Optimum Allocation of Resources Between Pasture Improvement and Other Opportunities on Southern Iowa Farms

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CONTENTS

SUMMARY

1. This study examines the optimum investment in pasture improvement in the southern pasture area of Iowa from the aspect of the farm as a whole. The supply of each resource is taken into account as well as a number of alternative uses for the resources. Four cropping alternatives, four systems of improving permanent pasture, three types of beef-feeding enterprises, both spring- and fall-farrowed hogs, a beef cow-calf enterprise, a supplementary farm laying flock and renting out of unimproved pasture are considered possible investment alternatives. The optimum farm plan is selected from the alternatives for each of several resource situations by application of the technique of linear programming.

2. The following farm situation is used as the basis for the study: A farm size of 160 acres which consists of 110 acres of cropland and 38 acres of permanent pasture. The remaining 12 acres consist of idle land, roadways and farmstead. The soil types are principally Shelby-Grundy-Haig and Shelby-Seymore-Edina. The farm has adequate machinery and crop storage facilities for the crop program. Other service buildings include 963 square feet of beef housing and poultry housing for a 150-hen laying flock.

3. The resource situations studied include six capital levels and three labor levels. The capital levels are: $1,000, $2,000, $4,000, $8,000, $16,000 and unlimited capital. The labor supply levels are: operator alone supplying 260 man-hours of labor per month, the operator plus family labor of 130 man-hours per month in June, July and August and unlimited labor supply. There is the same amount of housewife labor available for the farm laying flock in each labor situation.

4. Investment in permanent pasture improvement will be consistent with the objectives of maximizing farm profits if (a) resources are available to invest in enterprises that can profitably use the increased production of pasture forage and (b) alternatives more profitable than those enterprises using permanent pasture have been fully exploited. Unless the above two conditions are met, farm profits will be greater if the permanent pasture is left unimproved and the resources are used in some other alternative.

5. The spring and fall hog enterprises bring a higher return on capital than any of the beef enterprises considered in this study. However, hogs bring a somewhat lower return per man-hour of labor than the beef enterprises. Where there is an abundance of labor, the beef enterprises are unable to compete with the hogs for the available capital. The result is that permanent pasture goes unused or is rented out.

6. The beef-feeding enterprises using permanent pasture provide an opportunity for taking advantage of a large supply of capital with a limited labor supply. As the supply of capital becomes more abundant relative to the supply of labor, the beef-feeding enterprises are expanded, and the permanent pasture is renovated to provide pasture forage for the increased number of animals in the program.

7. The beef cow-calf enterprise is unable to compete with the pasture feeding of yearling steers for the use of the resources. The beef enterprises are included in the plans under conditions of limited labor supply. Deferred feeding and full feeding of yearling steers on pasture bring a higher labor return than the beef cow-calf enterprise and, consequently, have a higher priority for the use of the resources under such circumstances.

8. Limiting the hog enterprises to 10 fall litters and 15 spring litters results in the investment in pasture feeding of yearling steers and pasture improvement at lower capital levels than would otherwise be the case. By restricting the size of the hog enterprises, farm profits are sacrificed.

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Pasture land represents an important portion of the total land in southern Iowa. One opportunity for increasing resource productivity and farm incomes in this part of the state is to invest capital in pasture improvement. Experiments show that capital invested in pasture improvement and renovation, and the livestock to utilize the increased forage production, can greatly increase the value of products produced on land unadapted to continuous cropping; yields of forage and livestock products can be increased as much as threefold.

However, the practices of improving and renovating pastures are proceeding at a slow rate. One reason suggested is capital limitations. Most farmers operate with limited funds. Accordingly, if they are to make greatest profits, they must use each dollar, acre and labor hour where it will bring the greatest return. The question is not so much whether pasture improvement and renovation is *profitable*; but whether it is more profitable than alternative uses of scarce capital and labor. For example, pasture improvement may cost $5 per year and return $8 in the same period. It is profitable in this sense: Each $1 in costs returns $1.60 in sales. However, if the same $1 invested in fertilizer for crops or in hogs returns $1.80, pasture improvement should not be included in the farming plan until these more profitable opportunities have been fully exploited. It should, of course, be included before other investments which return less than $1.60.

The profitable amount of pasture improvement, or the most profitable management plan for the entire farm, must be related to the amount of capital possessed and its earning rates in alternative enterprises and practices. Because of limited capital and differences in returns between various farm enterprises, the pasture-management plan which is best for one farm need not be best for a neighboring farm. An operator extremely limited on capital may maximize his profits if he invests all his funds in enterprises which return more per dollar than investments in pasture improvement or renovation. His neighbor, with ample capital at his command, may find that after these "first" investment opportunities, pasture improvement will return more than still other investment opportunities. Hence, from the standpoint of profit maximization, pasture improvement would be advisable for the second farmer but not for the first.

[1] Project 1220, Iowa Agricultural Experiment Station.

PURPOSE OF THE STUDY

This study is designed to determine the capital levels under which pasture improvement and renovation are profitable for a particular situation in southern Iowa. It considers pasture improvement in the framework of farm management where capital and labor can be used for many alternatives. The problem is to determine the most profitable allocation of capital, labor and land among the many investment opportunities of the farm. Pasture improvement is but one of these investment opportunities.

The questions to be answered in the study are: (1) What pattern of resource allocation or farm organization should be used for different amounts of investment capital? (2) At what level of capital investment does pasture improvement or renovation become more profitable than alternative investment opportunities? (3) What particular economic considerations cause pasture improvement to be profitable at one capital level and not at another?

To answer these questions it is necessary to treat the farm as a whole: One enterprise must be given the same role as another in determining the optimum use of resources. Consequently, the discussion which follows centers around other investment opportunities for the farm as a unit, as much as around pasture improvement and renovation.

A LINEAR PROGRAMMING APPLICATION

The empirical technique used in answering these questions is linear programming. This is a procedure for determining the most profitable plan, considering the limited supply of each resource. Many plans suppose that only land is limited and, therefore, that any plan can be adopted regardless of the amount of capital or labor considered. In linear programming, however, the limitational effect of each resource is expressed in the designation of the optimum plan. The "interactions" of various limiting resources are considered, and the final plan specified is tailored to fit all categories of resources.

The limited resources included in this study are: cropland, investment capital, barn space, poultry space, pasture land, operator labor in each of 12 months and housewife labor in each of 12 months. Labor of each month is considered a different resource since February, for example, cannot be substituted for July labor. Hence, any plan using February labor

must be restricted to the labor available in this month. A plan cannot be used which requires more labor than is available in any one month. Neither can the plan be one which requires land or capital beyond that possessed by the individual farm. In this study there are 29 limited resources, considering operator and housewife labor in each of the 12 months, which together determine the optimum plan. Also, limitations in farrowing space have been used for some calculations—raising the number of limited resources to 31.

Given the farm situation and the input coefficients or resource requirements, linear programming allows determination of the one plan out of thousands or millions of plans which will maximize profits. For example, suppose that a farmer has the opportunity of producing two enterprises and has $5,000 in capital. This capital can be allocated between two enterprises in 5,000 ways, if whole dollars are used as the "transfer units." If, in addition, he has 150 hours of labor in June the hours can be used in 150 ways. Considering the capital and labor together, the two enterprises can have $150 \times 5{,}000$ or 750,000 different possible plans in combining capital and labor. Since this study considers not two but 29 different limitational resources and 63 different enterprises or investment opportunities, the number of possible plans is extremely great. The most profitable plan has been, given the constraints mentioned elsewhere, determined for several different resource situations.

Each particular resource and its limitational quantity is considered in determining the optimum plan. For example, availability of housewife labor in February helps determine the amount of pasture improvement which is profitable. Since poultry is a supplementary enterprise depending on housewife labor, it can not be larger than allowed by the most limiting resource. The most limiting resource is housewife labor in February. Since ample housing space already is available on the farm, capital investment in poultry returns more than capital invested in pasture improvement. (This would not be so if housing for poultry were not already available.) Therefore, if the housewife had more time available in February, she could keep more hens and fewer funds could be invested in pasture improvement. Conversely, pasture improvement does not become profitable until the poultry enterprise is expanded to the limits of housewife labor in February.

The above example shows how resources limited to one enterprise affect the optimum plan for the farm as a whole and the amount invested in different opportunities. Of course, not only housewife labor is limitational. All of the resource categories mentioned serve in this manner.

YEAR AND LOCATION

The objectives of this study relate to a particular location and period of time. The location selected as a basis for this study is the soils pattern of Troy Township in Clarke County. The soils are principally Grundy-Shelby-Haig and Shelby-Seymour-Edina with some small areas of Weller and Lindley. This location is one soil situation where the problem studied is of considerable importance. While other soil associations are similar, the optimum farming programs may differ from those outlined in this bulletin. Additional studies are needed in other locations where soils and climate result in different yields and may cause different plans to be optimum. The yields used in planning represent average weather conditions. Hence, year-to-year outcomes might differ, depending on the weather of particular seasons.

The plans presented represent profit expectations as averages for a period of years. The prices used in determining the optimum plans reflect the average price relationships among factors and products in the 15-year period from 1939 to 1953. Using feed grains as a base, the prices are adjusted to the average level of the 1949 to 1953 period. Hence, even though prices rise or fall, the same plans will generally be optimum as long as the 15-year or "normal" relationships between product prices are maintained. However, for any year in which the prices of particular products fall or rise relative to other products, other plans might give greater profits.

Finally, efficient management is assumed for all enterprises. The same plans would, however, be optimum for less efficient managers if the level of efficiency were lowered by a proportional amount for all enterprises. The only situation where the plans would not apply without important changes would be if the manager is highly efficient for some types of production but inefficient for other enterprises.

Given the qualifications outlined above, the analysis which follows shows the farming plan and the amount of pasture improvement which is most profitable for farms with different quantities of capital and labor.

SITUATIONS STUDIED

This study deals with plans which farms can use to maximize net returns. The farm situation to which these plans apply is described in detail since physical characteristics have important bearing on the enterprises which best fit into a maximum profit plan. For example, it makes a considerable difference in evaluating investment opportunities whether or not the farm has buildings suitable for housing livestock. If buildings are lacking, scarce capital would need to be allocated to livestock housing should such an enterprise be included in the plan. It is possible that the capital would bring a higher return if spent on fertilizer.

A farm of 160 acres is used in this study. The farm is considered to be owner-operated. Leasing arrangements and problems of beginning farmers are not analyzed in this study. Of the 160 acres, 110 acres are considered suitable for cropping, 38 acres are classified as permanent pasture land unsuited for continuous tillage. The remaining 12 acres are taken up by farmstead, roads and wasteland. The cropland is composed of the following proportions of the various soil types: Grundy-Haig, moderate erosion and 1-5 degree slope, 44 percent; Grundy-Haig, moderate erosion and 6-9 percent slope, 29.4 percent; Shelby, moderate erosion and 7-11 percent slope, 26.1 percent;

Shelby, severly eroded and 7-11 percent slope, 5 percent.[2]

The service buildings on the farm consist of poultry housing, grain storage facilities and some buildings suitable for housing beef cattle. The poultry housing is considered adequate for a supplementary laying flock of 150 hens. Grain storage facilities are considered adequate to handle the production from the cropland. Beef housing includes 963 square feet of building space. Hogs can be included in the production program only if the necessary housing space can be provided. Since an established farm is used, it is supposed that the operator has sufficient machinery and equipment for cropping operations. Therefore, use of capital for investment in machinery need not be considered for the crop enterprises.

Labor Supply

Three levels of labor supply are considered in this study: Labor Situation A includes only 260 man-hours of operator labor available per month. Labor Situation B consists of operator labor of 260 man-hours per month plus an additional 130 man-hours of family labor during June, July and August. Labor Situation C assumes unlimited labor. That is, all labor required beyond the supply of the farm family can be hired at the prevailing wage. Each of the three labor situations include, however, a quantity of housewife labor available only to the poultry flock. Housewife labor amounts to 1 hour per day during the months of January, February, November and December; 1½ hours per day during March, April, September and October, and 2 hours per day for May, June, July and August.

All enterprises except poultry compete freely for non-housewife labor. Poultry is a supplementary enterprise in respect to labor use since it uses only the housewife labor. The man-hours of labor available per month under each situation and the housewife labor are given in table 1.

Capital Supply

A distinction is made between "investment" capital and "production" capital in this study. It is rather difficult to draw a definite line between expenditures representing investment and those representing a production expense. However, for purposes of this study, the initial money expenditure needed to establish an enterprise is classified as investment capital inputs. The investment capital category includes the purchase of livestock, investment in buildings and equipment and the initial expenditures for improving or renovating permanent pasture. Expenditures which must be incurred over the production period once the enterprise has been established are classified as production expenditures. The latter category includes expenditures for feed, seed, fuel, fertilizer and costs incurred in maintaining the level of productivity of improved or renovated pasture land.

Limitations are placed on "investment" capital (i.e., the quantity of capital available for investment purposes) in this study. It is assumed that the equity in real estate and machinery provides the necessary base for obtaining the amount of "production" capital necessary for farm operations.[3] Six different levels of "investment" capital are considered, and an optimum plan is worked out for each: $1,000, $2,000, $4,000, $8,000, $16,000 and unlimited capital. These six capital levels with the three levels of labor availability and the 160 acres of land constitute 18 separate resource situations. An optimum program must be determined for each situation.

For all capital situations we assume that the farm does not have livestock at the outset. (However, if livestock were on hand, they could readily be sold; the resulting value could then be included in the amount of capital available to the farm.) Consequently, any livestock included in the optimum farm plans must be charged against the supply of capital used in determining the solutions.

An interest charge has not been made for the capital used in the programs. If the capital must be obtained from credit sources, the income would be lowered by the corresponding interest charge.

[2] This breakdown of the farmland was obtained from a summarization of all soil maps available of individual farms in Troy Township, Clarke County.

TABLE 1. MAN-HOURS OF LABOR AVAILABLE UNDER EACH LABOR SITUATION.

Month	Situation A	Situation B	Situation C	Housewife labor for A, B and C
January	260	260		31.0
February	260	260		28.0
March	260	260		46.5
April	260	260	free	45.0
May	260	260	to hire	62.0
June	260	390	required	60.0
July	260	390	quantity	62.0
August	260	390	of	62.0
September	260	260	labor	45.0
October	260	260		46.5
November	260	260		30.0
December	260	260		31.0

ENTERPRISES CONSIDERED

Investment in improvement or renovation of permanent pasture to permit expansion of enterprises using this source of forage is but one alternative for the use of the resources. Therefore, to answer the question of the profitability of improving permanent pasture, alternatives other than those directly associated with the use of permanent pasture must be considered. The maximum profit farm plan will consist of some combination of the enterprises described below. The resulting plans will be the optimum subject to the resource restrictions previously discussed.

Crop Rotations: Two crop rotations are considered: a corn-corn-oats-meadow (CCOM) and a corn-corn-oats-meadow-meadow (CCOMM) rotation. The meadow in each of these rotations is an alfalfa-red clover-timothy mixture. In addition, two levels of fertilization are considered with each rotation: (1) no

[3] An alternative method of treating capital is discussed in Appendix A. There no distinction has been made between investment and production capital. All types of expenditures necessary have been taken into consideration and charged against the total quantity of capital assumed available. Similar results are obtained from either approach in this study.

fertilizer application and (2) fertilizer application at the estimated rate recommended for these crops in these rotations in south-central Iowa. Hence, there are four alternatives in regard to the cropping system: $CCOM_o$, $CCOMM_o$, $CCOM_f$ and $CCOMM_f$.[4]

Beef Cow-Calf Enterprise: Calves produced in the beef cow-calf enterprise are sold as good to choice feeder calves, with the exception of heifer calves kept for replacement. The stock cows are bred to calve early in the spring. The cow and calf are carried on pasture throughout the grazing season, and the calf is sold in October weighing about 400 pounds. The breeding herd is replaced every 8 years. On the basis of a 90-percent calf drop and a 50:50 sex ratio, 30 percent of the heifers born each year must be kept for replacements to maintain the herd.

Yearlings Fed on Drylot: Choice yearling feeder steers are purchased in October weighing about 610 pounds. The steers are brought to full feed as rapidly as possible and are fed out in drylot to grade choice. They reach the market about March weighing approximately 1,060 pounds. Taking into account an estimated death loss of 1.5 percent, the average quantity of beef produced per steer purchased amounts to about 434 pounds over the course of the feeding period.

Yearlings Full Fed on Pasture: Choice yearling feeder steers are purchased in October at a weight of about 610 pounds. These animals are wintered and then put on full feed on pasture the following spring. They are fed out to grade choice, reaching the market in October at a weight of about 1,120 pounds. Taking into account an estimated death loss of 1.5 percent, the quantity beef produced during the feeding period per steer purchased averages about 493 pounds.

Deferred Feeding of Yearlings: Choice yearling steers are purchased in October weighing about 610 pounds. The steers are wintered and put on pasture the following spring. They do not receive grain while on pasture. At the end of the grazing season, they are finished out in drylot to grade choice, reaching the market in December at a weight of about 1,135 pounds. Pounds of beef produced per steer purchased averages about 508 pounds over the course of the feeding period, taking into account a 1.5-percent death loss.

Spring-Farrowed Hogs: Under the spring-farrowing system, the pigs are farrowed in March. The number of pigs farrowed and saved per litter is 6.6. These pigs are raised on pasture and reach market in September at a weight of 225 pounds. One gilt is saved per litter for replacement. The pounds of pork sold per litter are estimated to average 1,560 pounds, including 300 pounds of sow.

Fall-Farrowed Hogs: Under the fall-farrowing system, the pigs are farrowed in August or September. The average number of pigs farrowed and saved per litter is 6.7. The pigs are fed out on drylot and marketed in February or March at a weight of 225 pounds. After saving one gilt per litter for replacement, there is an average 1,583 pounds of pork sold per litter. This includes 300 pounds of sow.

Unimproved Permanent Pasture:[5] Permanent pasture is used in its natural condition as one possible alternative. The predominant plant species found in this type of pasture is Kentucky bluegrass but many poorer quality species are also found. The carrying capacity of this type of pasture is relatively low. However, it does represent an alternative which requires little or no resource inputs in the actual production of forage.

Improved or Permanent Pasture Fertilized with Nitrogen:[6] Under this alternative, resources are needed to increase the forage yield of the permanent pasture. Annual applications of nitrogen fertilizer are made, and the pasture is clipped for weed control. The predominate plant species in the pasture is Kentucky bluegrass, and weeds are reduced by clipping.

Phosphate-Lespedeza Pasture Improvement:[7] The phosphate-lespedeza improvement involves application of phosphate fertilizer and sowing of lespedeza without preparing a seedbed. This type of improvement has an estimated life of from 10 to 15 years. However, periodic fertilizer treatments are needed to maintain the yield.[8]

Complete Pasture Renovation:[9] This type of improvement involves liming and fertilizing, preparation of a seedbed and seeding to a good pasture mixture. The mixture used in this case is birdsfoot trefoil and orchardgrass. Renovated pastures containing birdsfoot trefoil are estimated to have a life of 10 years or longer if periodic applications of fertilizer are made and weeds are controlled.

Rental of Unimproved Permanent Pasture: Renting out of unimproved Kentucky bluegrass pasture at $4.00 per acre is included as a fifth alternative in the use of permanent pasture. This alternative was included to determine whether farmers with very limited resources would be better off to put their limited funds in crops and disregard investment in livestock entirely.

Poultry: A supplementary poultry enterprise also is included. This enterprise is a small farm laying flock cared for entirely by the housewife. It does not compete with the other enterprises for the non-housewife labor. However, it does compete with the other enterprises for the available supply of capital.

This brief discussion summarizes the alternatives considered in relation to the farm situation outlined previously. Altogether the several categories represent 63 different investment opportunities. These alter-

[4] The subscript (o) refers to the nonuse of fertilizer whereas (f) indicates application of fertilizer at the estimated rate recommended.

[5] Heady, Earl O., Olson, Russell O. and Scholl, J. M. Economic efficiency in pasture production and improvement in southern Iowa. Iowa Agr. Exp. Sta. Res. Bul. 419.

[6] Ibid.

[7] Ibid.

[8] This type of pasture improvement is no longer generally recommended. Lespedeza, an annual legume, fails to reseed except in thin grass sods. Grass sods well supplied with phosphate usually become dense enough to prevent reseeding of lespedeza either from the direct effect of the phosphate on the grass or indirectly through the fertilized effect on volunteering white clover. Grass pastures can be improved more efficiently with fertilizers containing nitrogen.

[9] Heady, op.cit.

natives will be analyzed in relation to the various resource situations already described.

THE LINEAR PROGRAMMING TECHNIQUE

The purpose of this section is twofold. First, to outline briefly, in non-mathematical terms, the logic and assumptions of linear programming as they apply to the problem of this study. Second, to point out the advantages and limitations of the technique. Details given elsewhere include a more rigorous treatment of the theory of linear programming.[10]

Linear programming is a mathematical technique for determining the maximum value of some desired function subject to linear inequalities. As a research tool, the technique can be applied to any problem in which its mathematical assumptions can be reasonably well approximated.

The Process

The technique of linear programming centers around the process. The process is a specific manner by which a productive event is carried out. Two productive events are regarded as the same process if they use the same inputs and produce the same products with all factor-factor, factor-product and product-product ratios equal. Productive events which are dissimilar in any one of these respects are different processes (i.e., enterprises). A process which uses only two resources, X and Y, may be represented geometrically as in fig. 1. The proportion in which these two resources are combined to produce the outputs of the process P_1 are represented by a vector passing through the origin. The unit level of output may be represented by arbitrarily marking off some length on the vector, P_1, such as OA. The inputs in the process are then stated in relation to this level of output, designated as the "unit" level. To produce OA of P_1 requires X_1 units of the resource X and Y_1 units of the resource Y. If the output of this process is doubled, then the input of each resource also is doubled; the second unit of output requires the same resources in the same proportions as the first unit, OA.

A second process, which uses the same resources as P_1 but in different proportions, may be represented by a second vector, P_2. In the second process, P_2, OB is designated as the "unit" level of output. It requires X_1 units of resource X and Y_2 units of resource Y. The ratio between X and Y per unit level of output in process P_1 is X_1/Y_1; in process P_2 it is X_1/Y_2. Since $Y_1 < Y_2$, $X_1/Y_1 \neq X_1/Y_2$. Therefore, P_1 and P_2 are different processes according to the definition of a process. For this reason, each level of fertilization for crops or each different method of handling a given type of livestock specifies a different process in the analysis which follows.

[10] Dorfman, Robert. Application of linear programming to the theory of the firm. University of California Press, Berkeley and Los Angeles. 1951. Charnes, A., Cooper, W. W. and Henderson, A. An introduction to linear programming. John Wiley and Sons, Inc., New York. 1953. Koopmans, Tjalling C. Activity analysis of production and allocation. John Wiley and Sons, Inc., New York. 1951.

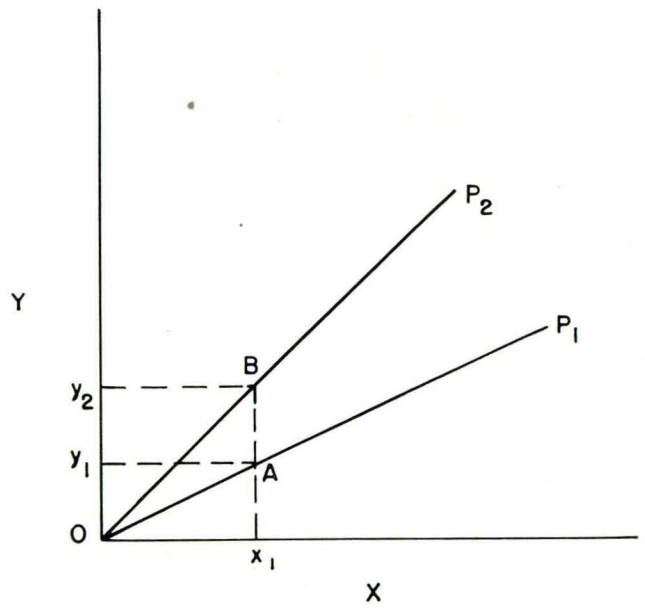

Fig. 1. Differentiation between processes using the same resources and producing the same product.

The Assumptions

As the process has been defined, resources are combined in certain fixed proportions to produce a specified quantity of product.

Linearity: The functional relationship between inputs of resources and outputs of products is linear and homogeneous of degree one. Further, the ratio of the quantity of one resource to another and to the quantity of product is constant and independent of the level at which the process is used. Linear programming derives its name from this assumption of linear relationships.

However, the concept of diminishing returns can be included—as in the case of considering several rates of fertilizer application. As the quantity of fertilizer applied to an acre of land is increased, each additional unit of fertilizer results in a smaller addition to total yield. The ratio of land to fertilizer declines along the curve, and each point on the curve can be regarded as a different process. We simply suppose that a linear relationship holds true between the points selected on the curve. The curve can be made "less linear" by selecting points which are closer together and increasing the number of processes considered. Farmers are not particularly interested in the yield response to 1-pound variations in the rate of fertilization, but rather in somewhat larger variations in the increments of fertilizer, say 10- or 20-pound units.

Because of problems of risk and uncertainty and the variability of experimental results, it is doubtful whether greater precision in input-output ratio is needed for farm analysis.

Divisibility: It is assumed that the resources used and the products produced are divisible at unit levels. The services of machinery, labor, buildings, etc. may

be used in any small positive amount (i.e., for 1 hour, 1 day or 1 week) desired up to the limit of the quantity of services available. However, in livestock production, resources must be applied as discrete units such as an animal.

Additivity: Two or more processes can be included in the solution simultaneously so long as there are sufficient resources for the combination of enterprises. The combined output of products will be the sum of the production from the individual enterprises. The combined consumption of each resource will be the sum of the consumption by the individual processes, but the combined consumption of each resource may not exceed the total supply available.

In agriculture the production of one enterprise may be related to the production of another in such a way that when the two are produced together the total output is greater than when they are produced separately. An example of this is the complementary relationship between corn and legumes when grown in rotation. The production of corn and the production of the legume might be regarded as separate processes. However, when both are included in the optimum solution, the assumption of additivity is violated. This difficulty can be avoided by considering a rotation as a process (rather than the production of each individual crop as a separate process). Hence, rotations such as CCOM, COMM or CCOMM are separate processes (i.e., single enterprises), and the effect is reflected in differences in the combined output of the complementary crops.

Similarly, we can deal with livestock which are limited by the amount of forage produced on the farm. The quantity of forage, and hence the livestock produced, depends on the rotation used. A rotation with a high proportion of forage permits a larger livestock program than a rotation with only a small proportion of forage. Therefore, livestock using forage from two different rotations are different processes of enterprises to be analyzed.

Finiteness: To apply linear programming to any problem, the number of available alternatives must be finite. In an agricultural firm the possible variations in the production technique are almost unlimited. There are many different types and sizes of machines available for a particular type of production, each with a somewhat different requirement for labor and capital and capable of accomplishing the task with varying degrees of efficiency. In addition, the timing of production can be altered over a considerable range in many instances—particularly with respect to livestock production. Because of seasonal variations in supply and demand, the price of the same product marketed at different times of the year may vary considerably. Therefore, products produced and sold at different times are, in effect, different products and must be regarded as produced by different processes. If all of the possible alternatives were included in a linear programming problem, the number of processes and limited resources would be too great for the computations necessary to arrive at a solution. However, as a practical approach to the problem, many of the possible variations need not be considered if we are interested only in finding the best program among those examined, rather than from among all possible alternatives.

Single-Valued Expectations: The input-output coefficients or resource requirements per unit of output and prices are regarded as single-valued. That is, they are assumed to be known with certainty, and they have no variability. This same assumption is made by budgeting and other techniques used in making farm recommendations.

The Logic of the System

The logic underlying the procedure can be demonstrated graphically in a simple two-process (or enterprise) situation. When more than two processes are involved, mathematics of a higher order are needed to represent the logic. However, the principles are the same.

In fig. 2, units of process P_1 are measured along the vertical axis, and P_2 is measured along the horizontal axis. The supply of resource X_1 (land, for instance) permits production of OA units of P_1 or OB units of P_2. By joining the points A and B by a straight line, we arrive at a curve which indicates all of the possible combinations of P_1 and P_2 which can be produced from the given supply of resource X_1. If all of the resource X_1 is used in producing P_1 and P_2, any combination of the two processes (falling on line AB) can be produced. Combinations represented by points within the triangle OAB also are possible if some of X_1 goes unused. Line AB might be called a process substitution curve, its slope representing the rate at which process P_2 substitutes for process P_1 in use of resource X_1.

Added curves or lines can be drawn to represent two additional resources X_2 and X_3 used by either or both processes. Each of these curves has the same

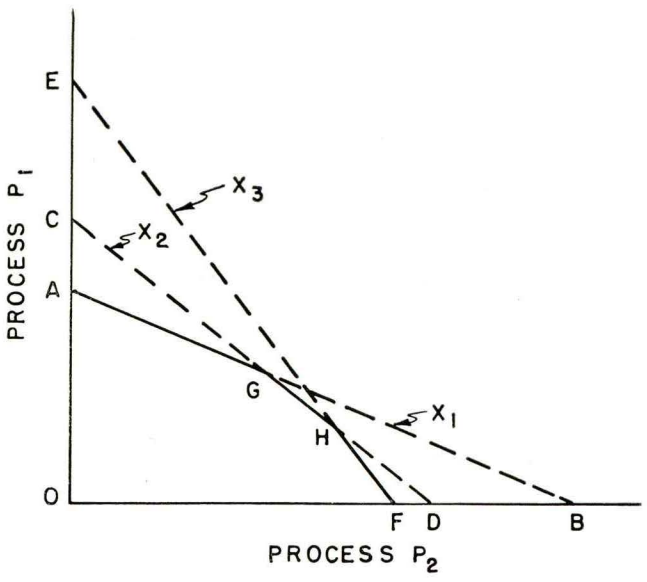

Fig. 2. Process substitution curve.

interpretation, with respect to the resource it represents, as does curve AB. When two or more resources are considered, the possible combinations of the two processes must be made to fit the supplies of all resources. For example, the supply of resource X_1 allows OB units of P_2, but the supply of X_3 limits output to OF units of P_2. If resources are used only for P_2, the level of the output is determined by resource X_3; some of resources X_1 and X_2 go unused since X_3 is the limitational resource.

The possible combinations of P_1 and P_2 which can be produced are now defined by the curve $AGHF$. This segmented curve corresponds to the product substitution curve of traditional marginal analysis except that $AGHF$ represents substitution possibilities between processes and is not a smooth, continuous curve. On each segment of this curve, the rate of substitution between the processes or enterprises is determined with respect to a different resource. The substitution rate along the segment AG is in respect to resource X_1; along GH it is in respect to X_2; along HF it is in respect to X_3.

The combination of these two processes which will result in maximum profits is determined by the point at which an iso-revenue curve between P_1 and P_2 is tangent to the curve $AGHF$. A unique combination of enterprises is obtained only if the tangency point is at a corner such as A, G, H or F. If the tangency occurs along a line segment such as GH, all combinations represented between points G and H are equally profitable.

In some instances the relative supply of some fixed resources is very large. These resources then do not impose restrictions on the optimum plan. This situation is represented in fig. 3 where there are two processes and three resources. In fig. 3a, the supply of X_2 is sufficient to produce OB units of P_1 or OF units of P_2 or any combination of the two processes as represented by the line BF. The supply of X_3 is sufficient to permit any combination represented by the line CE. However, the supply of resource X_1 permits production of only OA units of P_1, OD units of P_2 or any combination represented by the line AD. The line AD lies entirely below either BF or CE. Therefore, the plan is limited alone by resource X_1, and the production possibility curve becomes AD.

With sufficient supply of the resource X_1, relative to the supply of the other two resources, the situation is changed. The plan is no longer limited by a single resource. In fig. 3b, for example, the supply of X_1 has been increased, and the production possibility curve is now AGE. It is made up of segments of the resource curves for both X_1 and X_3. The resource curve for X_2 lies above AGE at all points and, therefore, does not limit the program in any sense. If the supply of X_1 were further increased, so that OA is greater than OB, then X_1 would no longer be limiting; the optimum program would be determined entirely with respect to the resources X_2 and X_3. We now see how the relative quantities of different resources effect the optimum plan. In fig. 3, for example, the slope of the iso-revenue curve may be greater than the slope of the line AD but less than the slope of CE. The optimum program then includes production of only

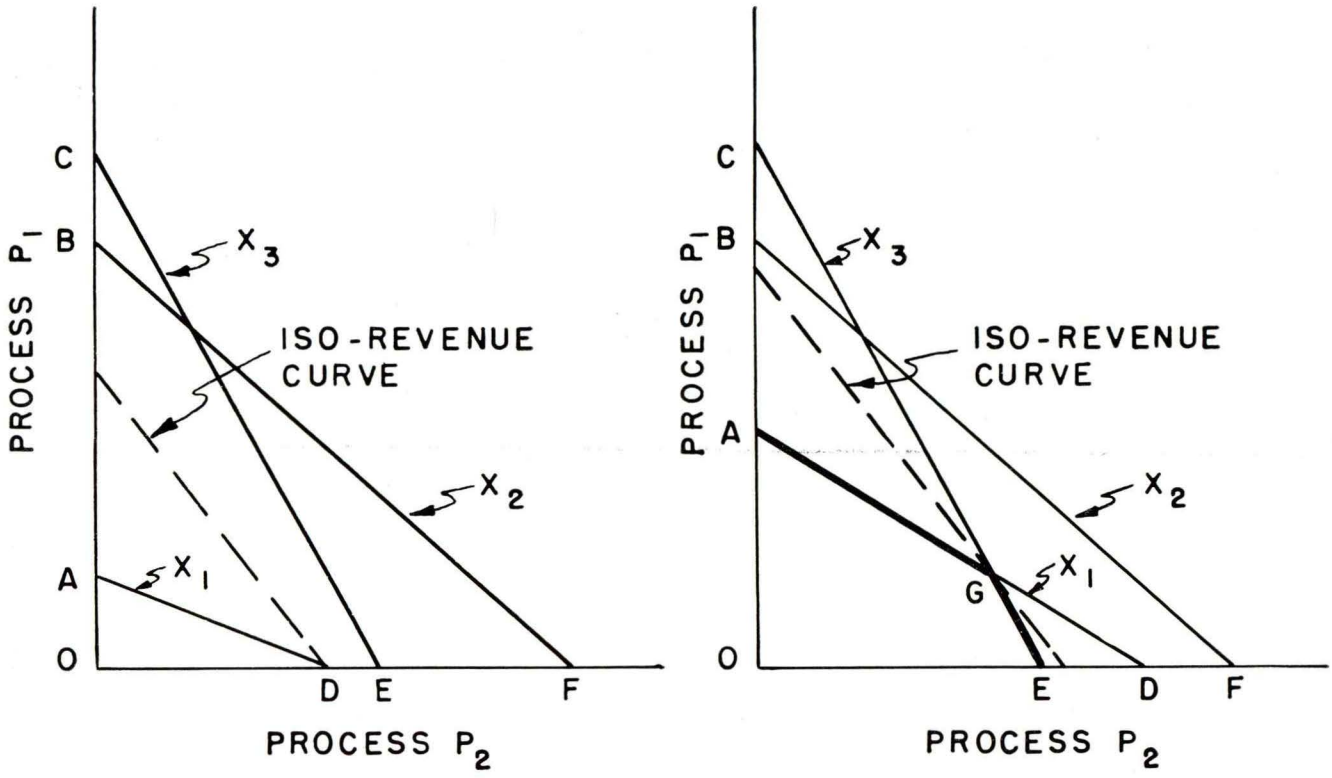

Fig. 3. Effect of the relative supplies of resources on the optimum program.

P_2 in fig. 3a, but it includes a combination of P_1 and P_2 (represented by the point G) in fig. 3b.

With linear programming a great number of alternatives can be compared in relation to the resource limitations on a farm. It permits selection of the most profitable combination of enterprises in terms of the opportunity costs associated with the various alternatives. Furthermore, it provides an integrated analysis of the farm as a whole, rather than a segmented analysis of the firm by parts.

The computational procedure used in this linear programming study is relatively simple. It uses the "simplex" method which is discussed in detail elsewhere and will not be reproduced here.[11]

[11] A detailed discussion of the computational procedure of linear programming is presented in Charnes, Cooper and Henderson, op.cit.

TABLE 2. LIST OF PROCESSES OR ENTERPRISES INCLUDED IN STUDY.

Enterprise number	Enterprise	Type of rotation supplying feed requirements*	Type of pasture used
P_1	Renting out unimproved pasture	----------	----------
P_2	Beef cow-calf	$CCOM_0$	Unimproved Kentucky bluegrass
P_3	Beef cow-calf	$CCOM_0$	Improved Kentucky bluegrass
P_4	Beef cow-calf	$CCOM_0$	Phosphate-lespedeza
P_5	Beef cow-calf	$CCOM_0$	Renovated pasture
P_6	Beef cow-calf	$CCOMM_0$	Unimproved Kentucky bluegrass
P_7	Beef cow-calf	$CCOMM_0$	Improved Kentucky bluegrass
P_8	Beef cow-calf	$CCOMM_0$	Phosphate-lespedeza
P_9	Beef cow-calf	$CCOMM_0$	Renovated pasture
P_{10}	Beef cow-calf	$CCOM_f$	Unimproved Kentucky bluegrass
P_{11}	Beef cow-calf	$CCOM_f$	Improved Kentucky bluegrass
P_{12}	Beef cow-calf	$CCOM_f$	Phosphate-lespedeza
P_{13}	Beef cow-calf	$CCOM_f$	Renovated pasture
P_{14}	Beef cow-calf	$CCOMM_f$	Unimproved Kentucky bluegrass
P_{15}	Beef cow-calf	$CCOMM_f$	Improved Kentucky bluegrass
P_{16}	Beef cow-calf	$CCOMM_f$	Phosphate-lespedeza
P_{17}	Beef cow-calf	$CCOMM_f$	Renovated pasture
P_{18}	Yearlings fed in drylot	$CCOM_0$	----------
P_{19}	Yearlings fed in drylot	$CCOMM_0$	----------
P_{20}	Yearlings fed in drylot	$CCOM_f$	----------
P_{21}	Yearlings fed in drylot	$CCOMM_f$	----------
P_{22}	Yearlings full fed on pasture	$CCOM_0$	Unimproved Kentucky bluegrass
P_{23}	Yearlings full fed on pasture	$CCOM_0$	Improved Kentucky bluegrass
P_{24}	Yearlings full fed on pasture	$CCOM_0$	Phosphate-lespedeza
P_{25}	Yearlings full fed on pasture	$CCOM_0$	Renovated pasture
P_{26}	Yearlings full fed on pasture	$CCOMM_0$	Unimproved Kentucky bluegrass
P_{27}	Yearlings full fed on pasture	$CCOMM_0$	Improved Kentucky bluegrass
P_{28}	Yearlings full fed on pasture	$CCOMM_0$	Phosphate-lespedeza
P_{29}	Yearlings full fed on pasture	$CCOMM_0$	Renovated pasture
P_{30}	Yearlings full fed on pasture	$CCOM_f$	Unimproved Kentucky bluegrass
P_{31}	Yearlings full fed on pasture	$CCOM_f$	Improved Kentucky bluegrass
P_{32}	Yearlings full fed on pasture	$CCOM_f$	Phosphate-lespedeza
P_{33}	Yearlings full fed on pasture	$CCOM_f$	Renovated pasture
P_{34}	Yearlings full fed on pasture	$CCOMM_f$	Unimproved Kentucky bluegrass
P_{35}	Yearlings full fed on pasture	$CCOMM_f$	Improved Kentucky bluegrass
P_{36}	Yearlings full fed on pasture	$CCOMM_f$	Phosphate-lespedeza
P_{37}	Yearlings full fed on pasture	$CCOMM_f$	Renovated pasture
P_{38}	Deferred feeding of yearlings	$CCOM_0$	Unimproved Kentucky bluegrass
P_{39}	Deferred feeding of yearlings	$CCOM_0$	Improved Kentucky bluegrass
P_{40}	Deferred feeding of yearlings	$CCOM_0$	Phosphate-lespedeza
P_{41}	Deferred feeding of yearlings	$CCOM_0$	Renovated pasture
P_{42}	Deferred feeding of yearlings	$CCOMM_0$	Unimproved Kentucky bluegrass
P_{43}	Deferred feeding of yearlings	$CCOMM_0$	Improved Kentucky bluegrass
P_{44}	Deferred feeding of yearlings	$CCOMM_0$	Phosphate-lespedeza
P_{45}	Deferred feeding of yearlings	$CCOMM_0$	Renovated pasture
P_{46}	Deferred feeding of yearlings	$CCOM_f$	Unimproved Kentucky bluegrass
P_{47}	Deferred feeding of yearlings	$CCOM_f$	Improved Kentucky bluegrass
P_{48}	Deferred feeding of yearlings	$CCOM_f$	Phosphate-lespedeza
P_{49}	Deferred feeding of yearlings	$CCOM_f$	Renovated pasture
P_{50}	Deferred feeding of yearlings	$CCOMM_f$	Unimproved Kentucky bluegrass
P_{51}	Deferred feeding of yearlings	$CCOMM_f$	Improved Kentucky bluegrass
P_{52}	Deferred feeding of yearlings	$CCOMM_f$	Phosphate-lespedeza
P_{53}	Deferred feeding of yearlings	$CCOMM_f$	Renovated pasture
P_{54}	Spring-farrowed hogs	$CCOM_0$	----------
P_{55}	Spring-farrowed hogs	$CCOMM_0$	----------
P_{56}	Spring-farrowed hogs	$CCOM_f$	----------
P_{57}	Spring-farrowed hogs	$CCOMM_f$	----------
P_{58}	Fall-farrowed hogs	----------	----------
P_{59}	Laying flock	----------	----------
P_{60}	$CCOM_0$ entire production sold	----------	----------
P_{61}	$CCOMM_0$ entire production sold	----------	----------
P_{62}	$CCOM_f$ entire production sold	----------	----------
P_{63}	$CCOMM_f$ entire production sold	----------	----------

*The symbol $CCOM_0$ or $CCOMM_0$ refers to a rotation without fertilizer. The symbol $CCOM_f$ or $CCOMM_f$ refers to a rotation to which fertilizer is applied.

TABLE 3. RESOURCE REQUIREMENTS OF EACH PROCESS PER UNIT LEVEL OF OUTPUT.

Enterprise number	Unit	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}	P_{14}
Unit level of output		acre	cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt
Net price/unit output	$	4.00	31.80	28.82	29.83	30.34	25.13	22.16	23.16	23.68	31.32	28.35	29.36	29.87	24.48
Investment capital	$	0	42.45	44.98	51.69	52.46	42.45	44.98	51.69	52.46	42.45	44.98	51.69	52.46	42.45
Pasture land	acre	1	0.685	0.582	0.551	0.373	0.685	0.582	0.551	0.373	0.685	0.582	0.551	0.373	0.685
Cropland	acre	0	0.562	0.562	0.562	0.562	0.404	0.404	0.404	0.404	0.446	0.446	0.446	0.446	0.308
Operator labor: Jan.	man-hours	0	0.458	0.458	0.458	0.458	0.458	0.458	0.458	0.458	0.458	0.458	0.458	0.458	0.458
Feb.	"	0	0.458	0.458	0.458	0.458	0.458	0.458	0.458	0.458	0.458	0.458	0.458	0.458	0.458
March	"	0	0.559	0.559	0.559	0.559	0.537	0.537	0.537	0.537	0.549	0.549	0.549	0.549	0.531
April	"	0	0.702	0.702	0.702	0.702	0.649	0.649	0.649	0.649	0.628	0.628	0.628	0.628	0.500
May	"	0	0.605	0.605	0.605	0.605	0.421	0.421	0.421	0.421	0.515	0.515	0.515	0.515	0.361
June	"	0	0.630	0.630	0.630	0.630	0.516	0.516	0.516	0.516	0.573	0.573	0.573	0.573	0.483
July	"	0	0.846	0.846	0.846	0.846	0.641	0.641	0.641	0.641	0.744	0.744	0.744	0.744	0.577
Aug.	"	0	0.449	0.449	0.449	0.449	0.336	0.336	0.336	0.336	0.394	0.394	0.394	0.394	0.301
Sept.	"	0	0.242	0.242	0.242	0.242	0.225	0.225	0.225	0.225	0.234	0.234	0.234	0.234	0.220
Oct.	"	0	0.464	0.464	0.464	0.464	0.339	0.339	0.339	0.339	0.403	0.403	0.403	0.403	0.299
Nov.	"	0	0.627	0.627	0.627	0.627	0.456	0.456	0.456	0.456	0.544	0.544	0.544	0.544	0.402
Dec.	"	0	0.446	0.446	0.446	0.446	0.403	0.403	0.403	0.403	0.425	0.425	0.425	0.425	0.389
Housewife labor (Feb.)	"	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beef housing	sq. ft.	0	11.06	11.06	11.06	11.06	11.06	11.06	11.06	11.06	11.06	11.06	11.06	11.06	11.06

TABLE 3—(cont.)

Enterprise number	Unit	P_{15}	P_{16}	P_{17}	P_{18}	P_{19}	P_{20}	P_{21}	P_{22}	P_{23}	P_{24}	P_{25}	P_{26}	P_{27}	P_{28}	P_{29}
Unit level of output		cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt
Net price/unit output	$	21.51	22.52	23.03	11.45	9.31	11.29	9.10	10.67	10.07	10.27	10.38	10.32	9.72	9.92	10.03
Investment capital	$	44.98	51.69	52.46	33.97	33.97	33.97	33.97	29.91	30.41	31.75	31.89	29.91	30.41	31.75	31.89
Pasture land	acre	0.582	0.551	0.373	0	0	0	0	0.138	0.118	0.112	0.075	0.138	0.118	0.112	0.075
Cropland	acre	0.308	0.308	0.308	0.183	0.131	0.145	0.100	0.030	0.030	0.030	0.030	0.022	0.022	0.022	0.022
Operator labor: Jan.	man-hours	0.458	0.458	0.458	0.575	0.575	0.575	0.575	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038
Feb.	"	0.458	0.458	0.458	0.575	0.575	0.575	0.575	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038
March	"	0.531	0.531	0.531	0.591	0.584	0.588	0.584	0.040	0.040	0.040	0.040	0.039	0.039	0.039	0.039
April	"	0.500	0.500	0.500	0.116	0.067	0.092	0.064	0.057	0.057	0.057	0.057	0.049	0.049	0.049	0.049
May	"	0.361	0.361	0.361	0.141	0.081	0.112	0.077	0.393	0.393	0.393	0.393	0.383	0.383	0.383	0.383
June	"	0.483	0.483	0.483	0.149	0.112	0.130	0.082	0.395	0.395	0.395	0.395	0.389	0.389	0.389	0.389
July	"	0.577	0.577	0.577	0.219	0.153	0.186	0.120	0.406	0.406	0.406	0.406	0.395	0.395	0.395	0.395
Aug.	"	0.301	0.301	0.301	0.090	0.053	0.072	0.049	0.424	0.424	0.424	0.424	0.418	0.418	0.418	0.418
Sept.	"	0.220	0.220	0.220	0.093	0.088	0.091	0.083	0.448	0.448	0.448	0.448	0.447	0.447	0.447	0.447
Oct.	"	0.299	0.299	0.299	0.669	0.629	0.650	0.626	0.499	0.499	0.499	0.499	0.492	0.492	0.492	0.492
Nov.	"	0.402	0.402	0.402	0.705	0.650	0.678	0.646	0.487	0.487	0.487	0.487	0.478	0.478	0.478	0.478
Dec.	"	0.389	0.389	0.389	0.608	0.594	0.601	0.593	0.471	0.471	0.471	0.471	0.469	0.469	0.469	0.469
Housewife labor (Feb.)	"	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beef housing	sq. ft.	11.06	11.06	11.06	5.62	5.62	5.62	5.62	4.95	4.95	4.95	4.95	4.95	4.95	4.95	4.95

TABLE 3—(cont.)

Enterprise number	Unit	P_{30}	P_{31}	P_{32}	P_{33}	P_{34}	P_{35}	P_{36}	P_{37}	P_{38}	P_{39}	P_{10}	P_{41}	P_{42}	P_{43}	P_{44}
Unit level of output		cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt
Net price/unit output	$	10.65	10.05	10.25	10.35	10.29	9.69	9.89	9.99	15.49	13.11	13.90	14.31	14.65	12.27	13.07
Investment capital	$	29.91	30.41	31.75	31.89	29.91	30.41	31.75	31.89	29.02	31.02	36.30	36.92	29.02	31.02	36.30
Pasture land	acre	0.138	0.118	0.112	0.075	0.138	0.118	0.112	0.075	0.549	0.467	0.441	0.299	0.549	0.467	0.441
Cropland	acre	0.024	0.024	0.024	0.024	0.016	0.016	0.016	0.016	0.071	0.071	0.071	0.071	0.051	0.051	0.051
Operator labor: Jan.	man-hours	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.039	0.039	0.039	0.039	0.039	0.039	0.039
Feb.	"	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.038	0.039	0.039	0.039	0.039	0.039	0.039	0.039
March	"	0.040	0.040	0.040	0.040	0.039	0.039	0.039	0.039	0.045	0.045	0.045	0.045	0.042	0.042	0.042
April	"	0.053	0.053	0.053	0.053	0.046	0.046	0.046	0.046	0.084	0.084	0.084	0.084	0.065	0.065	0.065
May	"	0.388	0.388	0.388	0.388	0.380	0.380	0.380	0.380	0.074	0.074	0.074	0.074	0.051	0.051	0.051
June	"	0.392	0.392	0.392	0.392	0.387	0.387	0.387	0.387	0.078	0.078	0.078	0.078	0.063	0.063	0.063
July	"	0.401	0.401	0.401	0.401	0.392	0.392	0.392	0.392	0.105	0.105	0.105	0.105	0.079	0.079	0.079
Aug.	"	0.421	0.421	0.421	0.421	0.416	0.416	0.416	0.416	0.055	0.055	0.055	0.055	0.040	0.040	0.040
Sept.	"	0.448	0.448	0.448	0.448	0.447	0.447	0.447	0.447	0.382	0.382	0.382	0.382	0.380	0.380	0.380
Oct.	"	0.495	0.495	0.495	0.495	0.490	0.490	0.490	0.490	0.569	0.569	0.569	0.569	0.553	0.553	0.553
Nov.	"	0.482	0.482	0.482	0.482	0.475	0.475	0.475	0.475	0.562	0.562	0.562	0.562	0.540	0.540	0.540
Dec.	"	0.470	0.470	0.470	0.470	0.468	0.468	0.468	0.468	0.504	0.504	0.504	0.504	0.499	0.499	0.499
Housewife labor (Feb.)	"	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beef housing	sq. ft.	4.95	4.95	4.95	4.95	4.95	4.95	4.95	4.95	4.80	4.80	4.80	4.80	4.80	4.80	4.80

TABLE 3—(cont.)

Enterprise number	Unit	P_{45}	P_{46}	P_{47}	P_{48}	P_{49}	P_{50}	P_{51}	P_{52}	P_{53}	P_{54}	P_{55}	P_{56}	P_{57}	P_{58}	P_{59}
Unit level of output		cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt	cwt
Net price/unit output	$	13.47	15.43	13.05	13.84	14.25	14.75	12.19	12.99	13.39	13.21	11.69	13.10	11.54	6.04	1.14
Investment capital	$	36.92	29.02	31.02	36.30	36.92	29.02	31.02	36.30	36.92	6.26	6.26	6.26	6.26	6.17	0.34
Pasture land	acre	0.299	0.549	0.467	0.441	0.299	0.549	0.467	0.441	0.299	0	0	0	0	0	0
Cropland	acre	0.051	0.057	0.057	0.057	0.057	0.039	0.039	0.039	0.039	0.130	0.094	0.103	0.071	0	0
Operator labor: Jan.	man-hours	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.132	0.132	0.132	0.132	0.202	0
Feb.	"	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.132	0.132	0.132	0.132	0.158	0
March	"	0.042	0.044	0.044	0.044	0.044	0.041	0.041	0.041	0.041	0.170	0.165	0.168	0.163	0.146	0
April	"	0.065	0.075	0.075	0.075	0.075	0.059	0.059	0.059	0.059	0.250	0.214	0.233	0.203	0.113	0
May	"	0.051	0.063	0.063	0.063	0.063	0.043	0.043	0.043	0.043	0.252	0.209	0.231	0.196	0.098	0
June	"	0.063	0.070	0.070	0.070	0.070	0.059	0.059	0.059	0.059	0.245	0.218	0.231	0.210	0.108	0
July	"	0.079	0.092	0.092	0.092	0.092	0.071	0.071	0.071	0.071	0.295	0.247	0.271	0.232	0.104	0
Aug.	"	0.040	0.048	0.048	0.048	0.048	0.036	0.036	0.036	0.036	0.203	0.176	0.190	0.168	0.171	0
Sept.	"	0.380	0.381	0.381	0.381	0.381	0.379	0.379	0.379	0.379	0.148	0.144	0.146	0.143	0.271	0
Oct.	"	0.553	0.561	0.561	0.561	0.561	0.548	0.548	0.548	0.548	0.199	0.170	0.185	0.161	0.259	0
Nov.	"	0.540	0.551	0.551	0.551	0.551	0.533	0.533	0.533	0.533	0.223	0.184	0.204	0.171	0.227	0
Dec.	"	0.499	0.502	0.502	0.502	0.502	0.497	0.497	0.497	0.497	0.142	0.132	0.137	0.129	0.227	0
Housewife labor (Feb.)	"	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.89
Beef housing	sq. ft.	4.80	4.80	4.80	4.80	4.80	4.80	4.80	4.80	4.80	0	0	0	0	0	0

TABLE 3—(cont.)

Enterprise number	Unit	P_{60}	P_{61}	P_{62}	P_{63}
Unit level of output		feed units	feed units	feed units	feed units
Net price/unit output	$	0.85	0.79	0.80	0.75
Investment capital	$	0	0	0	0
Pasture land	acre	0	0	0	0
Cropland	acre	0.02470	0.02520	0.01907	0.01919
Operator labor: Jan.	man-hours	0	0	0	0
Feb.	"	0	0	0	0
March	"	0.00219	0.00178	0.00169	0.00136
April	"	0.01573	0.01283	0.01204	0.00977
May	"	0.01901	0.01552	0.01468	0.01182
June	"	0.02012	0.02150	0.01716	0.01939
July	"	0.02963	0.02926	0.02450	0.02529
Aug.	"	0.01217	0.01026	0.00950	0.00803
Sept.	"	0.00308	0.00333	0.00265	0.00299
Oct.	"	0.01278	0.01043	0.00988	0.00794
Nov.	"	0.01762	0.01439	0.01362	0.01096
Dec.	"	0.00449	0.00368	0.00347	0.00280
Housewife labor (Feb.)	"	0	0	0	0
Beef housing	sq. ft.	0	0	0	0

The preceeding discussion treats our application of the technique of linear programming in a general fashion. Some of the points may be further clarified by following through the manner in which the problem was formulated in this particular study.

FORMULATION OF THE PROCESSES IN THE STUDY

The more common terms *enterprise* or *investment opportunity* are substituted for the term process in the remainder of this study. Enterprises which represent different combinations of products or use resources in different proportions are, thus, different processes or investment opportunities. A CCOM rotation is a different process than the same rotation with fertilizer. Yearling steers using forage produced with a CCOM rotation is a different process than the same enterprise using forage from a CCOM rotation which is fertilized. Or, yearling steers produced with a CCOM rotation with fertilization and unimproved pasture is a different process from the same type of livestock and crop rotation but using improved pasture. Beef calves produced with four different kinds of pasture improvement represent four different processes which must be evaluated for profit.

Considering all of the possible combinations or enterprises, this study includes 63 different processes or activities. Linear programming is used to consider the one combination, among thousands of combinations, which will give maximum returns under different resource situations. The 63 processes included in this study are listed in table 2.

Units of Output

The units of measurement for output used in this study are as follows: The output of crop rotations, where the entire crop production is sold on the cash market, is expressed in feed units.[12] The output of pork is measured in terms of 100-pound weights of pork produced and marketed. With the spring-farrowing enterprise, each 100 pounds of pork marketed includes 80.8 pounds of market hog and 19.2 pounds of sow. Each 100 pounds of pork marketed from the fall-farrowing enterprise includes 81.0 pounds of market hog and 19.0 pounds of sow. Beef output units are in terms of 100-pound weights of beef produced and marketed. Each 100-pound unit of beef produced and marketed from the beef cow-calf enterprise is composed of 40.4 pounds of steer calf, 28.5 pounds of hiefer calf and 31.1 pounds of cull cow. The output units of the steer-feeder enterprises are 100 pounds of fat steer. A unit of output from the poultry enterprise includes 3.96 pounds of old hen, 0.34 pound of cull pullet and 16.25 dozen eggs.

Having determined the units for measuring the output of each enterprise, the resource requirements can then be expressed in terms of these units. The resource requirements for each of the enterprises considered are presented in table 3. Then, knowing the available quantities of the various resources and the net return per unit of output for each enterprise, the profit-maximizing plan can be calculated from the array of alternatives being considered.

PROFIT-MAXIMIZING PLANS

Optimum programs or plans have been computed for each of the 18 resource situations described. All of the plans have been determined under the restriction that the livestock program shall not exceed the forage production of the farm. In addition, the size of the spring-farrowing hog enterprise is limited to 15 litters and the fall hogs to 10 litters. This restriction is later removed, and the optimum plans are calculated accordingly for each resource situation.

One possible reason why a farmer may not want a very large hog enterprise might be a dislike for raising hogs. Other reasons may be limitations on space and facilities. For these reasons, the limits of 15 spring litters and 10 fall litters are used to determine the effect of such restrictions on the profit-maximizing plans. These limits have been arbitrarily chosen on the basis of data from the Iowa Crop Reporting Service and the Southern Iowa Farm Business Association which indicate the average number of spring and fall litters per farm.

Plans With Sizes of Hog Enterprises Restricted

A summary of the plans obtained under the above resource situations or restrictions with the sizes of the hog enterprises limited is given in table 4. Each of the plans includes 110 acres of the corn-corn-oats-meadow rotation with the crops fertilized at the recommended rate and a supplementary poultry flock of 148 hens. At low levels of capital, the pasture land is rented out as a result of insufficient funds to purchase livestock to make use of the pasture. The hog enterprises bring a higher return on capital than the beef enterprises. As the supply of capital is increased, the sizes of the spring and fall hog enterprises approach their maximum limit. It then becomes profitable to invest in livestock to make use of the permanent pasture land and the additional capital. However, pasture is not improved until the pasture consumption of the beef enterprises exceeds the supply of unimproved pasture.

Where the sizes of the hog enterprises is restricted to 15 spring litters and 10 fall litters, a labor supply of 260 man-hours per month is adequate at all capital

[12] A feed unit is calculated by taking corn as the basis and assuming that 1 bushel of corn is equivalent to 1 feed unit. The other crops in the rotation are converted to the equivalent of corn on the basis of total digestible nutrients. A bushel of oats is equal to ½ bushel of corn on this basis and, therefore, is equal to ½ a feed unit. A ton of mixed clover-timothy-alfalfa hay is equivalent to 22.4 bushels of corn or 22.4 feed units. An acre in this area in a CCOM rotation and receiving no fertilization is estimated to produce 27.74 bushels of corn, 4.86 bushels of oats and 0.46 ton of mixed hay. Multiplying each of these quantities by their respective value in terms of feed units, the total numbers of feed units produced on an acre with this rotation is obtained: (1) (27.74) + (0.5) (4.86) + (22.43) (0.46) = 40.49 feed units per acre. The gross price of a feed is calculated by multiplying the quantity of each crop produced on an acre by its respective price. By dividing the total value of the crop production per acre by the number of feed units, the price per feed unit is determined. A similar procedure is followed for arriving at costs per feed unit. The difference between gross price and cost per feed unit gives the net value of 1 feed unit. Because different rotations have different proportions of each crop, these values will differ for each rotation.

TABLE 4. OPTIMUM PLANS WITH SIZE OF HOG ENTERPRISE LIMITED.*

Investment capital situations	Labor situations		
	A. Operator only	B. Operator plus family labor	C. Unlimited labor
$1,000	110 acres CCOMr rotation 38 acres pasture rented out 148-hen laying flock 10 litters of spring hogs $2,414 net return	Same as in column A	Same as in column A
$2,000	110 acres CCOMr rotation 38 acres pasture rented out 148-hen laying flock 5 litters of fall hogs 15 litters of spring hogs $3,609 net return	Same as in column A	Same as in column A
$4,000	110 acres CCOMr rotation 9 acres pasture rented out 148-hen laying flock 15 litters of spring hogs 10 litters of fall hogs 10 yearling steers on a deferred-feeding pasture program $4,652 net return	Same as in column A	Same as in column A
$8,000	110 acres CCOMr rotation 148-hen laying flock 15 litters of spring hogs 10 litters of fall hogs 31 steers full fed on pasture 6 steers on a deferred-feeding pasture program $5,846 net return	Same as in column A	Same as in column A
$16,000	110 acres CCOMr rotation 148-hen laying flock 15 litters spring hogs 10 litters fall hogs 20 steers deferred-feeding program† 19 steers full fed on pasture† $6,045 net return	Same as in column A	Same as in column A
Unlimited	Same as $16,000 Capital situation	Same as in column A	Same as in column A

*All values have been rounded to nearest whole number.
†These enterprises utilized completely renovated pasture. Beef enterprise in preceding plans in this table were on unimproved Kentucky bluegrass pasture.

levels considered. Therefore, increasing the labor supply does not permit any improvement in the plan which would result in greater profits.

PLAN 1. OPERATOR LABOR AND $1,000 CAPITAL

This plan consists of 110 acres of a corn-corn-oats-meadow rotation fertilized at the recommended rate, 10 litters of spring-farrowed hogs, a 148-hen laying flock and 38 acres of pasture rented out.

The manner in which the available resources are divided among the enterprises in this plan is shown in table 5. All of the resources available to the farm are listed in the left margin of this table: investment capital, cropland, pasture land, operator labor, housewife labor and building space for beef cattle. Also included in the list are the capacity limitations (maximum number of litters permitted) that have been imposed on the spring- and fall-farrowing hog enterprises in this set of plans. Each month of labor has been listed separately since unused labor cannot be stored to be used in a later month where labor is in short supply. Only 1 month of housewife labor has been listed since only one enterprise, poultry, uses this source of labor. Therefore, only the most restrictive month need be listed. The unit of measurement of each resource is indicated in the second column of the table. Listed in the third column is the quantity of each resource available to the farm in this resource situation. In the next four columns are the quantities of each resource consumed by each enterprise in the plan. The quantity of each resource that goes unused or is in excess supply under the "best" or "most profitable" farm plan is indicated in the last column.

The plan in this case is limited by the available quantity of cropland, pasture land, investment capital and housewife labor in February. (Resource limitations are indicated by the zeros appearing in the last column of table 5 opposite these resources.) Some operator labor and all beef housing goes unused because of the limited supply of the above four resources.

If the calculation of the above plan is considered step by step, it will be found that the most profitable single enterprise with capital limited to $1,000 is the corn-corn-oats-meadow rotation with fertilization. The size of this enterprise is determined by the quantity of cropland. The quantity of all other resources is sufficient for an acreage of crops greater than allowed by cropland. Under this plan, net return is

TABLE 5. USE OF RESOURCES UNDER THE $1,000 CAPITAL-OPERATOR LABOR SITUATION.

Resources		Unit	Resources available	Spring hogs	Pasture rented out	CCOM$_f$ rotation	Laying flock	Resources unused
Investment capital		$	1,000	950	0	0	50	0
Pasture land		acre	38	0	38	0	0	0
Cropland		acre	110	(4)*	0	110	0	0
Labor:	Jan.	man-hours	260	20	0	0	0	240
	Feb.	"	260	20	0	0	0	240
	March	"	260	24	0	10	0	226
	April	"	260	25	0	70	0	165
	May	"	260	23	0	85	0	152
	June	"	260	21	0	99	0	140
	July	"	260	21	0	141	0	98
	Aug.	"	260	21	0	55	0	184
	Sept.	"	260	20	0	15	0	225
	Oct.	"	260	20	0	57	0	183
	Nov.	"	260	20	0	79	0	161
	Dec.	"	260	18	0	20	0	222
Housewife labor (Feb.)		"	28	0	0	0	28	0
Spring hog limit		litters	15	10	0	0	0	5
Fall hog limit		litters	10	0	0	0	0	10
Beef housing		sq. ft.	963	0	0	0	0	963

*Numbers in parentheses indicate the acreage of rotation meadow utilized by each of the livestock enterprises either as pasture or hay.

$767. No other single enterprise could bring as great a profit from the available resources.

A plan including only the CCOM$_f$ rotation is one possibility. However, net returns can be increased by including additional enterprises in the plan. The problem then is: Which second enterprise will increase net return by the largest amount; what should be the level or size of each enterprise in the revised plan?

The second most profitable enterprise to come in under this resource situation is the spring hog enterprise. It is limited in size by the quantity of investment capital. If the spring hog enterprise is increased up to the limit of investment capital, the plan includes a crop enterprise up to the limit of the cropland and a hog enterprise up to the limit of the capital supply. Four acres of rotation meadow previously used for hay is now used as hog pasture. This revised plan results in a net return of $2,163—or $1,396 more than the plan including only the CCOM$_f$ rotation. The hog enterprise competes with the crop enterprise for labor. However, the supply of labor is more than adequate and does not become a limiting resource for either of these enterprises.

Another revision in the farm plan can be made to further increase net return. The pasture land can be rented out at the going rental rate—in this instance, $4 per acre. Since no costs are involved and none of the other limited resources are required, this enterprise increases net revenue by $152. The permanent pasture could be utilized by beef cattle. However, this alternative would draw capital away from the hog enterprise. The loss in net returns by reducing the hog enterprises would more than offset the increase from adding a beef enterprise. In other words, the opportunity cost of adding the beef enterprise is greater than the net returns it would bring. Therefore, the best alternative is to rent the permanent pasture out in this resource situation.

One more enterprise can, however, come in to increase profit. Poultry competes with the other enterprises only for investment capital, labor being supplied by the housewife. Therefore, poultry is supplementary to other enterprises with respect to labor. The supply of housewife labor in the most limiting month, February, will provide for a laying flock of 148 hens. A flock of this size draws $50 of investment capital away from the hog enterprise forcing it to be reduced somewhat. In terms of opportunity cost, the net return from poultry is greater than the net return that must be given up if poultry is added to the plan, as long as the labor, buildings and equipment are available. The net return is increased to $2,414. This is the optimum plan under this resource situation (shown in northwest cell of table 4). This plan results in the largest net return; any further revision of the plan would result in a lower net return.

The budget for the profit-maximizing plan with $1,000 investment capital and labor supplied by the operator alone is given in table 6. The gross value of the products sold amounts to $10,168. The annual production expenses amount to $3,882, not including the fixed costs of the farm.

This relatively simple plan has been discussed in detail to illustrate the types of considerations involved in arriving at the highest profit organization. As the quantity of investment capital is increased, it becomes possible to invest in enterprises which will more fully utilize the available supply of labor and building

TABLE 6. BUDGET FOR THE $1,000 CAPITAL-OPERATOR LABOR SITUATION

Crops	Corn	Oats	Hay
Acres	55	27.5	27.5
Production	3,928	819 bu.	64 ton
Utilization			
Fed to hogs	798 bu.	----	9 ton*
Fed to poultry	236 bu.	----	----
Marketed	2,894 bu.	819 bu.	55 ton

Sales and expenses	Gross sales	Annual production expenses
Crops	$5,747†	$2,717
Hogs	3,218	610‡
Poultry	1,050	555‡
Pasture	152§	----
Total	$10,168	$3,882**

*Equivalent quantity of hay fed to hogs as pasture.
†Does not include the value of crops fed on the farm.
‡Does not include the value of home-grown feeds consumed.
§Rent received for the pasture.
**The fixed costs of the farm such as property taxes, depreciation on buildings and equipment and interest on land and improvements are not included in these expense items.

TABLE 7. USE OF RESOURCES UNDER THE $2,000 CAPITAL-OPERATOR LABOR SITUATION.

Resources		Unit	Resources available	Fall hogs	Pasture rented out	$CCOM_t$ rotation	Laying flock	Spring hogs	Resources unused
Investment capital		$	2,000	485	0	0	50	1,465	0
Pasture land		acre	38	0	38	0	0	0	0
Cropland		acre	110	0	0	110	0	(6)*	0
Labor:	Jan.	man-hours	260	10	0	0	0	31	219
	Feb.	"	260	10	0	0	0	31	219
	March	"	260	13	0	10	0	37	200
	April	"	260	18	0	70	0	39	133
	May	"	260	18	0	85	0	35	122
	June	"	260	18	0	99	0	33	110
	July	"	260	8	0	141	0	33	78
	Aug.	"	260	15	0	54	0	33	158
	Sept.	"	260	21	0	15	0	31	193
	Oct.	"	260	20	0	57	0	31	152
	Nov.	"	260	18	0	79	0	31	133
	Dec.	"	260	10	0	20	0	28	202
Housewife labor (Feb.)		"	28	0	0	0	28	0	0
Spring hog limit		litters	15	0	0	0	0	15	0
Fall hog limit		litters	10	5	0	0	0	0	5
Beef housing		sq. ft.	963	0	0	0	0	0	963

*Numbers in parentheses indicate the acreage of rotation meadow utilized by each of the livestock enterprises either as pasture or hay.

space. This will be seen from an examination of succeeding plans which consider the same alternatives but with a greater supply of capital.

PLAN 2. OPERATOR LABOR AND $2,000 CAPITAL

The optimum plan under this resource situation includes 110 acres of cropland devoted to a corn-corn-oats-meadow rotation. The crops receive applications of fertilizer at the recommended rate. The livestock system includes 15 litters of spring hogs, 5 litters of fall hogs and a laying flock of 148 hens. The entire acreage of permanent pasture is left unimproved and is rented out.

There are five limitational resources in this situation, as shown in table 7: investment capital, pasture land, cropland, February housewife labor and the spring hog capacity limitation. With $2,000 investment funds, the supply of capital is sufficient to produce more than 15 litters of spring hogs. However, the spring hog enterprise is restricted to 15 litters. Investment capital remains to be allocated to the next most profitable alternative, fall-farrowed hogs. The fall hog enterprise is expanded up to the limit of the remaining capital. There still exists a surplus of operator labor.

The pasture land goes unused or is rented out since limited capital does not permit investment in forage-using livestock. If capital is invested in cattle to use the pasture rather than in hogs, profits would be reduced. Since there is not enough capital to invest in both types of enterprises, the most profitable alternative, hogs, is expanded to the limit of the resources. Profits would be greater, in this and the previous situation, by leaving pasture idle rather than diverting funds to its use or improvement. Table 8 shows that the crop program is the same as for the preceeding plan. However, the utilization pattern of crops differs because of the expanded livestock program. In this plan an additional 900 bushels of corn is consumed on the farm; also, 5 tons more hay are used. Consequently, gross crop sales are reduced by $1,341. However, the gross sales from the spring hog enterprise are increased by $1,746; the fall hog enterprise increases from zero to $1,506. The net return under this plan is $3,609.

PLAN 3. OPERATOR LABOR AND $4,000 INVESTMENT CAPITAL

The plan with $4,000 investment capital consists of 110 acres of $CCOM_t$ rotation, 15 litters of spring hogs, a 148-hen laying flock, 10 litters of fall hogs, 10 yearling steers on a deferred-feeding system and 9 acres of permanent pasture rented out. The division of the supply of resources among these enterprises is shown in table 9.

The limiting resources are: capital, pasture land, cropland, housewife labor in February and the capacity limits on spring and fall hogs. Some of the $4,000 capital remains unused when the capacity limit of the fall hog enterprise is reached. The remaining capital then is invested in choice yearling feeder steers. However, the quantity of capital available for this investment is too small to purchase enough steers, even on a deferred-feeding program, to fully utilize the available unimproved pasture. Consequently, the 9 acres unused pasture could be rented out.

The gross value of products marketed with the above plan is $13,820 (table 10). The annual cash expenses incurred with this plan, not including fixed costs, total $5,296; net return is $4,652.

TABLE 8. BUDGET FOR THE $2,000 CAPITAL-OPERATOR LABOR SITUATION.

Crops	Corn	Oats	Hay
Acres	55	27.5	27.5
Production	3,928 bu.	819 bu.	64 ton
Utilization			
Fed to spring hogs	1,231 bu.	----	14 ton*
Fed to fall hogs	467 bu.	----	----
Fed to poultry	236 bu.	819 bu.	50 ton
Marketed	1,994 bu.		

Sales and expenses	Gross sales†	Annual production expenses‡
Crops	$4,406	$2,717
Spring hogs	4,965	939
Fall hogs	1,506	386
Poultry	1,050	555
Pasture	152§	----
Total	$12,079	$4,597**

*Equivalent quantity of hay fed to hogs as pasture.
†Does not include the value of crop production fed on the farm.
‡Does not include the value of home-grown feeds.
§Rent received for the pasture.
**Not including farm overhead costs.

TABLE 9. USE OF RESOURCES UNDER THE $4,000 CAPITAL-OPERATOR LABOR SITUATION.

Resources		Unit	Resources available	Spring hogs	Fall hogs	Laying flock	CCOMr rotation	Pasture rented out	Yearling steers deferred fed on unimproved pasture	Resources unused
Investment capital		$	4,000	1,465	977	50	0	0	1,508	0
Pasture land		acre	38	0	0	0	0	9	29	0
Cropland		acre	110	(6)*	0	0	110	0	(0.75)*	0
Labor:	Jan.	man-hours	260	31	21	0	0	0	2	206
	Feb.	"	260	31	21	0	0	0	2	206
	March	"	260	37	27	0	10	0	1	185
	April	"	260	37	37	0	70	0	2	112
	May	"	260	35	37	0	85	0	1	102
	June	"	260	33	37	0	99	0	1	90
	July	"	260	33	16	0	141	0	1	69
	Aug.	"	260	33	30	0	55	0	1	141
	Sept.	"	260	31	43	0	15	0	19	152
	Oct.	"	260	31	41	0	57	0	27	104
	Nov.	"	260	31	36	0	79	0	26	88
	Dec.	"	260	28	22	0	20	0	25	165
Housewife labor (Feb.)		"	28	0	0	28	0	0	0	0
Spring hog limit		litters	15	15	0	0	0	0	0	0
Fall hog limit		litters	10	0	10	0	0	0	0	0
Beef housing		sq. ft.	963	0	0	0	0	0	250	713

*Numbers in parentheses indicate the acreage of rotation meadow utilized by each of the livestock enterprises either as pasture or hay.

TABLE 10. BUDGET FOR THE $4,000 CAPITAL-OPERATOR LABOR SITUATION.

Crops	Corn	Oats	Hay
Acres	55	27.5	27.5
Production	3,928 bu.	819 bu.	64 ton
Utilization			
Fed to spring hogs	1,231 bu.		14 ton*
Fed to fall hogs	942 bu.		
Fed to poultry	236 bu.		
Steers, deferred feeding on unimproved pasture	323 bu.		2 ton
Marketed	1,197 bu.	819 bu.	48 ton

Sales and expenses	Gross sales†	Annual production expenses‡
Crops	$3,271	$2,717
Spring hogs	4,965	939
Fall hogs	3,034	778
Poultry	1,050	556
Steers	1,464	306
Pasture rented out	36§	
Total	$13,820	$5,296**

*Equivalent quantity of hay fed to hogs as pasture.
†Does not include the value of crop production fed on the farm.
‡Does not include the value of home-grown feeds.
§Rent received for the pasture.
**Not including farm overhead charges.

PLAN 4. OPERATOR LABOR AND $8,000 INVESTMENT CAPITAL

The increased supply of investment capital in the $8,000 situation, the supply of other resources remaining the same, is used to expand the beef enterprise. The supply of capital is now large enough to allow purchase of more steers than can be carried with a deferred-feeding program on unimproved pasture. Therefore, a shift is made to a more intensive beef-feeding system—full feeding of yearling steers on pasture—having a lower pasture requirement per animal. The beef program now consists of 31 steers on a full-feeding program and six steers on a deferred-feeding program. The supply of capital is not large enough to allow a complete shift to the more intensive program. The pasture still is unimproved because of the limited supply of capital. However, pasture is no longer rented out. As a practical matter, it is not likely that one would carry the six steers on the deferred-feeding program because of the in-

TABLE 11. USE OF RESOURCES UNDER THE $8,000 CAPITAL-OPERATOR LABOR SITUATION.

Resources		Unit	Resources available	Spring hogs	Fall hogs	CCOMr rotation	Yearling steers on unimproved pasture		Laying flock	Resources unused
							deferred fed	full fed		
Investment capital		$	8,000	1,465	977	0	880	4,628	50	0
Pasture land		acre	38	0	0	0	17	21	0	0
Cropland		acre	110	(6)*	0	110	(0.5)*	(1)*	0	0
Labor:	Jan.	man-hours	260	31	20	0	1	6	0	202
	Feb.	"	260	31	20	0	1	6	0	202
	March	"	260	37	27	10	1	5	0	180
	April	"	260	39	37	70	1	5	0	108
	May	"	260	35	37	85	1	57	0	45
	June	"	260	33	37	99	1	57	0	33
	July	"	260	33	16	141	1	57	0	12
	Aug.	"	260	33	30	55	1	62	0	79
	Sept.	"	260	31	43	15	12	68	0	91
	Oct.	"	260	31	41	57	16	75	0	40
	Nov.	"	260	31	36	79	16	72	0	26
	Dec.	"	260	28	22	20	14	72	0	104
Housewife labor (Feb.)		"	28	0	0	0	0	0	28	0
Spring hog limit		litters	15	15	0	0	0	0	0	0
Fall hog limit		litters	10	0	10	0	0	0	0	0
Beef housing		sq. ft.	963	0	0	0	146	766	0	51

*Numbers in parentheses indicate the acreage of rotation meadow utilized by each of the livestock enterprises either as pasture or hay.

TABLE 12. BUDGET FOR THE $8,000 CAPITAL-OPERATOR LABOR SITUATION.

Crops	Corn	Oats	Hay
Acres	55	27.5	27.5
Production	3,928 bu.	819 bu.	64 ton
Utilization			
Steers, full fed on pasture	1,485 bu.		2 ton
Steers, deferred feeding	189 bu.		1 ton
Spring hogs	1,231 bu.		14 ton*
Fall hogs	942 bu.		
Poultry	236 bu.		
Marketed	—154 bu.†	819 bu.	47 ton

Sales and expenses	Gross sales‡	Annual production expenses§
Crops	$1,591	$2,717
Steers, full fed on pasture	4,370	786
Steers, deferred feeding	855	179
Spring hogs	4,965	939
Fall hogs	3,034	778
Poultry	1,050	555
Corn purchased		213
Total	$15,865	$6,167**

*Equivalent quantity of hay fed to hogs as pasture.
†The negative value here indicates that corn is purchased rather than sold.
‡Does not include the value of crops fed on the farm.
§Does not include the value of home-grown feeds.
**Not including farm overhead charges.

convenience of keeping the two beef enterprises seperate. The capital and labor used by this small enterprise could be used to carry a larger full-feeding program with only a slight sacrifice in profits.

The division of the available supply of resources among the enterprises in the above plan is given in table 11. The resources limiting the plan are: investment capital, pasture land, cropland, housewife labor in February and the capacity limits for spring and fall hog enterprises.

The livestock program requires more corn than is produced on the farm; an additional 154 bushels are purchased (table 12). Forage production still exceeds the forage requirements of the livestock program, and 47 tons of hay are marketed. The gross value of products marketed amounts to $15,865. The annual cash outlay on production expenditures amounts to $6,167; net return is $5,846.

PLAN 5. OPERATOR LABOR AND $16,000 INVESTMENT CAPITAL

The optimum or profit-maximizing plan includes: 110 acres of a corn-corn-oats-meadow rotation, 148 laying hens, 15 litters of spring hogs, 10 litters of fall hogs, 20 yearling steers on a deferred-feeding program on renovated pasture and 19 yearling steers which are full fed on renovated pasture. To supply the pasture forage required by the beef program, some capital must be invested in renovation to increase the carrying capacity of the permanent pasture.

The progression in the use of pasture land from the alternatives considered in this study as the supply of capital increases is as follows: With very limited capital, pasture land is rented out. As the supply of capital increases and with no more profitable alternatives the first step is to use the unimproved permanent pasture in a deferred-feeding program. With a further increase in the capital supply, it becomes profitable to use the unimproved pasture land in a more intensive manner—namely, by using a system of full feeding on pasture. In the latter system, concentrates are fed while the animals are on pasture, and the pasture requirement per animal is less than for the deferred-feeding system. Consequently, more animals can be carried on a given area of land. With still more capital, funds are invested in renovation of the pasture and utilized by a deferred-feeding program. The capital level at which the pasture is completely renovated is about $9,312. Further increases in the capital supply results in a shift to a full-feeding program on the renovated pasture.

Although capital is available in this resource situation, the beef enterprise is not shifted entirely over to full feeding of yearlings on pasture. This is the result of the limited space for housing beef animals. If the entire acreage of permanent pasture land were used in a full-feeding program, the number of steers would exceed the housing facilities of the farm. If the number of steers on the full-feeding program were limited to the housing available, then some of the

TABLE 13. USE OF RESOURCES UNDER THE $16,000 CAPITAL-OPERATOR LABOR SITUATION.

Resources		Unit	Resources available	Spring hogs	Fall hogs	CCOMr rotation	Laying flock	Yearling steers on renovated pasture		Resources unused
								deferred fed	full fed	
Investment capital		$	16,000	1,465	977	0	50	3,816	3,006	6,686
Pasture land		acre	38	0	0	0	0	31	7	0
Cropland		acre	110	(6)*	0	110	0	(1.5)*	(0.5)*	0
Labor:	Jan.	man-hours	260	31	21	0	0	4	4	201
	Feb.	"	260	31	21	0	0	4	4	201
	March	"	260	37	27	10	0	4	4	178
	April	"	260	39	37	70	0	4	4	106
	May	"	260	35	37	85	0	2	35	66
	June	"	260	33	37	99	0	2	35	54
	July	"	260	33	16	141	0	2	35	33
	Aug.	"	260	33	30	55	0	2	38	102
	Sept.	"	260	31	43	15	0	38	42	91
	Oct.	"	260	31	41	57	0	55	45	31
	Nov.	"	260	31	36	79	0	53	44	17
	Dec.	"	260	28	22	20	0	51	43	96
Housewife labor (Feb.)		"	28	0	0	0	28	0	0	0
Spring hog limit		litters	15	15	0	0	0	0	0	0
Fall hog limit		litters	10	0	10	0	0	0	0	0
Beef housing		sq. ft.	963	0	0	0	0	496	467	0

*Numbers in parentheses indicate the acreage of rotation meadow utilized by each of the livestock enterprises either as pasture or hay.

TABLE 14. BUDGET FOR THE $16,000 CAPITAL-OPERATOR LABOR SITUATION.

Crops	Corn	Oats	Hay
Acres	55	27.5	27.5
Production	3,928 bu.	819 bu.	64 ton
Utilization			
Steers, full fed on pasture	904 bu.		1 ton
Steers, deferred feeding	643 bu.		3 ton
Spring hogs	1,231 bu.		14 ton*
Fall hogs	942 bu.		
Poultry	236 bu.		
Marketed	—28 bu.†	819 bu.	45 ton

Sales and expenses	Gross sales‡	Annual production expenses§
Crops	$1,560	$2,717
Steers, full fed on pasture	2,662	507
Steers, deferred feeding	2,912	731
Spring hogs	4,965	939
Fall hogs	3,034	778
Poultry	1,050	555
Corn purchased		39
Total	$16,183	$6,266**

*Equivalent quantity of hay fed to hogs as pasture.
†The negative value here indicates that corn is purchased rather than sold.
‡Does not include the value of crops fed on the farm.
§Does not include the value of home-grown feeds.
**Not including farm overhead charges.

pasture would go unused. The combination of 20 steers on the deferred-feeding system and 19 steers on the full-feeding system permits the most profitable use of available pasture land and building space.

In the $16,000 capital-operator labor resource situation, the capital supply does not restrict the plan. Under the optimum plan, $6,686 still remains unused (table 13). The limiting resources are pasture land, cropland, housewife labor in February, the capacity limit on the spring and fall hog enterprises and the amount of beef housing available. In previous plans the 963 square feet of available beef housing was never fully used. Capital was so limiting that it did not permit expansion of the beef enterprises to the extent where all the available housing was needed.

The budget for this plan is given in table 14. Livestock feed requirements require the purchase of 28 bushels of corn in addition to farm production. This is considerably less than the amount of corn purchased in Plan 4. Although more beef is produced in Plan 5 than in Plan 4, a greater proportion is produced under deferred feeding—a system requiring less corn per pound of beef produced than the full-feeding system.

In Plan 5—operator labor and $16,000 investment capital—some capital remains unused under the optimum plan. The capital supply is now great enough that it is no longer a limiting resource. Consequently, additional capital beyond about $10,314 cannot be used in any of the alternatives considered unless either the supply of land, beef housing or capacity limits on hogs also are increased. The same is true with respect to labor. In each of the plans considered thus far, labor is nonlimiting even when the supply is restricted to the operator alone.

The preceding plans were determined under the restriction that the spring hog enterprise cannot exceed 15 litters and the fall hog enterprise cannot exceed 10 litters. The manner in which removal of this restriction changes the optimum plans is examined in the following section.

Plans With Arbitrary Limits on Sizes of Hog Enterprises Removed

The same resource situations and enterprise alternatives considered in previous sections are analyzed below, with limits on size of the hog enterprise removed. The profit-maximizing plans relate to the farm unit previously described. While there is no capacity restriction on the size of the spring and fall hog enterprises, the size of the livestock program is still limited to the forage production of the farm.

A summary of the optimum plans for each of the capital-labor situations under this second set of conditions is given in table 15. The six capital levels are listed in the first column of the table. The three labor levels are listed at the head of the second, third and fourth columns. The optimum plan for each capital-labor situation is presented in the corresponding cell of the table.

Plan 6. Operator Labor and $1,000 Investment Capital

This plan is identical to Plan 1 where the size of the hog enterprises was limited to 15 spring and 10 fall litters. Even though restrictions on hog capacity are removed, the supply of capital limits the size of the hog enterprises to less than the capacity limitations previously used. The details of this plan were presented earlier and need not be repeated here.

Plan 7. Operator Labor and $2,000 Investment Capital

With restrictions on the size of the hog enterprises removed, the profit maximizing plan with $2,000 in capital consists of: 20 litters of spring hogs, 110 acres of a $CCOM_f$ rotation, 148 laying hens and 38 acres of permanent pasture rented out.

The manner in which the available resources are divided among the enterprises in the plan is given in table 16. The limiting resources are investment capital, pasture land, cropland and housewife labor in February.

The livestock program in this plan consumes 1,874 bushels of the corn and 19 tons of the rotation hay (table 17). The balance of the crop production is marketed. The gross value of products marketed is $12,205, with annual production expenses of $4,522. The net return is $3,811.

Plan 8. Operator Labor and $4,000 Investment Capital

Increasing the supply of capital from $2,000 to $4,000, with hog restrictions removed but the supply of all other resources the same, results in a plan with 40 litters of spring hogs. The other enterprises in the plan are: 110 acres of a $CCOM_f$ rotation, 148 laying hens and 38 acres of permanent pasture rented out. The capital supply is too small to invest in beef cat-

TABLE 15. OPTIMUM PLANS WITHOUT AN ARBITRARY LIMIT ON SIZES OF HOG ENTERPRISES.

Investment capital levels	Labor levels		
	A. Operator labor	B. Operator plus family labor in June, July and Aug.	C. Unlimited labor
$1,000	110 acres CCOMr rotation 38 acres permanent pasture rented out 148-hen laying flock 10 litters spring hogs $2,414 net return	Same as in column A	Same as in column A
$2,000	110 acres CCOMr rotation 38 acres permanent pasture rented out 148-hen laying flock 20 litters spring hogs $3,811 net return	Same as in column A	Same as in column A
$4,000	110 acres CCOMr rotation 38 acres permanent pasture rented out 148-hen laying flock 40 litters spring hogs $6,602 net return	Same as in column A	Same as in column A
$8,000	101 acres CCOMr rotation 148-hen laying flock 60 litters spring hogs 13 steers-deferred feeding on unimproved pasture 1 steer-deferred feeding renovated pasture $9,632 net return	110 acres CCOMr rotation 148-hen laying flock 67 litters spring hogs 4 litters fall hogs 7 steers-deferred feeding on unimproved pasture 19 acres pasture rented out $10,974 net return	110 acres CCOMr rotation 148-hen laying flock 68 litters spring hogs 13 litters fall hogs 38 acres pasture rented out $9,308 net return*
$16,000	100 acres CCOMr rotation 148-hen laying flock 58 litters spring hogs 1 litter fall hogs 25 steers-deferred feeding on renovated pasture $10,124 net return	110 acres CCOMr rotation 148-hen laying flock 66 litters spring hogs 4 litters fall hogs 11 steers-deferred feeing on unimproved pasture 1 steer-full fed on unimproved pasture 6 acres pasture rented out $11,180 net return	110 acres CCOMr rotation 148-hen laying flock 68 litters spring hogs 95 litters fall hogs 38 acres pasture rented out $14,709 net return*
Unlimited	Same as above	Same as above	Same as above

*In these plans a charge has been made for all labor used, hired labor as well as labor supplied by the farm family. Whereas, in the limited labor situations (A and B), no charge was made for family labor under the assumption that it has a zero opportunity cost. Therefore, to make these net returns comparable with the other plan, one need only add the total charge made for family labor actually used to the net return figure given for the unlimited labor situations.

tle to utilize the permanent pasture and still maximize farm profits. With such limited capital, the spring hog enterprise represents a more profitable use of the available funds.

The division of the available resources among the enterprises in the plan is shown in table 18. The limiting resources are again investment capital, pasture land, cropland and housewife labor in February. The budget for the optimum plan (table 19) shows crop marketing to decline to 374 bushels of corn and 26

TABLE 16. USES OF RESOURCES UNDER THE $2,000 CAPITAL-OPERATOR LABOR SITUATION WITH NO CAPACITY LIMITATION ON THE HOG ENTERPRISES.

Resources		Unit	Resources available	Pasture rented out	Spring hogs	Laying flock	CCOMr rotation	Resources unused
Investment capital		$	2,000	0	1,950	50	0	0
Pasture land		acre	38	38	0	0	0	0
Cropland		acre	110	0	(8)*	0	110	0
Labor:	Jan.	man-hours	260	0	41	0	0	219
	Feb.	"	260	0	41	0	0	219
	March	"	260	0	49	0	10	201
	April	"	260	0	52	0	70	138
	May	"	260	0	47	0	85	128
	June	"	260	0	43	0	99	118
	July	"	260	0	43	0	141	76
	Aug.	"	260	0	43	0	55	162
	Sept.	"	260	0	41	0	15	204
	Oct.	"	260	0	41	0	57	162
	Nov.	"	260	0	41	0	79	140
	Dec.	"	260	0	37	0	20	203
Housewife labor (Feb.)		"	28	0	0	28	0	0
Beef housing		sq. ft.	963	0	0	0	0	963

*Numbers in parentheses indicate the acreage of rotation meadow utilized by each of the livestock enterprises either as pasture or hay.

tons of hay. The proportion of the crop production marketed through hogs increases. The gross value of sales amounts to $16,278, and the annual production expense is $5,804. The net return under this plan is $6,602.

PLAN 9. OPERATOR LABOR AND $8,000 INVESTMENT CAPITAL

The most profitable use of the additional $4,000 of investment capital (i.e., the $8,000 plan as compared to $4,000 plan) is made by increasing the spring hog enterprise by 20 litters and adding 14 yearling steers on a deferred-feeding program on pasture. This capital level represents the point at which it becomes profitable to begin investing capital in pasture renovation. There is a shortage of July labor in the plan for this situation (table 20). If the entire supply of capital is invested, July labor must be withdrawn from the crop enterprise and used in the livestock enterprises. Consequently the acreage of $CCOM_f$ rotation is reduced from 110 acres to 101 acres. In actual practice, the additional July labor needed can be obtained by working slightly longer hours during July rather than by reducing the acreage in crops. The other limiting resources, besides July labor, are investment capital, pasture land and housewife labor in February.

The livestock program is now so large that corn must be purchased to meet the feed requirements (table 21). The gross value of products marketed is $23,478. The annual cash outlay on production expenditures is $9,973, and the net return for the farm is $9,632.

TABLE 17. BUDGET FOR THE $2,000 CAPITAL-OPERATOR LABOR SITUATION WITHOUT CAPACITY LIMITATION ON THE HOG ENTERPRISES.

Crops	Corn	Oats	Hay
Acres	55	27.5	27.5
Production	3,928 bu.	819 bu.	64 ton
Utilization			
Spring hogs	1,638 bu.		19 ton*
Poultry	236 bu.		
Marketed	2,054 bu.	819 bu.	45 ton

Sales and expenses	Gross sales†	Annual production expenses‡
Crops	$4,396	$2,717
Spring hogs	6,607	1,250
Poultry	1,050	555
Pasture rented out	152§	
Total	$12,205	$4,522**

*Equivalent quantity of hay fed to hogs as pasture.
†Does not include the value of crops fed on the farm.
‡Does not include the value of home-grown feeds.
§Rents received for pasture.
**Not including farm overhead charges.

TABLE 19. BUDGET FOR THE $4,000 CAPITAL-OPERATOR LABOR SITUATION WITHOUT A CAPACITY RESTRICTION ON THE HOG ENTERPRISES.

Crops	Corn	Oats	Hay
Acres	55	27.5	27.5
Production	3,928 bu.	819 bu.	64 ton
Utilization			
Spring hogs	3,317 bu.		38 ton*
Poultry	236 bu.		
Marketed	374 bu.	819 bu.	26 ton

Sales and expenses	Gross sales†	Annual production expenses‡
Crops	$1,692	$2,717
Spring hogs	13,384	2,532
Poultry	1,050	555
Pasture rented out	152§	
Total	$16,278	$5,804**

*Equivalent quantity of hay fed to hogs as pasture.
†Does not include the value of crops consumed on the farm.
‡Does not include the value of home-grown feeds.
§Rent received for pasture.
**Not including farm overhead charges.

PLAN 10. OPERATOR LABOR AND $16,000 INVESTMENT CAPITAL

Investment capital of $16,000 permits a plan which includes: 58 litters of spring hogs, 25 yearling steers deferred fed on renovated pasture, one litter of fall hogs, 148 laying hens and 100 acres of a $CCOM_f$ rotation. The limitation resources are pasture land, July labor, November labor and February housewife labor. Investment capital is no longer a limiting resource—$5,443 remains unused under the optimum plan (table 22). Ten acres of cropland lie idle under this plan because of labor shortages in July and November. The livestock enterprises can successfully compete with the crop enterprise for labor in the limiting months. However, the additional labor required for operating the 10 acres would be obtained

TABLE 18. USE OF RESOURCES UNDER THE $4,000 CAPITAL-OPERATOR LABOR SITUATION WITHOUT A CAPACITY RESTRICTION ON THE HOG ENTERPRISES.

Resources		Unit	Resources available	Pasture rented out	Spring hogs	Laying flock	$CCOM_f$ rotation	Resources unused
Investment capital		$	4,000	0	3,950	50	0	0
Pasture land		acre	38	38	0	0	0	0
Cropland		acre	110	0	(16.25)*	0	110	0
Labor:	Jan.	man-hours	260	0	83	0	0	177
	Feb.	"	260	0	83	0	0	177
	March	"	260	0	100	0	10	150
	April	"	260	0	105	0	70	85
	May	"	260	0	96	0	85	79
	June	"	260	0	88	0	99	73
	July	"	260	0	88	0	141	31
	Aug.	"	260	0	88	0	55	117
	Sept.	"	260	0	83	0	15	162
	Oct.	"	260	0	83	0	57	120
	Nov.	"	260	0	83	0	79	98
	Dec.	"	260	0	75	0	20	165
Housewife labor (Feb.)		"	28	0	0	28	0	0
Beef housing		sq. ft.	963	0	0	0	0	963

*Numbers in parentheses indicate the acreage of rotation meadow utilized by each of the livestock enterprises either as pasture or hay.

TABLE 20. USE OF RESOURCES UNDER THE $8,000 CAPITAL-OPERATOR LABOR SITUATION WITHOUT A CAPACITY RESTRICTION ON THE HOG ENTERPRISES.

Resources		Unit	Resources available	Spring hogs	Laying flock	CCOMr rotation	Yearling steers, deferred feeding: unimproved pasture	Yearling steers, deferred feeding: renovated pasture	Resources unused
Investment capital		$	8,000	5,850	50	0	1,949.0	160.0	0
Pasture land		acre	38	0	0	0	37.0	1.0	0
Cropland		acre	110	(24.25)*	0	101	(0.95)*	(0.05)*	9
Labor:	Jan.	man-hours	260	123	0	0	2.6	0.4	134
	Feb.	"	260	123	0	0	2.6	0.4	134
	March	"	260	148	0	9	2.5	0.5	100
	April	"	260	155	0	64	2.4	0.6	38
	May	"	260	141	0	78	1.6	0.4	39
	June	"	260	129	0	91	1.6	0.3	38
	July	"	260	128	0	130	1.6	0.4	0
	Aug.	"	260	129	0	50	1.6	0.4	79
	Sept.	"	260	123	0	14	26.0	2.0	95
	Oct.	"	260	123	0	52	36.0	2.0	47
	Nov.	"	260	121	0	72	34.0	2.0	31
	Dec.	"	260	110	0	18	33.0	2.0	97
Housewife labor (Feb.)		"	28	0	28	0	0	0	0
Beef housing		sq. ft.	963	0	0	0	321.0	21	621

*Numbers in parentheses indicate the acreage of rotation meadow utilized by each of the livestock enterprises either as pasture or hay.

TABLE 21. BUDGET FOR THE $8,000 CAPITAL-OPERATOR LABOR SITUATION WITHOUT A CAPACITY RESTRICTION ON THE HOG ENTERPRISES.

Crops	Corn	Oats	Hay
Acres	50	25	25
Production	3,595 bu.	750 bu.	58 ton
Utilization			
Spring hogs	4,913 bu.		55 ton*
Steers, deferred feeding, unimproved pasture	415 bu.		2 ton
Steers, deferred feeding, renovated pasture	30 bu.		1 ton
Poultry	236 bu.		
Marketed	—1,997 bu.†	750 bu.	

Sales and expenses	Gross sales‡	Annual production expenses§
Crops	$ 600	$2,487
Spring hogs	19,823	3,751
Steers, deferred feeding, unimproved pasture	1,883	394
renovated pasture	122	31
Poultry	1,050	555
Corn purchased		2,756
Total	$23,478	$9,973**

*Equivalent quantity of hay fed to hogs as pasture.
†The negative value here indicates that corn was purchased rather than sold.
‡ Does not include the value of crops consumed on the farm.
§Does not include the value of home-grown feeds.
**Not including farm overhead charges.

in practice by working somewhat longer hours in the critical months or by using some of the idle capital to hire labor.

The pasture land is completely renovated under this plan. Renovation of the entire acreage of permanent pasture land takes place at a capital level of about $10,557. The beef enterprise is a deferred feeding of yearling steers on pasture. The full feeding of steers on pasture cannot profitably compete with the spring hog enterprise for summer labor. Therefore, a more intensive use of the pasture land is not undertaken by using the full-feeding beef system even though capital is available to invest in additional steers.

The combined effect of the increased livestock program and decreased crop acreage makes it necessary to purchase 2,324 bushels of corn (table 23). The amount of oats sold is now 752 bushels. All of the forage produced in the rotation is consumed on the farm. The net return under this plan is $10,124. Gross value of sales is $24,901, and annual production expense is $10,905.

TABLE 22. USE OF RESOURCES UNDER THE $16,000 CAPITAL-OPERATOR LABOR SITUATION WITHOUT A CAPACITY RESTRICTION ON THE SIZE OF THE HOG ENTERPRISES.

Resources		Unit	Resources available	Spring hogs	Fall hogs	Laying flock	Yearling steers, deferred feeding, renovated pasture	CCOMr rotation	Resources unused
Investment capital		$	16,000	5,677	141	50	4,689	0	5,443
Pasture land		acre	38	0	0	0	38	0	0
Cropland		acre	110	(23.25)*	0	0	(1.75)*	100	10
Labor:	Jan.	man-hours	260	119	3	0	5	0	133
	Feb.	"	260	119	3	0	5	0	133
	March	"	260	144	4	0	5	9	98
	April	"	260	152	5	0	5	64	34
	May	"	260	138	5	0	3	77	37
	June	"	260	126	5	0	3	90	36
	July	"	260	126	3	0	3	128	0
	Aug.	"	260	126	4	0	3	50	77
	Sept.	"	260	120	6	0	47	14	73
	Oct.	"	260	120	6	0	67	52	15
	Nov.	"	260	119	5	0	65	71	0
	Dec.	"	260	107	3	0	63	18	69
Housewife labor (Feb.)		"	28	0	0	28	0	0	0
Beef housing		sq. ft.	963	0	0	0	610	0	353

*Numbers in parentheses indicate the acreage of rotation meadow utilized by each of the livestock enterprises either as pasture or hay.

TABLE 23. BUDGET FOR THE $16,000 CAPITAL-OPERATOR LABOR SITUATION WITHOUT A CAPACITY LIMITATION ON THE HOG ENTERPRISES.

Crops	Corn	Oats	Hay
Acres	50	25	25
Production	3,606 bu.	752 bu.	58 ton
Utilization			
Steers, deferred feeding, renovated pasture	790 bu.		4 ton
Spring hogs	4,767 bu.		54 ton*
Fall hogs	136 bu.		
Poultry	236 bu.		
Marketed	—2,324 bu.†	752 bu.	

Sales and expenses	Gross sales‡	Annual production expenses§
Crops	$ 601	$2,494
Steers, deferred feeding, renovated pasture	3,578	898
Spring hogs	19,234	3,639
Fall hogs	438	112
Poultry	1,050	555
Corn purchased		3,207
Total	$24,901	$10,905**

*Equivalent quantity of hay consumed by hogs as pasture.
†Negative value here indicates that corn is purchased rather than sold.
‡Does not include the value of crops consumed on the farm.
§Does not include the value of home-grown feeds.
**Not including farm overhead charges.

PLAN 11. OPERATOR PLUS FAMILY LABOR AND $8,000 INVESTMENT CAPITAL

In this resource situation, the supply of labor is increased to 390 man-hours per month in June, July and August. In each of the other months, the labor supply is provided solely by the operator and amounts to 260 man-hours per month.

The profit-maximizing plan consists of 110 acres of a $CCOM_f$ rotation, a 148-hen laying flock, 67 litters of spring hogs, four litters of fall hogs, seven steers on a deferred-feeding program on unimproved pasture and 19 acres of unimproved pasture rented out. The limiting resources are: capital, pasture land, cropland, April labor and housewife labor in February (table 24).

At the $8,000 capital level, a greater supply of summer labor, holding the supply of all other resources constant, permits expansion of the spring hog enterprise. As a result, a greater proportion of the available capital is invested in spring-farrowed hogs. However, the investment in the spring hog enterprise is stopped before the capital supply is exhausted because of the limited supply of rotation pasture. The remaining capital is invested in fall hogs and yearling steers. The fall hog enterprise brings a higher return on capital than the beef enterprise but cannot be expanded beyond four litters because of a shortage of labor in April. The remaining capital is invested in a beef enterprise. The deferred feeding of yearling steers on pasture also requires some April labor. Since the beef enterprise brings a higher return on labor than the hogs, it is able to compete for enough labor for a six-steer enterprise. However, six steers will not use the available supply of unimproved pasture. Consequently, there is no reason to use any of the limited capital for the renovation of pasture land; the 19 acres of unused pasture is rented out.

In the optimum plan, the feed requirements of the livestock exceed the corn production of the farm by 2,391 bushels (table 25). The difference is made up by purchasing corn. The forage produced in the rotation is all consumed on the farm.

The gross value of the sales under this plan is $26,125, with annual cash expenses of $11,279. The net return is $10,974.

PLAN 12. OPERATOR PLUS FAMILY LABOR AND $16,000 INVESTMENT CAPITAL

The profit-maximizing plan in this resource situation consists of: 66 litters of spring hogs, four litters of fall hogs, 11 steers deferred fed on unimproved pasture, one steer full fed on unimproved pasture, 148 laying hens, 110 acres of a $CCOM_f$ rotation and 6 acres of permanent pasture rented out.

The limiting resources are: pasture land, cropland, operator labor in April, May and November and housewife labor in February (table 26). The capital supply no longer restricts the plan; $7,223 remains unused under the optimum plan. The limited supply of labor and cropland makes it impossible to fully utilize the available supply of capital with the alternatives considered in this study and still maximize farm profits.

TABLE 24. USE OF RESOURCES UNDER THE $8,000 CAPITAL-OPERATOR PLUS FAMILY LABOR SITUATION WITHOUT A CAPACITY RESTRICTION ON SIZE OF THE HOG ENTERPRISES.

Resources		Unit	Resources available	Spring hogs	Fall hogs	Laying flock	Pasture rented out	Yearling steers, deferred feeding, unimproved pasture	$CCOM_f$ rotation	Resources unused
Investment capital		$	8,000	6,537	387	50	0	1,027	0	0
Pasture land		acre	38	0	0	0	19	19	0	0
Cropland		acre	110	(27)*	0	0	0	(0.5)*	110	0
Labor:	Jan.	man-hours	260	137	8	0	0	1	0	113
	Feb.	"	260	137	8	0	0	1	0	113
	March	"	260	165	10	0	0	2	10	73
	April	"	260	173	15	0	0	2	70	0
	May	"	260	158	14	0	0	1	85	2
	June	"	390	145	15	0	0	1	99	130
	July	"	390	144	7	0	0	1	141	97
	Aug.	"	390	144	12	0	0	1	55	178
	Sept.	"	260	137	17	0	0	13	15	78
	Oct.	"	260	137	16	0	0	19	57	31
	Nov.	"	260	136	14	0	0	18	79	13
	Dec.	"	260	123	9	0	0	18	20	90
Housewife labor (Feb.)		"	28	0	0	28	0	0	0	0
Beef housing		sq. ft.	963	0	0	0	0	170	0	793

*Numbers in parentheses indicate the acreage of rotation meadow utilized by each of the livestock enterprises either as pasture or hay.

With an abundant supply of capital, the fullest use of the available labor is achieved by including a small beef enterprise in the plan. While the plan does provide for one yearling steer full fed on unimproved pasture, in addition to the 11 on the deferred-feeding system, the inconvenience of carrying a single animal on such an enterprise would make it impractical. Its appearance in the plan is a result of assuming that the labor supply is rigidly fixed and requirements of the enterprises for each month's labor are the same regardless of the size of the enterprise. Pasture is unimproved, not because of a lack of capital, but because of a shortage of labor. The number of steers permitted by the amounts of available labor can be easily carried on the unimproved pasture. Consequently, no investment is made in pasture improvement.

The quantity of feed corn purchased amount to 2,516 bushels (table 27). The entire quantity of forage produced in the rotation is consumed by the livestock on the farm. The gross cash sales of crop and livestock products amounts to $26,675, and the annual cash expense incurred in producing this amount of product is $11,623. The net return over all costs is $11,180.

TABLE 25. BUDGET FOR THE $8,000 CAPITAL-OPERATOR PLUS FAMILY LABOR SITUATION WITHOUT A CAPACITY LIMITATION ON THE HOG ENTERPRISES.

Crops	Corn	Oats	Hay
Acres	55	27.5	27.5
Production	3,928 bu.	819 bu.	64 ton
Utilization			
Steers, deferred feeding, unimproved pasture	220 bu.		1 ton
Spring hogs	5,490 bu.		63 ton*
Fall hogs	373 bu.		
Poultry	236 bu.		
Marketed	−2,391 bu.†	819 bu.	

Sales and expenses	Gross sales‡	Annual production expenses§
Crops	$ 655	$2,717
Steers, deferred feeding, unimproved pasture	997	208
Spring hogs	22,148	4,191
Fall hogs	1,201	308
Poultry	1,050	555
Pasture rented out	152**	
Corn purchased		3,300
Total	$26,125	$11,279††

*Equivalent quantity of hay fed to hogs as pasture.
†Negative value here indicates that corn is purchased rather than sold.
‡Does not include the value of crops consumed on the farm.
§Does not include the value of home-grown feeds.
**Rent received for pasture.
††Not including farm overhead charges.

TABLE 27. BUDGET FOR THE $16,000 CAPITAL-OPERATOR PLUS FAMILY LABOR SITUATION WITHOUT CAPACITY LIMITATION ON THE HOG ENTERPRISES.

Crops	Corn	Oats	Hay
Acres	55	27.5	27.5
Production	3,928 bu.	819 bu.	64 ton
Utilization			
Steers, deferred feeding, unimproved pasture	375 bu.		1.9 ton
Steers, full fed, unimproved pasture	58 bu.		0.1 ton
Spring hogs	5,419 bu.		62 ton*
Fall hogs	373 bu.		
Poultry	236 bu.		
Marketed	−2,516 bu.†	819 bu.	

Sales and expenses	Gross sales‡	Annual production expenses§
Crops	$ 655	$2,717
Steers, deferred feeding	1,617	338
Steers, full fed	171	31
Spring hogs	21,863	4,137
Fall hogs	1,296	373
Poultry	1,050	555
Pasture rented out	23**	
Corn purchased		3,472
Total	$22,675	$11,623††

*Equivalent quantity of hay consumed by hogs as pasture.
†Negative value here indicates that corn is purchased rather than sold.
‡Does not include the value of crops consumed on the farm.
§Does not include the value of home-grown feeds.
**Rent received for pasture.
††Not including farm overhead charges.

PLAN 13. UNLIMITED LABOR AND $8,000 INVESTMENT CAPITAL

In this situation the labor restriction is removed entirely. It is assumed that all of the labor needed to maximize profits with the available supply of land and capital can be obtained. If the supply of labor from family sources is not adequate, additional labor can be hired at the going wage rate.

With labor no longer restrictive, the beef enterprises drop out of the plan entirely. The spring hog

TABLE 26. USE OF RESOURCES UNDER THE $16,000 CAPITAL-OPERATOR PLUS FAMILY LABOR SITUATION WITHOUT A CAPACITY RESTRICTION ON THE HOG ENTERPRISES.

Resources		Unit	Resources available	Spring hogs	Fall hogs	Laying flock	Pasture rented out	Yearling steers, unimproved pasture		CCOM rotation	Resources unused
								deferred fed	full fed		
Investment capital		$	16,000	6,452	417	50	0	1,666	182	0	7,223
Pasture land		acre	38	0	0	0	6	31	1	0	0
Cropland		acre	110	(26.75)*	0	0	0	(0.75)*	(0.25)*	110	0
Labor:	Jan.	man-hours	260	136	9	0	0	2	1	0	113
	Feb.	"	260	136	9	0	0	2	1	0	113
	March	"	260	164	11	0	0	1	1	10	73
	April	"	260	172	16	0	0	1	1	70	0
	May	"	260	157	16	0	0	1	1	85	0
	June	"	390	142	16	0	0	1	1	99	131
	July	"	390	143	7	0	0	1	1	141	97
	Aug.	"	390	143	13	0	0	2	1	55	176
	Sept.	"	260	136	18	0	0	22	2	15	67
	Oct.	"	260	136	17	0	0	30	2	57	18
	Nov.	"	260	134	15	0	0	30	2	79	0
	Dec.	"	260	122	9	0	0	28	3	20	78
Housewife labor (Feb.)		"	28	0	0	28	0	0	0	0	0
Beef housing		sq. ft.	963	0	0	0	0	276	30	0	657

*Numbers in parentheses indicate the acreage of rotation meadow utilized by each of the livestock enterprises either as pasture or hay.

TABLE 28. USE OF RESOURCES IN THE $8,000 CAPITAL-UNLIMITED LABOR SITUATION WITHOUT A CAPACITY RESTRICTION ON THE HOG ENTERPRISES.

Resources		Unit	Resources available	Spring hogs	Fall hogs	Laying flock	Pasture rented out	CCOM$_f$ rotation	Resources unused
Investment capital		$	8,000	6,658	1,292	50	0	0	0
Pasture land		acre	38	0	0	0	38	0	0
Cropland		acre	110	(27.5)*	0	0	0	110	0
Labor:	Jan.	man-hours	unlimited	140	28	0	0	0	–
	Feb.	"	"	140	28	0	0	0	–
	March	"	"	168	35	0	0	10	–
	April	"	"	177	49	0	0	70	–
	May	"	"	163	48	0	0	85	–
	June	"	"	147	48	0	0	99	–
	July	"	"	147	22	0	0	141	–
	Aug.	"	"	147	40	0	0	55	–
	Sept.	"	"	140	57	0	0	15	–
	Oct.	"	"	140	54	0	0	57	–
	Nov.	"	"	138	48	0	0	79	–
	Dec.	"	"	126	29	0	0	20	–
Housewife labor (Feb.)		"	28	0	0	28	0	0	0
Beef housing		sq. ft.	963	0	0	0	0	0	963

*Numbers in parentheses indicate the acreage of rotation meadow utilized by each of the livestock enterprises either as pasture or hay.

enterprise is expanded to the limit of the rotation meadow in the 110 acres of the CCOM$_f$ rotation, 68 litters, and the remaining capital is invested in fall hogs, 13 litters. Since there is no beef enterprise in the plan, the entire acreage of permanent pasture is rented out. A poultry enterprise of 148 hens also is included.

In this situation the limiting resources are investment capital, pasture land, cropland and housewife labor (table 28). The supply of each of these resources is entirely exhausted.

The hog program in this plan requires considerably more corn than can be produced on the farm (table 29). Consequently, 3,146 bushels of corn must be purchased. The 27.5 acres of forage produced in the rotation is used for hog pasture in the spring hog enterprise.

The gross value of products marketed is $28,429. The annual cash outlay on production expenses amounts to $15,249. Net return is $9,308. The net return of $9,308 is computed as if all the labor were hired. However, if any of the labor is supplied by the family, the labor charge would be reduced since it is assumed that family labor has a zero opportunity cost. In the unlimited labor situation, no explicit assumption has been made as to quantity of family labor available. The results are presented in a more general form by making a charge for all labor used. In applying these results to any given situation where the supply of family labor is known, the labor charge can be readily adjusted by subtracting out the quantity of labor supplied from family sources.[13]

TABLE 29. BUDGET FOR THE $8,000 CAPITAL-UNLIMITED LABOR SITUATION WITHOUT A CAPACITY RESTRICTION ON THE HOG ENTERPRISES.

Crops	Corn	Oats	Hay
Acres	55	27.5	27.5
Production	3,928 bu.	819 bu.	64 ton
Utilization			
Spring hogs	5,592 bu.		64 ton*
Fall hogs	1,245 bu.		
Poultry	236 bu.		
Marketed	—3,146 bu.†	819 bu.	

Sales and expenses	Gross sales‡	Annual production expenses§
Crops	$ 655	$2,717
Spring hogs	22,559	4,268
Fall hogs	4,013	1,029
Poultry	1,050	555
Pasture rented out	152**	
Corn purchased		4,341
Labor charges		2,339
Total	$28,429	$15,249††

*Equivalent quantity of hay consumed by hogs as pasture.
†Negative value here indicates that corn is purchased rather than sold.
‡Does not include the value of crops consumed on the farm.
§Does not include the value of home-grown feeds.
**Rent received for pasture.
††Not including farm overhead charges.

PLAN 14. UNLIMITED LABOR AND $16,000 INVESTMENT CAPITAL

The added capital available in this situation is used to increase the size of the fall hog enterprise. The plan now includes 95 litters of fall hogs. The other enterprises in the plan are: 68 litters of spring hogs, 110 acres of a CCOM$_f$ rotation, a 148-hen laying flock and 38 acres of permanent pasture rented out.

The limiting resources are investment capital, pasture land, cropland and housewife labor in February (table 30). Since labor can be obtained in any amount required, it does not limit the plan.

In the situations where the supply of labor is not limiting, the beef enterprises cannot compete with spring and fall hogs for capital or cropland. In this plan the crop enterprise is expanded to the limit of the cropland, and the spring hog enterprise is limited by the acreage of rotation pasture grown. The spring hog enterprise uses $6,658 of investment capital. The poultry enterprise uses $50 of the investment capital in expanding to the limit of the housewife labor. The remaining capital is used in the fall hog enterprise, which is the next most profitable alternative use of capital when labor is unlimited.

The gross sales of crops and livestock products with this plan amounts to $53,278, with annual production expenses of $34,697 (table 31). Net return is $14,709. This net return figure is based on the assumption that all labor is hired. If labor is supplied from family sources the net return is adjusted accordingly since family labor is assumed to have a zero opportunity cost.

Further increases in the supply of capital beyond

[13] Labor has been charged at the rate of $0.81 per man-hour.

TABLE 30. USE OF RESOURCES IN THE $16,000 CAPITAL-UNLIMITED LABOR SITUATION WITHOUT A CAPACITY RESTRICTION ON THE HOG ENTERPRISES.

Resources		Unit	Resources available	Spring hogs	Fall hogs	Laying flock	Pasture rented out	Resources unused	CCOMr rotation
Investment capital		$	16,000	6,658	9,292	50	0	0	0
Pasture land		acre	38	0	0	0	38	0	0
Cropland		acre	110	(27.5)*	0	0	0	0	110
Labor:	Jan.	man-hours	unlimited	140	198	0	0	_	0
	Feb.	"	"	140	198	0	0	_	0
	March	"	"	168	252	0	0	_	10
	April	"	"	177	350	0	0	_	70
	May	"	"	163	348	0	0	_	85
	June	"	"	147	349	0	0	_	99
	July	"	"	147	157	0	0	_	141
	Aug.	"	"	147	286	0	0	_	55
	Sept.	"	"	140	408	0	0	_	15
	Oct.	"	"	140	389	0	0	_	57
	Nov.	"	"	138	342	0	0	_	79
	Dec.	"	"	126	207	0	0	_	20
Housewife labor (Feb.)		"	28	0	0	28	0	0	0
Beef housing		sq. ft.	963	0	0	0	0	963	0

*Numbers in parentheses indicate the acreage of rotation meadow utilized by each of the livestock enterprises either as pasture or hay.

the $16,000 level simply results in an expanded fall hog enterprise as long as the supply of labor is unlimited. However, in these extremely large hog programs some problems are likely to develop which are not accounted for in the input-output data used. First of all, the difficulties of managing such a large operation require extremely high managerial ability. Secondly, with the high degree of specialization, the production techniques are not the same as those of smaller hog enterprises. Also, the risks of disease and parasites are greatly intensified with such large numbers of animals on a single farm.

RELATION OF PASTURE IMPROVEMENT TO LABOR AND CAPITAL SUPPLIES

The results of this study indicate that neither improvement of permanent pasture nor the same farm plan should be a universal recommendation to all farms. Supplies of resources differ on individual farms causing different organizations of enterprises, including pasture, to be most profitable. The maximum profit organization of enterprises for the farm as a whole depends on (1) existing price relationships, (2) the supplies of the various resources available to the farm and (3) resource requirements of each possible enterprise.

On the basis of the average price relationships from 1939 to 1953, hogs compete strongly with other livestock enterprises for available resources. In situations where labor is relatively abundant, the hog enterprises dominate the livestock program. The pasture land is not improved under these conditions because a higher return can be obtained by investing the resources in hogs.

When labor becomes a limiting resource, investment in beef enterprises becomes profitable. The beef enterprises bring a higher return per hour of labor used than the hog enterprises. However, permanent pasture is not improved until the capital supply increases, relative to the supply of labor, to the point where the number of animals that can be purchased exceeds the carrying capacity of the unimproved permanent pasture.

Restricting the size of the hog enterprises causes the beef enterprises and improvement of permanent pasture to enter the plan at lower capital levels than they otherwise would. This, of course, depends on the level at which hogs are limited. As a result of restricting the size of the hog enterprises, profits are sacrificed.

In general, farms limited in capital or farms having unlimited labor will not maximize farm profits by investing resources in pasture improvement. Whereas, farms limited in labor relative to the supply of capital may find pasture improvement a profitable alternative.

TABLE 31. BUDGET FOR THE $16,000 CAPITAL-UNLIMITED LABOR SITUATION WITHOUT A CAPACITY RESTRICTION ON THE HOG ENTERPRISES.

Crops	Corn	Oats	Hay
Acres	55	27.5	27.5
Production	3,928 bu.	819 bu.	64 ton
Utilization			
Spring hogs	5,592 bu.		64 ton*
Fall hogs	8,957 bu.		
Poultry	326 bu.		
Marketed	—10,858 bu.†	819 bu.	

Sales and expenses	Gross sales‡	Annual production expenses§
Crops	$ 655	$2,717
Spring hogs	22,559	4,268
Fall hogs	28,862	7,403
Poultry	1,050	555
Pasture rented out	152**	
Corn purchased		14,984
Labor charges		4,770
Total	$53,278	$34,697

*Equivalent quantity of hay consumed by hogs as pasture.
†Negative value here indicates that corn is purchased rather than sold.
‡Does not include the value of crops consumed on the farm.
§Does not include the value of home-grown feeds.
**Rent received for pasture.

APPENDIX A

An Alternative Method of Treating Capital Input Coefficients.

In this study, one of the main considerations in relation to capital has been the sum of money required in the initial period to enter a particular type of productive undertaking. The "investment" capital input coefficient, which has been used throughout this study, expresses the initial capital investment required per unit of output. This procedure does not explicitly take into account the requirement for annual "production" capital inputs. However, the annual production capital requirements are subtracted from the annual gross return per unit of output to arrive at a net return per unit of output for each process. An alternative to this procedure would be to add the annual "production" capital requirement to the "investment" capital requirement to arrive at a total capital requirement per unit of output for each process. However, the results are the same as before except for the poultry enterprise (table 32).

The poultry enterprise has such a high requirement for annual production capital per unit of output relative to the other enterprises that it cannot compete for the available capital until the supply reaches a relatively high level ($24,000). When the supply of operator labor becomes less limiting, it becomes more profitable to withdraw capital from the poultry enterprise and reallocate it to enterprises more efficient in the use of capital—hogs in this case. In general, the conclusions with regard to pasture improvement remain the same as before.

Since the results from treating capital in this alternative manner closely parallel the results obtained in this study, a more detailed description is unnecessary. The main advantage of expressing the capital requirements in the latter manner is that it avoids the rather arbitrary distinction between investment and production capital.

TABLE 32. PROFIT-MAXIMIZING PLANS OBTAINED UNDER ALTERNATIVE METHODS OF HANDLING CAPITAL REQUIREMENTS.

Capital level	Labor level		
	A. Operator only	B. Operator plus family labor	C. Unlimited labor
$2,717	110 acres CCOMf rotation 38 acres permanent pasture rented out net revenue $919	Same as in column A	Same as in column A
$4,000	4 litters spring hogs 38 acres permanent pasture rented out 110 acres CCOMf rotation net revenue $1,518	Same as in column A	Same as in column A
$8,000	18 litters spring hogs 38 acres permanent pasture rented out 110 acres CCOMf rotation net revenue $3,383	Same as in column A	Same as in column A
$16,000	45 litters spring hogs 38 acres permanent pasture rented out 110 acres CCOMf rotation net revenue $7,115	Same as in column A	Same as in column A
$24,000	14 steers-deferred fed on unimproved pasture 60 litters spring hogs 148-hen laying flock 101 acres CCOMf rotation net revenue $9,616	2 steers-deferred fed on unimproved pasture 67 litters spring hogs 4 litters fall hogs 110 acres CCOMf rotation 34 acres permanent pasture rented out net revenue $10,602	68 litters spring hogs 4 litters fall hogs 110 acres CCOMf rotation 38 acres permanent pasture rented out net revenue $8,480
$32,000	25 steers-deferred fed on renovated pasture 58 litters of spring hogs 1 litter of fall hogs 148-hen laying flock 101 acres CCOMf rotation net revenue $10,122	110 acres CCOMf rotation 6 acres unimproved pasture rented out 66 litters spring hogs 1 steer full-fed, unimproved pasture 148-hen laying flock net revenue $11,180	68 litters spring hogs 30 litters fall hogs 110 acres CCOMf rotation 38 acres permanent pasture rented out net revenue $10,254

*A labor charge has been made for all labor used in the unlimited labor situations. If some labor were supplied from family source, the net revenue would be adjusted accordingly.

APPENDIX B

Basic Data

The estimates of the resource requirements for each of the enterprises were obtained from published and unpublished results of studies conducted by the Iowa Agricultural Experiment Station and agricultural experiment stations of surrounding states. The data are drawn largely from experimental work and, therefore, reflect a rather high level of efficiency. In some instances data were not available for a particular type of enterprise, and it was necessary to resort to estimates based on the judgment of persons well acquainted with enterprises of that type. The estimates of the resource requirements varied somewhat among the various sources examined. The estimates used in this study are believed to be most nearly representative of the resource requirements under a relatively high level of efficiency with the existing conditions in the southern pasture area of Iowa.

Crop Rotations

Estimates of the crop yields for a corn-corn-oats-meadow and a corn-corn-oats-meadow-meadow rotation both with and without fertilizer application were obtained.

The annual expenses, excluding fertilizer costs, per acre of rotation were estimated to be $17.14 for the CCOM, $16.81 for the CCOMM, $17.95 for the $CCOM_f$ and $17.69 for the $CCOMM_f$. These expenses include fuel, grease, machinery, repairs and seed costs.[14] The fertilizer costs per acre of rotation were estimated to be $6.75 for the $CCOM_f$ and $6.62 for the $CCOMM_f$.

Livestock

The feed and pasture requirements of the various beef enterprises were from studies carried on at the experimental farms at Albia and Beaconsfield in the southern pasture area of Iowa. The feed requirements used are an average of 3 years of data, 1951 through 1953, and are given in table 33. Data were directly available on the following beef systems on renovated pastures: steers full fed on pasture, steers grazed then finished in drylot (deferred feeding) and a beef cow-calf enterprise. Also, data were directly available for the beef cow-calf enterprise on each of the levels of pasture improvement. Data were not directly available for the deferred feeding of yearling steers or full feeding of yearlings on the phosphate-lespedeza, improved Kentucky bluegrass or unimproved Kentucky bluegrass pasture.

The two types of swine enterprises considered in this study are spring-farrowed hogs raised on rotation pasture and fall-farrowed hogs raised in drylot. The type of pasture used with spring hogs was a mixture of alfalfa, red clover and timothy. The feed requirements for these enterprises were derived from a summary of farm records in Iowa and Illinois and are presented in table 33.[15]

The capital requirements of the various livestock enterprises assumed in this study are given in table 34. They are broken down into two categories—investment capital and annual expenses capital (production capital). The investment capital input includes investment in livestock and buildings where they are not already available.

Pasture improvement also involves some use of investment capital. Therefore, the investment capital input associated with a particular beef enterprise using pasture depends on the level of pasture improvement being used. Unimproved Kentucky bluegrass pasture does not involve any use of investment capital since the livestock uses this pasture in it's natural condition. The investment in initial materials per acre for each of the other levels of improvement is as follows: improved Kentucky bluegrass, $4.27; phosphate-lespedeza, $16.51; complete renovation, $26.40. The improvement of Kentucky bluegrass by nitrogen fertilization has to be repeated every year. The phosphate-lespedeza and complete renovation are esti-

[14] Bowlen, Bernard J. Production planning of crops for Iowa farms—using activity analysis and linear programming. Unpublished Ph. D. thesis. Iowa State College Library, Ames, Iowa. 1954.

[15] Gilson, James C. Optimum livestock production under varying resources and price-cost situations in northeast Iowa. Unpublished Ph. D. thesis. Iowa State College Library, Ames, Iowa. 1954.

TABLE 33. TOTAL FEED CONSUMPTION OF LIVESTOCK DURING A SINGLE PRODUCTION PERIOD.

Livestock enterprise	Quantity of product produced	Corn (bu.)	Protein supplement (lbs.)	Hay (ton)	Permanent pasture			
					Unimproved Kentucky bluegrass	Improved Kentucky bluegrass	Phosphate lespedeza improved	Complete renovation
Beef cattle: (per animal)								
Yearling steers full fed in drylot	434 lb.	47.5	148	0.365	---	---	---	---
Yearling steers full fed on pasture	493 lb.	47.3	33	0.068	0.68	0.58	0.55	0.37
Yearling steers grazed then finished in drylot	508 lb.	31.6	73	0.167	2.79	2.37	2.24	1.52
Beef cow-calf herd*	445 lb.	6.7	--	1.150	3.05	2.59	2.45	1.66
Hogs (per litter)*								
Spring-farrowed hogs	1,560 lb.	82.06	499.2	0.94†	---	---	---	---
Fall-farrowed hogs	1,583 lb.	94.19	712.4	----	---	---	---	---
Poultry (per hen)*	195 eggs	1.60	44	----	---	---	---	---

*Includes feed requirements for breeding herd and replacement stock.
†Hay equivalent consumed by the spring-farrowed hog system as rotation pasture which is provided by the forage produced in the crop rotation.

TABLE 34. CAPITAL REQUIREMENTS OF LIVESTOCK (AVERAGE 1949-53).

Enterprise	Initial investments		Annual capital expenditures§	
	Buildings and equipment‡	Livestock investment	Miscellaneous charges	Value of tractor and horse labor
Beef cow herd (per cow)*	--	$186.00	$0.50	$1.75
Yearlings on drylot (per steer)*	---	147.00	0.19	3.93
Yearlings full fed on pasture (per steer)*	---	147.00	0.19	6.94
Yearlings grazed then fed out (per steer)*	---	147.00	0.19	8.84
Spring hogs (per litter)*	$51	46.00	10.03	9.70
Fall hogs (per litter)*	51	46.00	10.18	12.53
Poultry (per hen)†	--	0.20	0.19	0.09

*Heady, E. O. and Olson, R. O. Substitution relationships, resource requirements and income variability in the utilization of forage crops. Iowa Agr. Exp. Sta. Res. Bul. 390.
†Rorholm, Niels, et al. Farm labor and costs, 1953. Mines report no. 217. Dept. Agr. Econ. University Farm, St. Paul, Minnesota. Sept. 1954.
‡Investment in minimum housing at new price.
§Does not include feed.

TABLE 35. LABOR REQUIREMENTS FOR CROPS AND LIVESTOCK.

Enterprise	Total man hours per year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Livestock													
Beef cow herd (per cow)*	15.0	13.6	13.6	15.1	10.2	5.1	5.1	5.1	5.1	5.1	5.1	6.7	10.2
Steers, yearlings fed in drylot (per steer)*	15.3	16.3	16.3	16.3	--	--	--	--	--	2.0	16.3	16.3	16.3
Steers, yearlings wintered full fed on pasture (per steer)*	18.6	1.0	1.0	1.0	1.0	10.5	10.5	10.5	11.6	12.6	13.7	13.2	13.2
Steers, yearlings wintered, pastured, finished in drylot (per steer)	10.9	1.8	1.8	1.8	1.8	0.9	0.9	0.9	0.9	17.4	24.8	23.8	22.9
Spring hogs (per litter)†	26	7.9	7.9	9.5	10.0	9.1	8.3	8.3	8.3	7.9	7.9	7.8	7.1
Fall hogs (per litter)†	33	9.7	7.6	7.0	5.4	4.7	5.2	5.0	8.2	13.0	12.4	10.9	10.9
Poultry (per 100 hens)‡	249	7.6	7.6	8.2	9.8	15.1	10.5	8.2	7.6	7.3	5.8	6.5	5.8
Crops													
Corn (per acre)§	7.0	--	--	--	11.8	22.0	13.1	10.7	--	2.0	14.8	20.4	5.2
Oats (per acre)§	5.0	--	--	7.1	17.9	--	--	37.5	37.5	--	--	--	--
Hay (per acre)§	7.6	--	--	--	--	--	38.9	33.1	--	28.0	--	--	--

*Heady, E. O. and Olson, R. O. Substitution relationships, resource requirements and income variability in the utilization of forage crops. Iowa Agr. Exp. Sta. Res. Bul. 390.
†Iowa State College. An appraisal of agricultural productive capacity in Iowa. Iowa Agr. Ext. Serv. Bul. AN-153. 1952.
‡Gilson, James C. Optimum livestock production under varying resource and price-cost situations in northeast Iowa. Unpublished Ph. D. thesis. Iowa State College Library, Ames, Iowa. 1954.
§Powlen, Bernard J. Production planning of crops for Iowa farms—using activity analysis and linear programming. Unpublished Ph. D. thesis. Iowa State College Library, Ames, Iowa. 1954.

TABLE 36. PRICE ASSUMPTION FOR PROGRAMMING.

Commodity	Adjusted 5-year average price
Corn	$ 1.38 per bu.
Oats	0.80 per bu.
Hay (clover-timothy-alfalfa mix)	20.09 per ton
Feeder stock	
Heifers—300 to 500 lbs. (good to choice), Oct.	21.97 per cwt.
Steers—300 to 500 lbs. (good to choice), Oct.	24.25 per cwt.
Heifers—500 to 800 lbs. (good to choice), Nov.	21.87 per cwt.
Steers—500 to 800 lbs. (choice), Nov.	24.17 per cwt.
Cows—1,000 lbs. (medium to good), average annual	14.92 per cwt.
Fed steers	
Choice—1,060 lbs., Oct.	25.99 per cwt.
Choice—1,120 lbs., Oct.	26.09 per cwt.
Choice—1,135 lbs., Dec.	25.99 per cwt.

TABLE 36—(cont).

Commodity	Adjusted 5-year average price
Market hogs—220 to 240 lbs. (choice)	
Sept.	21.87 per cwt.
Feb.	19.33 per cwt.
Sows—average annual	18.47 per cwt.
Eggs	0.37 per doz.
Chickens	0.25 per lb.
Soybean oilmeal supplement	5.65 per cwt.
Baby chicks	0.27 per ea.
Farm wage rates (hourly without board or room)	0.81 per hr.
Fertilizer:	
Per pound of available nitrogen	0.1390
Per pound of available phosphorus	0.1057
Per pound of available potassium	0.0520

mated to have a life of at least 10 years but require repeated fertilization at intervals over the life of the improvement. The average annual cost of the improvement, including repeated treatments, is $2.12 per acre for the photphate-lespedeza and $1.72 per acre for complete renovation.[16]

Labor

The labor requirements for each of the livestock enterprises and crops are given in table 35. The percentage of total labor required that is used in each month is also given. There is a wide variation among sources in the estimates of the number of man-hours required by each of the enterprises. The estimates used are those believed to be most representative of the labor requirements in the southern pasture area under a relatively high level of management.

[16] Heady, E. O., Olson, Russell and Scholl, J. M. Economic efficiency in pasture production and improvement in southern Iowa. Iowa Agr. Exp. Sta. Res. Bul. 419.

Prices

The prices used in this study are an adjusted average of the prices from 1949 to 1953 (table 36). The adjustment was made in the following manner: The average price of each of the commodities for the 15-year period, 1939 to 1953, was determined. The ratio of the price of corn to each of the other commodities in this series was then determined. This ratio might be thought of as representing the long period relationship between prices. The adjusted price series was determined on the basis of each commodity price being in the same ratio to the 5-year average price of corn, 1949 to 1953, as to the 15-year average price series. This calculation may be represented as follows:

$$\frac{\text{Ave. corn price (1949-53)}}{\text{Adj. price of product } X} = \frac{\text{Ave. corn price (1939-53)}}{\text{Ave. price of product } X \text{ (1939-53)}}$$