corn and milo (0.898). The other correlation coefficients ranged between 0.720 and 0.868. Barley had the highest coefficient of variation (101.0). Cattle again had the lowest coefficient of variation (68.2). In contrast with the relatively low coefficient of variation of wheat yields (59.9) the coefficient of variation of gross income of wheat was relatively high (89.7).

The results of the combination of the various enterprises are presented in Table 16. The coefficient of variation of wheat alone is reduced by the addition of either cattle or milo. The lowest coefficient of variation was that of the wheat-milo-cattle combination (72.2). On the basis of these data the conclusion is that the addition of either milo or cattle or both would reduce the variability of gross income. This reduction does not appear to be large, however.

Table 15

Correlation Coefficients, Coefficient of Variation, Average Gross Income, Variance, and Standard Deviation of Gross Income per Acre of Various Enterprises Based upon Yields at the Colby Kansas Experiment Station 1926-1949

	Wheat	Corn	Barley	Milo	Hogs	Cattle
Wheat	1.00	.676	.868	.743	.980	.793
Corn		1.00	.789	.898	.766	.734
Barley			1.00	.757	.791	.786
Milo				1.00	.756	.720
Hogs					1.00	.832
Cattle						1.00
Coefficient of variation	89.7	97.2	101.0	81.4	95.4	68.2
Average gross income	27.86	17.38	19.17	22.17	37.11	36.31
Variance	624.24	286.57	423.00	325.74	1255.36	623.19
Standard deviation	24.99	16.90	20.56	18.04	35.40	24.76

Table 16

Variance of Gross Income of Various Enterprise Combinations at the Colby Kansas Experiment Station for the Years 1926-1949

Enterprise combination	Variance	Coefficient of variation
Wheat	624.2	89.7
Milo	325.7	81.3
Barley	423.0	101.0
Corn	286.5	97.2
Hogs	1255.3	95.3
Cattle	623.1	68.1
Wheat-milo	405.0	80.4
Wheat-barley	484.8	94.0
Wheat-corn	370.6	85.1
Wheat-hogs	903.6	92.5
Wheat-cattle	561.6	73.8
Wheat-milo-barley	388.5	85.4
Wheat-milo-corn	334.1	80.5
Wheat-milo-cattle	432.3	72.2
Wheat-milo-hogs	619.2	85.6
Wheat-milo-barley-corn	340.7	85.2

Combination of enterprises does not substantially affect the distribution of yields at the Colby Station. Reference to Table 15, however, will indicate that the wheat-milo combination reduced the number of years yields were less than five bushels per acre from that of either wheat or milo alone. It also reduced the number of years that yields exceeded 50 bushels per acre. The effect of this combination was to decrease the range and variance from milo alone (Table 17) and increase the variance and range from wheat alone. The combinations did, however, reduce the number of years there was a complete crop failure. Only in the case of wheat and barley was the number of complete crop failures as great as for the individual original enterprises.

To facilitate further comparison Table 18 was prepared. The following combinations reduced the number of years that gross income was less than five dollars per acre from that of wheat alone: wheat-milo, wheat-hogs, wheat-cattle, wheat-milo-cattle, and wheat-milo-hogs. On the basis of these data variability of gross income may be reduced and the possibility of complete failures reduced by the addition of enterprises to that of wheat alone. This reduction is not large, but it may occur in strategic years.

Table 17

Frequency Distribution of Yields by Years
for the Colby Kansas Experiment Station
1926-1949

Bushels per acre	Wheat	Milo	Corn	Barley	Wheat Milo	Wheat Corn	Wheat Barley	Wheat Milo Corn Barley
				(Number of occurrences)				
0	3	5	5	5	2	1	3	1
0 - 4.9	5	5	7	8	3	3	4	5
5 - 9.9	3	0	1	5	4	5	6	2
10 - 14.9	1	3	1	1	3	2	2	3
15 - 19.9	3	3	4	3	1	3	3	1
20 - 24.9	3	1	4	2	1	2	3	5
25 - 29.9	3	2	2	2	6	6	2	4
30 - 34.9	3	3	3	1	0	1	2	3
35 - 39.9	3	3	2	1	5	2	1	0
40 - 44.9	0	1	0	0	1	0	1	1
45 & over	0	3	0	1	0	0	0	0
Total	24	24	24	24	24	24	24	24
				(Per cent)				
0 - 4.9	21	21	29	34	13	13	17	21
5 - 9.9	13	0	4	21	17	21	25	8
10 - 14.9	4	13	4	4	13	8	8	13
15 - 19.9	13	13	17	13	4	13	13	4
20 - 24.9	13	4	17	8	4	8	13	21
25 - 29.9	13	8	8	8	25	25	8	17
30 - 34.9	13	13	13	4	0	4	8	13
35 - 39.9	13	13	8	4	21	8	4	0
40 - 44.9	0	4	0	0	4	0	4	4
45 & over	0	13	0	4	0	0	0	0
Total	100	100	100	100	100	100	100	100

Table 18

Frequency Distribution of Gross Income by Years
for the Colby Kansas Experiment Station
1926-1949

	Gross income									
	0- 4.9	5- 9.9	10- 19.9	20- 29.9	30- 39.9	40- 49.9	50- 59.9	60- 69.9	70 & Over	To- tal
	(Number of occurrences)									
Wheat	6	3	3	2	2	5	1	1	1	24
Milo	5	2	6	2	5	3	0	1	0	24
Corn	8	3	3	5	3	1	0	1	0	24
Barley	9	2	4	4	2	0	1	1	1	24
Cattle	1	2	6	2	3	4	2	1	3	24
Hogs	4	4	2	2	2	1	4	2	3	24
Wheat-milo	4	5	3	3	3	2	3	1	0	24
Wheat-corn	7	1	4	4	2	3	2	1	0	24
Wheat-barley	6	3	4	3	3	3	0	1	1	24
Wheat-hogs	4	5	1	3	1	4	2	2	2	24
Wheat-cattle	2	1	8	2	3	3	4	0	1	24
Wheat-milo-cattle	2	4	5	1	5	2	4	0	1	24
Wheat-milo-hogs	3	6	1	4	2	2	3	2	1	24
Wheat-milo-corn-barley	6	3	2	5	4	1	2	1	0	24

continued

Table 18 continued

	Gross income									
	0- 4.9	5- 9.9	10- 19.9	20- 29.9	30- 39.9	40- 49.9	50- 59.9	60- 69.9	70 & Over	To- tal
	(Per cent)									
Wheat	25	13	13	8	8	21	4	4	4	100
Milo	21	8	25	8	21	13	0	4	0	100
Corn	33	13	13	21	13	4	0	4	0	100
Barley	37	8	17	17	8	0	4	4	4	100
Cattle	4	8	25	8	13	17	8	4	13	100
Hogs	17	17	8	8	8	4	17	8	13	100
Wheat-milo	17	21	12	12	13	8	13	4	0	100
Wheat-corn	29	4	17	17	8	13	8	4	0	100
Wheat-barley	25	13	17	13	13	13	0	4	4	100
Wheat-hogs	17	21	4	13	4	17	8	8	8	100
Wheat-cattle	8	4	33	8	13	13	17	0	4	100
Wheat-milo-cattle	8	17	21	4	21	8	17	0	4	100
Wheat-milo-hogs	13	25	4	17	8	8	13	8	4	100
Wheat-milo-corn-barley	25	13	8	21	17	4	8	4	0	100

Table 19

A Comparison of Gross Income in Various Years of
Certain Enterprises for Colby Kansas Experiment Station

Year	Wheat	Milo	Cattle
1926	28.00	0	9.45
1927	4.23	11.02	36.84
1928	49.86	17.54	43.27
1929	19.73	17.91	56.46
1930	34.60	38.79	20.80
1931	16.59	24.62	19.62
1932	17.55	17.96	18.35
1933	0	15.32	33.39
1934	9.48	0	17.53
1935	0	0	7.06
1936	0	0	4.97
1937	4.80	0	12.33
1938	7.73	7.13	15.07
1939	4.93	6.79	15.44
1940	5.77	13.50	21.08
1941	22.48	30.51	46.34
1942	30.54	22.00	72.84
1943	40.08	38.35	33.38
1944	54.38	45.83	55.13
1945	66.64	41.57	46.73
1946	48.81	38.92	46.84
1947	97.89	34.81	103.95
1948	47.96	63.66	64.53
1949	46.44	45.76	70.03

The practical importance of such a reduction may be visualized more adequately by observing Table 19. A straight wheat enterprise would have had no gross income in three years during the 1926-1949 period. A milo enterprise would have had a complete failure in five years. The cattle enterprise would have had no years in which there would have been a complete absence of gross income. The addition of milo to that of wheat would have resulted in only two years having a complete failure. The addition of cattle would have, of course, eliminated all years in which there would have been a complete failure. It should be borne in mind that the figures presented are gross figures. Since cost data were not available for this period, it is not possible to tell in what years variable costs would or would not have been covered.

Area Diversification

It is possible to achieve diversification by means other than producing a multiple number of products. Factor diversification does not appear to have great application to agriculture. Area diversification is possible, however, because producing plants may be located in different areas. To test the hypothesis that area diversification would reduce variability, the Colby and Garden City data were combined.

Table 20

Correlation Coefficients, Coefficient of Variation, Average Gross Income, Variance, and Standard Deviation of Gross Incomes of Various Enterprises Based upon Yields at the Colby and Garden City Kansas Experiment Stations 1925-1948

	Wheat (Colby)	Milo (Colby)	Wheat (Garden City)	Milo (Garden City)
Wheat(Colby)	1.00	.716	.864	.774
Milo(Colby)		1.00	.640	.640
Wheat(Garden City)			1.00	.526
Milo(Garden City)				1.00
Coefficient of variation	89.7	81.4	95.2	79.2
Average gross income	27.13	19.39	18.58	20.96
Variance	624.24	325.74	161.41	278.46
Standard deviation	24.98	18.05	17.70	16.61

The degree of association among the gross income of various products is shown in Table 20. The lowest correlation coefficient (0.526) was that of wheat (Garden City) and milo (Garden City). The highest correlation coefficient (0.864) was between wheat (Garden City) and wheat (Colby). It is interesting to compare the effect the addition of data for the years 1942 to 1948 had upon the variability of the Garden City data. The coefficient of variation for wheat was reduced from 126.0 to 95.2 and that for milo was reduced from 114.0 to 79.2. Crop production was much less variable for the six years which were not included in the one set of data.

In Table 21 the results of the combination of variances are presented. All of the resulting coefficients of variation were smaller than that of wheat alone at either of the stations. It is interesting to note that the lowest coefficient of variation (73.6) was for the Colby milo and Garden City wheat. A combination of all four crops, two at each station, showed a coefficient of variation of 74.6. On the basis of these data variability of gross income from straight wheat production at either station can be reduced by growing another crop at the other station. Again this reduction does not appear to be large, but it is of approximately the same relative magnitude as was caused by product diversification.

As a further illustration of the possibilities of area diversification Tables 22 and 23 have been prepared. Four counties bordering Thomas County were selected. Again the yields are highly correlated. Combination of county yields did not greatly influence the coefficient of variation. Two county combinations changed the Thomas County coefficient of variation in the direction of the coefficient of variation

Table 21

Variance of Gross Income of Various Enterprise Combinations at the Colby and Garden City Kansas Experiment Stations for the Years 1925-1948

Enterprise combination	Variance	Coefficient of variation
Wheat (Colby)	624.24	89.7
Wheat (Garden City)	161.41	95.2
Milo (Colby)	325.74	81.3
Milo (Garden City)	278.46	79.2
Wheat (Colby) + Wheat (Garden City)	342.54	80.9
Milo (Colby) + Wheat (Garden City)	194.91	73.6
Wheat (Colby) + Milo (Garden City)	387.00	86.0
Milo (Colby) + Milo (Garden City)	247.42	78.0
Wheat (Colby) + Wheat (Garden City) + Milo (Colby) + Milo (Garden City)	258.13	74.6

Table 22

Correlation Coefficients, Variance, Standard Deviation, and Coefficient of Variation and Average Wheat Yields for Five Selected Western Kansas Counties, 1914-1950[a]

	Thomas	Logan	Rawlins	Sherman	Sheridan
Thomas	1.00	.888	.927	.924	.978
Logan		1.00	.853	.886	.924
Rawlins			1.00	.934	.884
Sherman				1.00	.860
Sheridan					1.00
Coefficient of variation	70.8	78.8	57.6	69.6	73.3
Average (bushels)	9.6	8.0	11.8	10.2	9.0
Variance	49.5	39.1	45.8	51.0	43.5
Standard deviation	6.8	6.3	6.8	7.1	6.6

[a]Kansas State Board of Agriculture (15)

Table 23

Combination of Variances and Coefficients of Variation for Five Selected Western Kansas Counties[a] 1914-1950

County combination	Variance	Coefficient of variation
x_1	49.5	70.8
x_2	39.1	78.8
x_3	45.8	57.6
x_4	51.0	69.6
x_5	43.5	73.3
x_1 x_2	40.3	72.1
x_1 x_3	44.4	62.2
x_1 x_4	46.5	68.7
x_1 x_5	44.3	71.5
x_1 x_2 x_3	36.6	61.7
x_1 x_2 x_4	37.7	66.0
x_1 x_2 x_5	31.1	62.9
x_1 x_3 x_4	51.0	65.7
x_1 x_3 x_5	48.5	67.6
x_1 x_4 x_5	49.7	73.4
x_1 x_2 x_3 x_4 x_5	33.4	56.4

x_1 = Thomas x_2 = Logan x_3 = Rawlins

x_4 = Sherman x_5 = Sheridan

[a]Kansas State Board of Agriculture (15)

of the added county. Two of the three three-county combinations had a lower coefficient of variation than did Thomas County alone. There was a substantial reduction when all five counties were combined.

The above results would not apply to an individual farmer in Thomas County who would attempt to diversify by acquiring land in other counties. The data used were average county yields. Such data would show less variability than would individual farm data. Data were not available to measure the results of area diversification within a county. Such information would be of value to the individual farmer who might consider intra-county area diversification.

Flexibility

The purpose of this section is to relate the principles that have been developed regarding flexibility and diversification under conditions of technical and market uncertainty. The details of these precautions were developed separately. The question may be raised as to whether they are mutually exclusive or whether there is any possibility of using elements of both. It may be argued that they are opposites in nature; and, therefore, they cannot be combined. This argument would hold that the purpose of diversification, aside from complementarity and supplementarity, which were assumed as not being characteristic of enterprises in the area in question, is to reduce variability. On the other hand, flexibility may increase variability when there is rapid movement to take advantage of opportunities as they arise. Increased variability is not a necessary characteristic of a more flexible organization, but it may result from such increased flexibility.

It was pointed out earlier that there is no reason to suppose all entrepreneurs react in the same way to uncertainty. Some may not be adverse to considerable variability of income. It may be also that it is not variability that others wish to avoid but merely the possibility of withdrawals from the firm below some minimum, which is determined by what is considered necessary for family living. The decision maker's attitude will be determined by individual characteristics and by the attitude of the household with which he is in close proximity. To the extent that a diversified plan is a fixed plan, incapable of change, it is in conflict with flexibility. If by diversification we mean the organization of a producing unit to permit more than one product to be produced, then there does not appear to be a conflict. Within such an organization there may be latitude to produce one or more products in any particular year as opportunity dictates.

In the analysis which follows an empirical investigation of certain aspects of flexibility is made. The three enterprises which the preceding analysis has shown to have the lowest variability of income are used for the analysis in this section. It has not been established that these are the most profitable enterprises but experience has shown that wheat, milo, and cattle have been produced profitably in the area. The decision to use these three enterprises is somewhat arbitrary. It is made in the absence of a complete economic solution that would indicate the most profitable combination of products as well as the uncertainty associated with each in any particular year.

On the basis of the previous analysis, it would appear that one or all of the three mentioned products might be included in any organization for the area. The previous analysis indicates that the addition of any other product would increase rather than decrease variability. Only if technical or market conditions were unusually favorable for another commodity does it appear that profit would be increased by adding such an enterprise. It should be recognized that this point is reached in the absence of empirical investigation which would give a solution not only as to what should be produced but also as to how much should be produced.

It is within this framework that a flexible organization will be developed further. In producing wheat, an entrepreneur has the choice of cropping his ground every year or cropping and fallowing in alternate years. For the area considered alternate crop and fallow would be the best choice if an individual were planning on average yields and costs. This would be true because wheat on fallowed land will yield more than twice that on continuously cropped land over a long period. Reference to Table 24 indicates that such fallowing costs less than twice that of continuous cropping. Table 2 indicates, however, that there may have been a considerable number of years that continuous cropping would have been profitable. The problem then becomes one of predicting the yield of continuously cropped wheat at a time when a decision must be made regarding the alternatives. On land that is to be fallowed, it is not the common practice to perform a tillage operation in the fall after a crop has been harvested. Therefore, the cost of deferring the decision (or cost of flexibility) regarding fallow and continuous cropping is the cost of the one-way operations which must be performed if the crop is to be planted in a continuous sequence (Table 24).

Soil moisture at seeding time was selected as a possible predictive device to indicate wheat yields the following year. A regression was made between inches of available moisture at seeding time and wheat yields from continuously cropped land. The equation used was $Y = bX$, where Y = yield of wheat and X = inches of available moisture at seeding time. The solution was $Y = 4.4X$. In an attempt to see how

Table 24

Typical Operations and Costs of Producing an Acre of Wheat, Thomas County, Experiment Station Yields, 1947 Costs[a]

Input	Continuous cropping	Summer fallow
Oneway	.79	.79
Oneway	.79	.79
Duckfoot	--	.80
Duckfoot	--	.80
Rodweed	--	.52
Drill	.92	.92
Combine	2.92	2.92
Haul	.48	.48
Seed	.98	.98
Total Cost	6.88	9.56

[a]Scoville and Hodges (26, p. 16); Miller, Lindsey, and George (24, p. 27).

adequately the existing information at seeding time had been used, a multiple regression equation was derived using soil moisture at seeding time (X_1) and rainfall from seeding until harvest (X_2) as independent variables and yield (Y) as the dependent variate. The multiple R^2 - 0.517 indicated that

0.483 of the total variation was unaccounted for. It is not known with certainty how much of this variation is caused by factors affecting the yield of wheat after seeding time and how much prior to that time. Since insect damage, spring freezes, and disease have not been taken into account, it is probable that the use of soil moisture data is the best predictive device available at seeding time. This information might be utilized in two ways. One possible decision might be to plant if the value of the expected yield would cover the variable costs of planting and harvesting. These costs (Table 24) in 1947 would have amounted to $5.30. The price of wheat adjusted to long run prices and cost ratios would have been $1.98. A yield of 2.67 bushels would have been necessary to cover these costs. Reference to Table 2 will indicate that in twenty-four of the thirty-five years yields at the Colby Station exceeded this amount.

A more relevant decision, however, would be in terms of the opportunity cost of wheat on fallow. To determine this cost the following formula was derived:

Let X = expected net revenue for the first year of continuously grown wheat

Y = expected net revenue for the wheat on fallow

Z = expected net revenue for the second year of continuously grown wheat

Then when X > Y - Z the land should be planted to continuous wheat.

Y = 21.4 (average fallow yield) x 1.98 = 41.77 (total revenue) - 9.56 (total cost) = 32.21 (net revenue)

Z = 9.7 (average continuous yield) x 1.98 = 18.81 (total revenue) - 6.88 (total cost) = 11.93 (net revenue in second year)

Now Y - Z or 32.21 - 11.93 = $20.28 (opportunity cost of fallow). Then 20.28 ÷ 1.98 (price of wheat) = 10.24 bushels necessary to plant continuous wheat. The decision to seed wheat must be based upon two conditions: 1. the expected return must cover variable costs and 2. the expected return must cover the opportunity cost involved in foregoing a crop on fallowed land. Under average prices and yields the latter condition is the more rigorous. The meeting of the latter condition would automatically involve meeting the former when the assumed prices and cost were used.

A similar analysis must be applied to the decision to plant on fallowed ground. An entrepreneur would not seed on fallowed land if he could not cover the variable costs involved. There are, however, certain opportunity costs involved. These costs may be developed as follows:

Let N = expected net revenue on fallowed land

O = net revenue on continuously cropped land - this crop would follow the crop on fallowed land

P = net revenue on fallowed land - this crop would be planted on the land in year two if it is fallowed in year one.

Then $N > P - O$ if a decision is made to plant on fallowed land.

When 1947 prices and costs are used, the necessary yield would be determined as follows:

O = 9.7 (average continuous yield) x 1.98 = 18.81 (total revenue) - 6.88 (total cost) = 11.93 (net revenue in second year)

P = 21.4 (average fallow yield) x 1.98 = 41.77 (total revenue) - 9.56 (total cost) = 32.21 (net revenue)

Now 32.21 - 11.93 = 20.28 (opportunity cost of fallowing an additional year). Then 20.28 ÷ 1.98 = 10.24 bushels as indicated above.

The use of soil moisture as a possible predictive device was also used for wheat on fallowed land. Reference to Table 26 will indicate the nature of this information. Here also a multiple regression equation was derived using soil moisture at seeding time (X_1) and rainfall from seeding to harvest (X_2) as independent variates and the yield of wheat as a de-

Table 25

Probability of a Particular Wheat Yield on Continuously Cropped Land Being Greater than Certain Specified Amounts at Colby Kansas Experiment Station

Available moisture in inches	Bushels per acre 5	10	15	20
0.5	.359	.159	.051	.011
1.0	.468	.233	.084	.021
1.5	.583	.330	.138	.041
2.0	.688	.436	.209	.080
2.5	.779	.552	.305	.125
3.0	.851	.659	.409	.195
3.5	.929	.752	.520	.281
4.0	.938	.824	.626	.386
4.5	.961	.879	.716	.492
5.0	.974	.916	.788	.591
5.5	.985	.944	.848	.681
6.0	.990	.962	.893	.758

Calculated from the equation:

$Y = bX$

$b = 4.4$

Significant at the 5 percent level

$r = 0.363$

Significant at the 5 percent level

Inches of available moisture	Frequency
0 - 4.9	5
0.5 - 1.4	11
1.5 - 2.4	10
2.5 - 3.4	4
3.5 - 4.9	0
4.9 & more	1

Mean 1.58

Table 26

Probability of a Particular Wheat Yield on Summer Fallowed Land Being Greater than Certain Specified Amounts at Colby Kansas Experiment Station

Available moisture in inches	Bushels per acre 5	10	15	20
1	.496	.302	.184	.100
2	.504	.390	.251	.147
3	.641	.496	.337	.209
4	.732	.587	.432	.284
5	.808	.684	.532	.374
6	.879	.767	.629	.476
7	.913	.834	.719	.575
8	.945	.887	.794	.666
9	.966	.925	.853	.749

Calculated from the equation:
$Y = bX$
$b = 3.24$
Significant at the 1 percent level
$r = 0.456$
Significant at the 1 percent level

Inches of available moisture	Frequency
0 - .9	2
1 - 1.9	3
2 - 2.9	5
3 - 3.9	3
4 - 4.9	2
5 - 5.9	5
6 - 6.9	3
7 - 7.9	2
8 - 8.9	4
9 & more	2

Mean 5.05

Table 27

Multiple Regression Equations Relating Soil Moisture at Seeding Time (X_1), Rainfall from November to June 1 (X_2), and Yield Y at the Colby Kansas Experiment Station 1918-1949

Continuous cropping	Summer fallow
$Y = -10.8 + 2.4X_1 + 2X_2$	$Y = -25.9 + 2X_1 + 4.5X_2$
$R^2 = .517$	$R^2 = .884$
$b_{y1.2} = .403^a$	$b_{y1.2} = .445^a$
$b_{y2.1} = .621^a$	$b_{y2.1} = .823^a$

[a]Significant at the 5 percent level

pendent variate (Y). The multiple $R^2 = 0.884$. In this case only 0.116 of the variation was unaccounted for.

These data were utilized in making a comparison of a flexible cropping system and a rigid alternate crop and fallow organization. Before a decision was made to plant wheat with the flexible system, the expected return had to exceed the expected variable costs and the expected opportunity costs. The results of this comparison are presented in Table

30. The results show that the mean difference is not significant between the two systems. In view of the extreme variability of the two sets of data the mean difference would have to be between four and five dollars per acre per year before the difference would be statistically significant at a high level of probability. The alternate crop-fallow system appears to be the more stable of the two as evidenced by the differences in coefficients of variation.

A comparison of the continuous cropping system and the flexible system is made in Table 31. The flexible system is superior both in terms of the mean return and variability. This would indicate that the continuous cropping system is an inferior alternative in relation to the other two.

Table 33 is presented to show the difference in cropping systems between the flexible and the inflexible plans. With the flexible system there were four years in which continuous wheat was planted and six years (1935-1940) that no crops were planted. The full costs of fallowing were charged against the flexible organization during the period, although in actual practice it is likely that the land would not have been farmed this intensively. The use of soil moisture as a predictor led to the wrong decision in two of the years. It appears on the basis of past experience that it is a reliable indicator at seeding time for the next year's yield. Tables 28 and 29 are included for use in making plans in the long

Table 28

Probability of the Average Wheat Yield on Continuously Cropped Land Being Greater than Certain Specified Amounts at Colby Kansas Experiment Station

Available moisture in inches	Bushels per acre 5	10	15	20
0.5	.067	.001	.001	.001
1.0	.345	.001	.001	.001
1.5	.864	.008	.001	.001
2.0	.997	.212	.001	.001
2.5	.999	.726	.011	.001
3.0	.999	.933	.184	.006
3.5	.999	.982	.579	.036
4.0	.999	.994	.788	.212
4.5	.999	.997	.903	.467
5.0	.999	.998	.995	.691
5.5	.999	.999	.977	.816
6.0	.999	.999	.986	.885

Table 29

Probability of the Average Wheat Yield on Summer Fallowed Land Being Greater than Certain Specified Amounts at Colby Kansas Experiment Station

Available moisture in inches	Bushels per acre 5	10	15	20
1	.345	.046	.002	.001
2	.655	.136	.005	.001
3	.945	.421	.029	.001
4	.994	.885	.184	.001
5	.999	.997	.655	.036
6	.999	.999	.964	.382
7	.999	.999	.997	.816
8	.999	.999	.994	.955
9	.999	.999	.999	.994

Table 30

A Comparison of the Net Returns from a Flexible Cropping System with a System of Alternate Crop and Fallow for the Years 1918-1949 for Colby Kansas Experiment Station Using 1947 Adjusted Prices and Costs

System	Number of observations	Degrees of freedom	Mean net revenue	Sum of squares	Coefficient of variation
Crop-fallow	31	30	15.70	4185.90	75.21
Flexible	31	30	16.56	8496.27	101.4
	62	60	.86	12682.17	

t = 0.232 Not significant at the .5 level

Table 31

A Comparison of the Net Returns from a Flexible Cropping System with a Continuous Cropping System for the Years 1918-1949 for Colby Kansas Experiment Station Using 1947 Adjusted Prices and Costs

System	Number of observations	Degrees of freedom	Mean net revenue	Sum of squares	Coefficient of variation
Continuous	31	30	11.28	5394.70	119.0
Flexible	31	30	16.56	8496.27	101.4
	62	60	5.28	13890.97	

t = 1.36 Significant at the .2 probability level

Table 32

A Comparison of the Net Returns from a Continuous Cropping System and an Alternate Crop and Fallow System for the Years 1918-1949 for Colby Kansas Experiment Station Using 1947 Adjusted Prices and Costs

System	Number of observations	Degrees of freedom	Mean net revenue	Sum of squares	Coefficient of variation
Continuous cropping	31	30	11.28	5394.70	119.0
Crop-fallow	31	30	15.70	4185.90	75.2
	62	60	4.42	9580.60	

t = 1.38 Significant at the .2 probability level

Table 33

A Comparison of the Cropping Systems and Net Returns by Years of an Alternate Crop and Fallow, a Flexible Cropping and a Continuous Cropping System at the Colby Kansas Experiment Station Using 1947 Adjusted Prices and Costs

Year[a]	Flexible cropping system	Organization net revenue	Alternate crop and fallow net revenue	Continuous cropping net revenue
1918	Continuous wheat	12.33	14.08	12.33
1919	Continuous wheat	15.60	27.39	15.69
1921	Fallow	-5.50	23.53	18.07
1922	Crop on fallow	46.13	21.22	23.61
1923	Fallow	-5.50	29.80	8.76
1924	Crop on fallow	43.60	22.76	17.28
1925	Fallow	-5.50	17.16	6.19
1926	Crop on fallow	30.49	13.40	-2.72
1927	Fallow	-5.50	-1.46	-4.90
1928	Crop on fallow	61.19	28.74	25.79
1929	Fallow	-5.50	11.28	9.36
1930	Crop on fallow	66.98	31.64	36.88
1931	Fallow	-5.50	20.44	15.30
1932	Crop on fallow	56.55	25.65	-3.91
1933	Fallow	-5.50	-4.26	-3.48
1934	Crop on fallow	14.48	5.39	-6.68
1935	Fallow	-5.50	-4.26	-3.48
1936	Fallow	-3.70	-4.26	-3.48
1937	Fallow	-3.70	-0.50	-3.17
1938	Fallow	-3.70	4.62	4.01
1939	Fallow	-3.70	1.52	-2.13
1940	Fallow	-3.70	2.02	-3.48
1941	Crop on fallow	38.21	17.26	15.49
1942	Continuous wheat	35.09	20.06	35.69
1943	Continuous wheat	14.64	22.38	14.70

continued

[a]1920 was not used since soil moisture at seeding time was not available.

Table 33 continued

Year	Flexible cropping system	Organization net revenue	Alternate crop and fallow net revenue	Continuous cropping net revenue
1944	Fallow	-5.50	27.78	33.71
1945	Crop on fallow	57.51	33.08	26.78
1946	Fallow	-5.50	19.67	15.49
1947	Crop on fallow	65.63	30.96	39.06
1948	Fallow	-5.50	14.46	5.79
1949	Crop on fallow	33.78	15.04	6.98
	Total	513.21	486.59	349.53
	Mean	16.56	15.70	11.28
	Coefficient of variation	101.4	75.2	119.0

run. The confidence limits for corresponding levels of probability are much narrower for average yields than for the yields of a particular year.

The concept of flexibility may have additional application to other aspects of farm organization. If cattle are to be added to a wheat enterprise, various cattle programs may be analyzed on the basis of flexibility. A cattle program in which inputs come late in the production process would be more flexible than one which requires a large portion of its inputs early in the production process.

For purposes of illustration two cattle programs recommended by the Kansas Agricultural Experiment Station are compared. The deferred cattle program is one in which three hundred to five hundred pound good quality beef calves are purchased in the fall of the year. The calves are wintered well on both roughage and concentrate. They are pastured throughout the following summer and are started on concentrate in the late summer. They are sold in the fall after having been fed intensively. At marketing time such cattle will weigh from nine hundred to one thousand pounds. Such a program extends over a full year and requires certain special inputs early in the production process. Pasture of a permanent or temporary nature must be made available. The cost of the concentrate to be fed in the second fall may be relatively high in price if crop conditions are not favorable.

Contrasted to such a program might be a wintering program. It is recommended that five to six hundred pound animals of common quality be purchased in the fall. These cattle are wintered on roughage and wheat pasture if it is available. In February or March a decision may be made as to marketing the cattle or feeding to heavier weights and marketing in April. A decision to enter such a program need not be made until it is known that all the necessary inputs are available. It may be carried on without grain if such an input is expensive in relation to other inputs.

The outline of a possible flexible organization is presented below. In terms of long run decisions such an organization would include equipment that could be used for wheat and (or) sorghum as conditions would indicate. If an entrepreneur possessed such equipment, the following short run decisions could be made:

September 1-20	Make a decision regarding whether or not to seed wheat on the basis of soil moisture and other information
November	On the basis of wheat pasture, feed supply, and market conditions make a decision regarding the advisability of wintering cattle
February-March	On the basis of market conditions and

	grain prices make a decision regarding feeding cattle to heavier weights
May 25-June 10	On the basis of soil moisture and other information make a decision regarding the planting of sorghum
July-September	Prepare land for wheat seeding - this would be an operation to permit flexibility.

Such an organization can be contrasted to an inflexible organization such as the alternate crop and fallow system presented earlier. The equipment for an alternate crop and fallow organization would be of a specialized nature and designed only for the production of wheat.

RELATION OF RESULTS TO EXPERIMENT STATION RECOMMENDATIONS

A unified set of recommendations regarding adjustments to meet conditions of risk and uncertainty advocated by the Kansas Agricultural Experiment Station does not exist. Certainly there have been studies on particular aspects of the problem. Throckmorton and Myers (29) have conducted agronomic investigations concerning the relative desirability of continuous cropping and fallow. These recommendations were based upon agronomic rather than economic considerations. Doll and Castle (5) prepared a budget study comparing various alternatives to wheat production on the basis of average income in Southwestern Kansas. It was found that certain enterprises when added to wheat would increase average income. The analysis was in terms of two enterprises and the study did not consider the effect of more than two enterprises on average income. Barber (1) completed a study of means of meeting weather risks in Kansas. It was concluded that on a typical sized farm, yield insurance would not provide a minimum income necessary for family living if another period such as the 1930's were encountered. Farm size and organization were not considered. No serious study has been made of the possibilities of flexibility.

The Kansas State College Extension Service at the present time advocates two or three enterprises as being optimum for most farms. Love and Coolidge (20, p. 18) stated:

> Records of successful farmers reveal that concentration on two or three major sources of cash income is more profitable than a large number of small enterprises. It is possible to have too many kinds, for example, with none large enough to be profitable. When they compete with each other for labor, investment, feed and equipment instead of supplementing each other, there are too many kinds.

It is interesting to note the reason given is valid only in a special case. Conditions for a profit maximization equilibrium specify that a farmer will operate in the competitive range unless the price of one product is zero. It is doubtful if farm records will yield information which will establish the optimum number of enterprises. what will?

Extension personnel allege bankers encourage considerable diversification so that they may have better collateral for their loans. This type of protection would be expected on the part of bankers under conditions of high price and technical uncertainty. In general farm magazines and papers have advocated more diversification and have deplored the existence of an agriculture that is based primarily upon one crop.

The Extension Service has advocated a non-flexible operating unit. "Get on a definite crop and livestock system and stay there" has been the most frequently given advice. In general the Experiment Station has concurred with this policy. Several years ago the research workers of the Department of Agricultural Economics periodically prepared outlook information entitled Picking Profitable Projects. This publication was discontinued since it was alleged that it tended to encourage the "in-and-outer".

The paucity of careful investigations on these problems indicates that very little basis exists for recommendations regarding either diversification or flexibility. There appears to be a belief that two or three enterprises will increase average income over one alone and will also reduce variability although empirical evidence that would support the latter belief is lacking. Also the desirability of a non-flexible system has been accepted and such a system is advocated. Such a recommendation either ignores the indifference surface of individuals or assumes certain characteristics of the indifference curves. Stability of income has been looked upon as a goal, and the extent to which it is competitive with the level of income has not been analyzed. No obvious recognition has been given to the fact that stability and level of income may be substitutes in the minds of some individuals.

In relating the findings of this study to these recommendations, it is necessary to keep in mind that the recommendations are not unanimous and are not definite regarding all points. This study would indicate that historically more than two enterprises would not greatly reduce variability as compared to two enterprises. When cattle or milo were combined with wheat at either Colby or Garden City, there was a reduction in variability. Area diversification also resulted in reduced variability and may have as much application as extensive product diversification. It should be borne in mind that the analysis has been in terms of variability of income rather than the most profitable combination of enterprises. Most of the arguments for a large number of enterprises, however, have been in terms of the stabilization of income rather than of increasing profitability. These findings would tend to support extension recommendations regarding the advisability of having two or three enterprises, but the reasons for arriving at this conclusion would be different.

Certain implications of the material included in this study on the possibilities of flexibility would undoubtedly conflict with recommendations of the Extension Service and the production departments of Kansas State College. The author of this thesis recognizes that the managerial capacity of farmers is quite variable. It is also recognized that stability of income is not necessarily a goal of all farmers. Therefore a flexible program, which will increase income but which at the same time will increase variability of income, may be preferred by some individuals to a more stable, less lucrative organization. It appears that this possibility has not been recognized. It is difficult, therefore, to reconcile the suggestions made in this thesis that certain farmers defer certain major decisions until more information is available with the non-flexible recommendations of the Extension Service and the Experiment Station. The evidence of this thesis indicates farmers may in fact have to make a choice between variability and the level of income. In the absence of any information relating to the ends of farmers, the decision must be left to the farmer as to which situation puts him on the higher indifference surface. The fact that little or no research has been done on the adaptation of the farm firm to conditions of uncertainty tends to obscure the true problem. The implicit assumption has been that the non-flexible organization should be adopted and followed. This assumption has tended to make interested individuals look elsewhere for a solution to this problem.

In conclusion, it would appear that this thesis would tend to substantiate the recommendations of the Extension Service and the Experiment Station in regard to diversification. Historically there has been some reduction in variability by the addition of certain crop or livestock enterprises to that of wheat for the area with which this study deals. This reduction is not large and does not appear to be increased significantly by the presence of more than two enterprises. The implication is that farmers may need to make a decision regarding flexibility or non-flexibility depending upon the utility function of the individual farmer.

SUMMARY

This study is an attempt to apply a knowledge of economic logic and statistical analysis to a production economics problem existing in society. It was not possible to supply empirical verification for all of the developed hypotheses. It is submitted, however, that the application of economic logic to develop hypotheses is a worth-while procedure since the development of the conceptual framework of a problem will isolate the relevant variables. Economic logic is also a guide in regard to what observations should be made.

The problem, decision making under conditions of imperfect knowledge, is one that may be established from the standpoint of a "felt" difficulty or on the basis of the established criteria of economic logic. It was established that imperfect knowledge exists regarding both the production functions and the prices facing farmers in Western Kansas. The problem was established from the standpoint of a felt difficulty by reference to the highly variable agricultural income that has existed historically.

An examination of the effect of the proximity of the household on the farm firm that operates under uncertain conditions was made. It was deduced that capital rationing

will exist when uncertainty describes the degree of knowledge with which an entrepreneur operates. There may also be competition between the firm and the household in the use of capital. The resulting variation in the use of capital may be a partial explanation of the variation in the size of farms in the United States. The desires of the household may be reflected in the choice of the production plan. In turn the distribution of the return from the farm through time may affect the spending and savings of the household.

An analysis was made of the reaction of the entrepreneur to the making of decisions under conditions of imperfect knowledge. General observation indicated that great variability may exist in the ability of individuals to make decisions under such conditions. It was concluded that this variability of management may correspond to various types of organizations. A flexible organization, which requires that frequent decisions be made, may be desirable to one individual. A non-flexible organization, which demands that the major decisions be made infrequently, may appeal to another. This may make the choice of production plans depend quite largely upon the utility function of the individual.

The economic logic of the precautions available to the farm organization that must exist under conditions of uncertainty was summarized. These precautions are diversification, liquidity, and flexibility. Plant flexibility was found to have application to the problem of this thesis. When prices are relatively favorable to the farmer, he may wish to expand his output by farming additional land. When the reverse situation exists, he may desire to curtail operation. A flexible plant would permit this expansion and contraction with a minimum of friction. There may be certain other flexibility applications relating to livestock programs. A breeding herd of either cattle, hogs, or sheep would be relatively inflexible compared to a program that involved the purchase of feeder animals. In an area where feed supplies are uncertain, the latter arrangement would permit entry into or exit from a livestock program with a minimum sacrifice. The sacrifice would be substantial in the case of a breeding herd.

Product flexibility may be defined as the organization of the producing plant so that when changes are made in the combinations of products, the resulting output may be produced more efficiently than if the change were made from a specialized plant designed for a particular combination of products. The most significant application of the above concept would be in the choice of machinery and the design of buildings. Machinery that may be used for more than one crop or machine sheds that could be adapted to the use of livestock would be examples of product flexibility.

Contractual flexibility would relate to the postponement of the making of rigid contracts until more information was available. An example would be renting versus the ownership of land. It was concluded that the renting of land is in general more flexible than ownership since it provides for rapid expansion and contraction if that becomes necessary. Ownership, however, may be more conducive to the reaping of windfall gains and losses than renting. The custom hiring of machinery would be another example of flexibility that would permit an expense to be suffered only if it became necessary to preform a particular operation.

Liquidity is another precaution available to the entrepreneur who must operate with imperfect knowledge. By holding part of his assets in a form so that they may be converted into cash easily, he is in a position to meet production expenses or family living demand if conditions so dictate. Since feed reserves have frequently been advocated as a means of combating uncertainty, it was pointed out that certain types of feed reserves such as roughage are quite illiquid. It was noted that liquidity or illiquidity is consistent with diversification, but a probable characteristic of a flexible organization would be a high degree of liquidity.

Diversification has been advocated by others as a means of combating uncertainty. The reasoning for such an advocation is that while the yields of all crops vary greatly in

Western Kansas they may not vary in the same direction or to the same extent. Similar reasoning would hold for prices. To the extent this is true, diversification would reduce variability of income. The logic can be expressed more rigorously be means of the following equation:

$$V_{\left(\frac{x + y}{2}\right)} = (1/2)^2 \left[V_x + V_y + 2rs_xs_y\right]$$

where V = variance

x = one enterprise

y = another enterprise

r = correlation coefficient

s = standard deviation.

Assume:

$$V_x = V_y$$

then

$$r = \frac{4V_{\left(\frac{x + y}{2}\right)} - V_x - V_y}{2s_xs_y}$$

$$r = \frac{2V_{\left(\frac{x + y}{2}\right)}}{V_x} - 1.$$

If

$$\frac{V_{\left(\frac{x + y}{2}\right)}}{V_x} = 1; \qquad r = 1$$

When the variances are equal and the resources are divided between the existing and the added enterprise, variability will be reduced by diversification if the correlation coefficient is less than 1.

An empirical analysis was made of the variability of physical production and gross income for various enterprise combinations. Data from the Colby and Garden City Experiment Stations were available to facilitate this analysis.

Difficulty was encountered in comparing the relative variability of two distributions that have different means. For that reason the coefficient of variation was the statistic that was used for the comparison. The coefficient of variation, however, cannot be tested for significance. A subjective interpretation of the results became necessary after these statistics had been calculated.

Yield data from the Garden City station indicated that the variability of wheat or milo alone could be reduced by some combination of the two. Kafir forage had a lower coefficient of variation than did any of the grain crops. This finding suggested the possibility of a livestock enterprise.

Price relationships were studied prior to the calculation of gross income for the various enterprises. Correlation coefficients were calculated among various enterprises. This indicated that certain basic factors cause all prices to change in the same general direction. There was no great advantage to any product on the basis of price variability. The coefficients of variation were of the same general magnitude.

Price and yield variability were combined so that gross income variability could be treated. Livestock were brought into the analysis by making them a function of feed production. Due primarily to the low variability of sorghum forage production, cattle had a lower variability of gross income than did any of the other commodities. Any of the combinations which included cattle had a correspondingly lower coefficient of variation. The gross income of the wheat-milo combination had a lower coefficient of variation than the gross income of either of these products alone. The addition of hogs resulted in a greater coefficient of variation than that of the combination of enterprises to which they were added.

The previous analysis indicated that at Garden City the variability of the gross income of one grain crop organization could be reduced by the addition of another enterprise. This reduction would result from the addition of a grain crop or a livestock enterprise. Since forage production was the most stable product among the various crops, the gross income from a forage consuming cattle enterprise was the most stable. The addition of another enterprise to cattle increased variability. At Garden City the data showed that milo was the most stable grain crop for the area. There were also a smaller number of years in which there was a complete milo crop failure.

The Colby data were in contrast to the Garden City data in that at Colby wheat was the most stable of the grain crops. Due to this fact and due to the high degree of association between wheat and other crops, the addition of crops other than wheat to that of wheat alone increased the variability of physical production. The wheat-milo combination had approximately the same variability as did wheat alone.

It was found, however, that a combination of various crops did reduce the number of years in which there was a complete crop failure. A combination with another enterprise may either increase or decrease the variance of the yield. The wheat-milo combination decreased the variance and range from milo alone and increased the variance and range from wheat alone.

A similar analysis was made relating to the variability of the gross income for the Colby Station. At Colby also cattle had the lowest coefficient of variation when compared with other enterprises. It was found that a wheat-milo combination had a lower coefficient of variation than did either alone. From these data it was concluded that cattle and milo offered the greatest possibility for diversification when diversifying from wheat alone. The reduction in variability was not large, but it may occur in strategic years since the number of years in which there were complete failures was reduced by a combination of enterprises.

To test the hypothesis that area diversification would reduce variability, the Colby and Garden City data were combined. It was found that the variability of wheat alone at either station was reduced by a combination including either wheat or milo from the other station. The reduction in variability was not large but was of the same relative magnitude as caused by product diversification. To illustrate further the possibilities of area diversification, average county wheat yields for the counties surrounding Thomas County, where the Colby station is located, were combined. The results were not conclusive. Data were not available to make an intra-county analysis.

In developing the empirical work on flexibility, soil moisture tests at seeding time were used as an indicator of the succeeding crop at the Colby Station. By the use of such a predictive device it was possible to compare an alternate crop and fallow system, a straight wheat program and a flexible organization on the basis of variability and the level of income. It was found that the continuous cropping system had the highest coefficient of variation and the lowest net income. The meaningful comparison was between the flexible organization and the alternate crop and fallow system. It was found the alternate crop and fallow system was the more stable of the two; however, the net income was somewhat greater for the flexible system in which soil moisture at seeding time was used as the means of determining whether or not to seed.

Data were not available for an empirical analysis of a flexible system that would include a livestock program. In lieu of such an analysis a verbal comparison of a flexible and non-flexible cattle system was made. The conclusion was drawn that the flexible system would be more realistic for the Colby area.

An attempt was made to relate the results of this thesis to the recommendations that are now being made for the area. In regard to diversification it was found that the results of this thesis would not conflict with the recommendations of the Experiment Station. However, there probably is a conflict when the recommendations of farm papers, bankers, and others are considered.

The recommendations regarding flexibility by the Experiment Station, however, have been in conflict with both the empirical analysis and the logic as it has been developed. The fact that individuals may react differently to bearing uncertainty apparently has not been considered by the Experiment Station when their recommendations were formulated. It was concluded that some farmers may not be willing to forego the increased income that may be forthcoming from a flexible organization to attain the greater stability of a non-flexible plan.

SELECTED REFERENCES

1. Barber, E. L. Meeting weather risks in Kansas wheat farming. Kansas Agricultural Experiment Station, Agricultural Economics Report No. 44. 1950.

2. Boulding, Kenneth. A reconstruction of economics. John Wiley and Sons, New York, New York. 1950.

3. Brown, Phelps. The frame work of the pricing system. Chapman and Hall, London, England. 1936.

4. Colby Branch Agricultural Experiment Station. Annual reports. 1914-49. Unpublished material. Colby, Kansas. 1914-49.

5. Doll, R. J. and Castle, E. N. Suggested adjustments for Southwestern Kansas agriculture. Kansas Agricultural Experiment Station, Circular 267. 1950.

6. Garden City Branch Agricultural Experiment Station. Annual reports. 1914-48. Unpublished material. Garden City, Kansas. 1914-48.

7. Hart, A. G. Anticipations, uncertainty and dynamic planning. Augustus M. Kelley, New York, New York. 1951.

8. ________. Assets, liquidity and investment. American Economic Review, 39: 170-181. 1949.

9. Heady, E. O. Implications of particular economics in agricultural economics methodology. Journal of Farm Economics, 31: 837-850. 1949.

10. ________. Uncertainty in market relationships. Journal of Farm Economics, 32: 240-257. 1950.

11. Hicks, J. R. Value and capital. 2nd edition. Oxford University Press, London, England. 1948.

12. Jesness, O. B., Editor. Readings on agricultural policy. Blakiston Company, Philadelphia, Pennsylvania. 1949.

13. Johnson, D. G. Forward prices for agriculture. University of Chicago Press, Chicago, Illinois. 1947.

14. Kalecki, M. The principle of increasing risk. Economica, 4: 440-447. 1947.

15. Kansas State Board of Agriculture. Biennial reports. 1914-50. Topeka, Kansas. 1914-50.

16. Kelley, P. L., Gerber, G. W. and Foster, D. H. Production trends and market prices. Kansas Agricultural Experiment Station, Agricultural Economics Report No. 46. 1950.

17. Knight, F. H. Risk, uncertainty and profit. Houghton Mifflin Company, Boston, Massachusetts. 1921.

18. Lange, O. Price flexibility and employment. Principia Press, Inc., Bloomington, Indiana. 1944.

19. Laude, H. H. and Hodges, J. A. The effect of drought on income. 1949. Unpublished material. Manhattan, Kansas. 1949.

20. Love, H. C. and Coolidge, J. H. Making your farm pay. Kansas State College Extension Service, Circular 226. 1950.

21. Makower, H. and Marshak, J. Assets, prices and monetary theory. Economica, 5: 261-288. 1938.

22. Marshak, J. Money and the theory of assets. Econometrica, 6: 311-325. 1938.

23. ________. Role of liquidity under complete and incomplete information. American Economic Review, 39: 182-195. 1949.

24. Miller, F., Lindsey, I. W. and George, A. G. Cost of operating machinery on Nebraska farms. Nebraska Agricultural Experiment Station, Bulletin 391. 1948.

25. Reder, M. W. Studies in the theory of welfare economics. Columbia University Press, New York, New York. 1949.

26. Scoville, O. J. and Hodges, J. A. Practices and costs on wheat farms in Western Kansas. Kansas Agricultural Experiment Station, Circular 268. 1950.

27. Snedecor, G. W. Statistical methods. 4th edition. Iowa State College Press, Ames, Iowa. 1948.

28. Stigler, G. J. Production and distribution in the short run. Journal of Political Economy, 47: 305-327. 1939.

29. Throckmorton, R. I. and Myers, H. E. Summer fallow in Kansas. Kansas Agricultural Experiment Station, Bulletin 293. 1941.

30. Tintner, G. Scope and method of econometrics. Journal of Statistical and Social Inquiry of Ireland, 18: 161-176. 1948.

31. ________. The theory of production under non-static conditions. Journal of Political Economy, 50: 645-668. 1942.

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