Variable Resource Programming for Appraising Farm Adjustment Opportunities

By Bill Bolton

Economists are faced with the continual need for reliable estimates of farmers' aggregate supply response. They search accordingly for procedures that will reduce the computational burden and strengthen the reliability of these estimates. The author describes how the "variable resource programming" technique can be used to help alleviate a major problem encountered when "representative" farms are analyzed to generate aggregate information. This is the problem of determining the proper kind and number of farms to include in the analysis. The article also illustrates how variable resource programming can contribute a wealth of information pertaining to other production research problems, such as determining the optimum combination of enterprises for specific farm resource situations.

IN RECENT years linear programming has become widely used as a research technique for determining the most profitable combination of enterprises for individual farms under specified conditions. Its use has also been extended to research on aggregate adjustment opportunities and limitations. This is accomplished by expanding the results from the programming of "representative" farms on the basis of resource quantities represented by each programmed situation. For example, Southern Regional Project S–42, a regional adjustment study being conducted cooperatively by Southern agricultural experiment stations and ERS, is using this technique to develop estimates of aggregate outputs for major crop and livestock enterprises at several different product prices.

One of the major problems in using linear programming to estimate aggregate supply response is that of choosing the kind and number of "representative" farms that will minimize the amount of aggregation bias. This bias is simply the discrepancy between (1) aggregate results obtained if every farm is analyzed separately and (2) the aggregate results obtained from a necessary shortcut, such as the analysis of representative farms. The results from programming a given resource situation are highly specific and usually limited with respect to the number of enterprises in the final plan. Therefore, a large number of representative farms may be required to properly reflect the feasible alternatives for an area.

Variable resource programming is a practical way of generating considerable information about the effects of variation in the resource base without having to program a large number of representative farms.[1]

This paper illustrates how the quantity of land can be varied over a wide range, with other factors or restrictions either remaining fixed or being varied proportionately with land. This is appropriate because the planning period normally used is so long that few resources remain "fixed."[2] Labor hiring activities are commonly used for many classes of labor. Non-real-estate capital items are assumed to be variable, available in unlimited quantities at a given interest rate, or available in proportion to some specified equity position. Land and resident labor force are the only resources generally assumed to be fixed, or semifixed, in quantity.

When the varied resource, such as land, forms part of the basis on which major resource situations are defined, variable resource programming has the effect of expanding the programmed situations to a much larger number than may be obtained otherwise. The aggregate results thus obtained may be more realistic than those obtained from programming a few "representative" farms with many more resource restrictions assumed, but with all restrictions fixed at one level.

[1] Since linear programming assumes linearity of all relationships, it is possible to examine the effects of varying one of the resources over its entire range by computing solutions at only a few points: namely, at those points where changes in the variable factor cause changes in the optimum program. For a complete discussion of variable resource programming see E. O. Heady and W. Candler, *Linear Programming Methods*, Iowa State College Press, Ames, 1958, Ch. 7.

[2] For further discussion on this point and its implications see Gerald W. Dean, Stanley S. Johnson, and Harold O. Carter, "Supply Functions for Cotton in Imperial Valley, California," *Agr. Econ. Res.*, Vol. XV, No. 1, January 1963, p. 7.

An Illustration

The basic data and assumptions being used in the Mississippi River Delta phase of the Southern Regional study, referred to earlier, are well adapted to use in developing an illustration of variable resource (land) programming. Following is a brief description of the procedure and and assumptions used in the Delta study.[3]

Nine resource situations were recognized: all combinations of three farm sizes and three soil compositions. Appropriate enterprise budgets were developed for each situation.

The three sizes of farm considered were: (1) under 100 acres of cropland, (2) 100 to 250 acres of cropland, and (3) over 250 acres of cropland. For programming purposes the three size groups were represented by farms with cropland of 40 acres, 160 acres, and 640 acres.

The physical resource (soil) situations recognized were: (1) clay land farms, (2) mixed land farms, and (3) sandy land farms. Each type of farm was composed of specific proportions of clay, loam (mixed), and sandy soils. For example, the mixed land farm contained 44 percent clay type soil, 42 percent loam type soil, and 14 percent sandy type soil.

Assumptions as to labor force varied by size of farm. On the small farm some unpaid family labor in addition to that of the operator was available and additional labor could be hired only for chopping and harvesting cotton. On the medium size farm, no unpaid family labor other than that of the operator was available and additional labor could be hired only for chopping and harvesting cotton. On the large farm all labor was hired.

Capital was assumed to be unlimited at the rate of interest specified.

Thus, major operating restrictions for each programmed situation were in terms of total cropland, resident labor (on a period basis), a cotton acreage limitation, and specified amounts of clay, loam, and sandy soils. No major changes were necessary in moving to the variable land programming technique.

[3] For additional background on data, procedures, and assumptions see *Progress of Regional Project S-42, July 1, 1958–September 30, 1962*, prepared by James H. White, Chairman, Technical Committee, University of Arkansas.

The results of variable land programming for the Delta mixed land farm are shown in table 1.[4] The optimum enterprise combination and the resulting net return at 100 acres of cropland, the initial program, are shown as enterprise combination A in table 1. An item of output for each computed program is the amount by which total cropland could be increased without changing the most profitable enterprise mix. In this case the figure was 68.5 acres. Therefore, the second program, designated as enterprise combination B in table 1, was run at 168.6 acres of cropland. The most profitable enterprise combination computed at 168.6 acres, however, applies for only 4.2 additional acres or through 172.8 acres of cropland. A third program is computed at 172.9 acres (enterprise combination C). This process can be repeated, computing a new program each time the enterprise mix changes, until no additions to net returns are made from further increases in acreage, or until there is no interest in additional programs.

All relationships are linear between any two consecutive optimum programs shown. Therefore, any program datum for any point between two computed programs can be determined easily by interpolation. For each 1-acre increase in cropland between enterprise combination C and enterprise combination D in table 1, for example, there is a $48.59 increase in net returns, a 7.08-acre decrease in clay corn (corn grown on clay soil), a 2.37-acre increase in clay soybeans, a 4.97-acre increase in clay wheat, and so on for other enterprises. At 176.9 acres of cropland then, net returns would be $9,826; acres of clay corn would be 22.0. Quantities of all other enterprises could be computed similarly.[5]

At any point the *composition* of the enterprise mix is determined by the previous optimum. The *amount* of each enterprise in the mix is determined

[4] Data used are based on advanced technology budgets from *Budgets for Major Farm Enterprises in the Mississippi River Delta of Arkansas, Louisiana, and Mississippi,* Dept. Agr. Econ. Cir. 281, La. Agr. Expt. Sta. in cooperation with Ark. and Miss. Sta. and U.S. Dept. Agr., June 1961.

[5] More generally, if B represents a new point to be computed, A the optimum preceding it, C the optimum succeeding it, X the the value of net returns (for any given enterprise), and Y the value of the resource being varied, then the value of X at the new point is: X at A plus (X at C minus X at A) (increase in Y from A to B divided by increase in Y from A to C).

Table 1.—*Optimum enterprise combinations with cropland varying upward from 100 acres, 1-man labor force, mixed land farm in the Mississippi River Delta area* [1]

Item	Enterprise combination								
	A	B	C	D	E	F	G	H	I
Total cropland ... acres	100.0	168.6	172.9	180.0	184.3	245.0	254.6	265.9	272.8
Clay corn [2] ... do	35.2	59.3	50.3	-	-	-	-	-	-
Mixed cotton ... do	19.8	33.4	34.2	35.6	36.5	11.5	8.2	3.1	-
Sandy cotton [2] ... do	14.7	24.8	25.4	26.5	27.1	36.0	37.4	39.1	40.1
Mixed corn ... do	21.5	36.2	37.2	38.7	39.6	89.7	91.9	93.3	94.4
Noncrop pasture ... do	8.8	14.8	15.2	15.8	16.2	21.6	22.4	23.4	24.0
Clay soybeans ... do	-	.1	10.5	27.3	-	-	-	.1	3.1
Clay wheat ... do	-	-	.1	35.4	36.2	-	-	-	-
Clay pasture ... do	-	-	-	.7	28.7	86.1	89.6	93.5	92.9
Mixed soybeans ... do	-	-	-	-	-	-	.1	13.4	18.3
Mixed pasture ... do	-	-	-	-	-	.1	5.0	-	-
Net returns [3] ... dollars	5,577	9,398	9,632	9,977	10,181	11,555	11,700	11,863	11,950
Total operating capital required ... do	6,476	10,912	11,084	11,164	11,257	11,034	11,021	10,970	10,940
Per acre operating capital required ... do	64.76	64.76	64.14	62.06	61.11	45.04	43.32	41.27	40.09

[1] Values for a 2-man labor force are obtained by multiplying by 2; for a 2-man labor force net returns (without labor costs) for enterprise combination A would be $11,154, total cropland would be 200 acres, clay corn would be 70.4 acres, etc. For a 3-man labor force the values are multiplied by 3, and so on for any size labor force.

[2] Clay corn means corn on clay type soils, sandy cotton means cotton on sandy type soils, etc.

[3] Returns to land and operator's labor and management.

by the rate of change between the preceding and the succeeding optimum. Clay corn, for instance, is in the enterprise mix in decreasing amounts at all points between combinations C and D, although it goes out completely at 180 acres. Pasture on clay soils, on the the other hand, enters the enterprise mix at 180 acres, but is not in at any point between 172.9 and 180 acres.[6]

Alternatively, quantities shown under enterprise combinations A and B, or any two consecutive combinations, can be represented as points on a two-dimensional chart, and connected by straight lines. This has been done for net returns in figure 1. Points shown on the one-man segment of the line in figure 1 correspond with the net returns shown in table 1. Net returns for any given total cropland can now be read directly from figure 1, and reference to table 1 will provide corresponding information on the enterprise mix.

Various labor restrictions become limitational between enterprise combinations A and I in table 1 and figure 1. The labor service incorporated in a single laborer, consisting of several labor restrictions, becomes increasingly scarce relative to land. According to the assumptions used here the fixed nature of the labor resource rests upon the characteristics of "lumpiness" or indivisibility of the input. That is, resident laborers are added in full units and their full productive services are available whether used to capacity or not. At some level of the resource being varied, however, it may become feasible and profitable to add more units of the fixed resources.

Since no other resources are really restrictive (i.e., the problem has been so stated that the cotton acreage restriction and the various soil restrictions vary with total cropland), it is possible to combine the programs already computed with larger labor forces. That is, if a two-man labor force were assumed, instead of the one-man force used to this point, labor availability in all periods would be doubled. Reprogramming, then, using a two-man labor force would simply double all values shown in table 1. The use of a three-man labor force would result in all these values being tripled. Su-

[6] Conventional linear programming, of course, yields information on the range of sizes (or other resources) over which a given enterprise mix applies. If a program were run for a 200-acre farm, with the same data used here, enterprise combination E would apply and the program would indicate that 184.3 acres and 245.0 acres constituted the lower and upper limits, respectively, for this program. It would *not* indicate the *amounts* of each enterprise that would apply at other acreages within this range, say at 225 acres. These could be determined only if enterprise combinations E and F were computed.

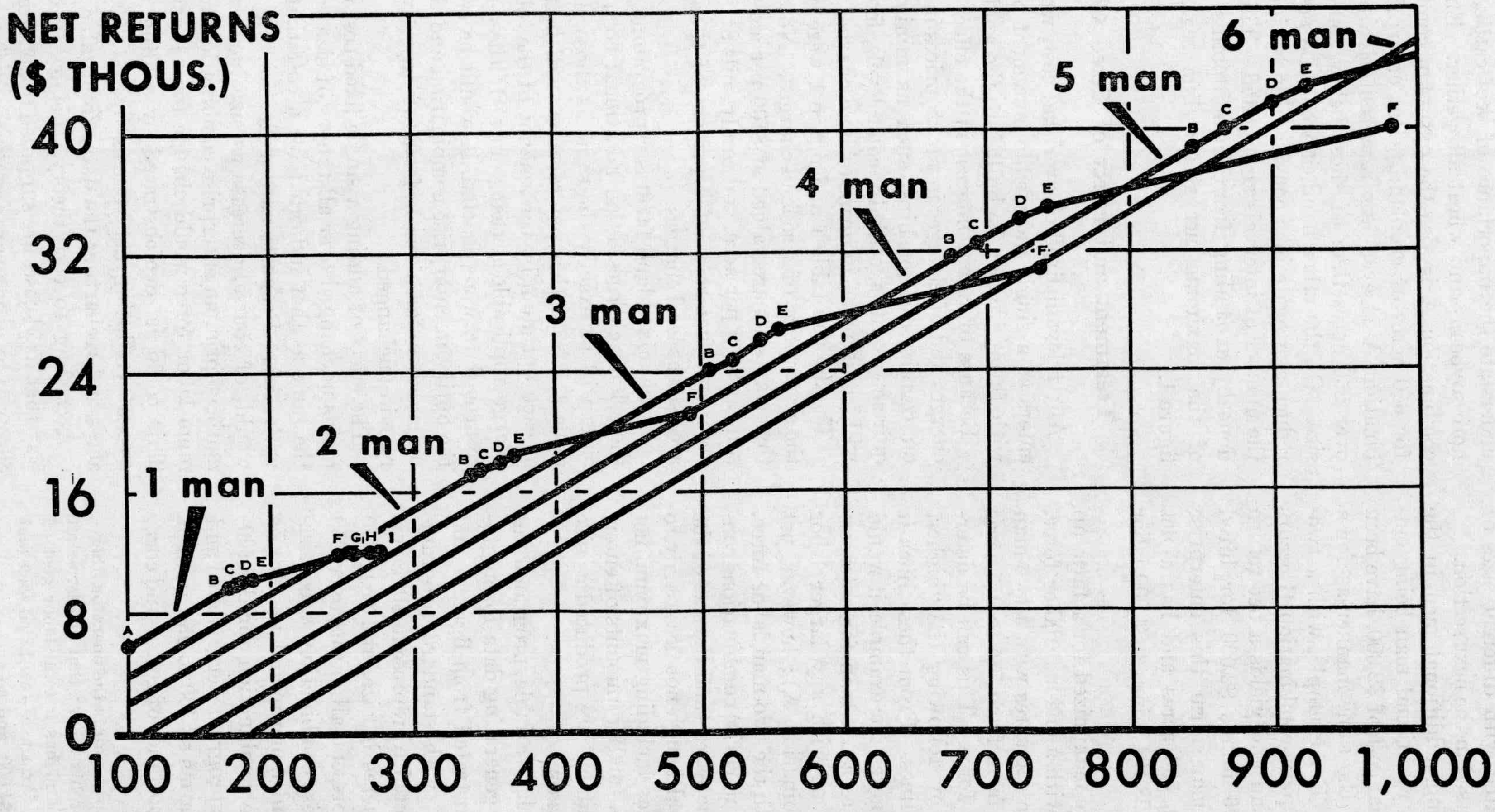

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FIGURE 1.—*Highest possible net returns for various enterprise combinations, by size of farm and size of labor force, owner-operated mixed land farms in the Mississippi River Delta area.*

pervisory time associated with different sizes of the labor force is discussed in the next section.

Net returns, assuming additional men in the labor force with each additional man being employed at a fixed annual cost of $2,000, have been plotted on figure 1 in the same manner as for a one-man labor force. For example, with a two-man labor force, enterprise combination B occurs at 337 acres of cropland and yields a net return of $16,796, or $18,796 minus $2,000 for hired labor.[7] For a three-man farm this enterprise combination occurs at 506 acres and has a net return of $24,194, or $28,194 minus a $4,000 labor cost.

Thus, net returns are maximized for a farm up to a size of 245 acres with a one-man labor force, for a farm from 245 to 420 acres with a two-man labor force, and for a farm from 785 to 975 acres with a five-man labor force. This can be determined from figure 1 by following the "highest possible net returns" lines. From these lines it can be seen that at 275 acres, for example, it would be possible to operate as a one-man farm (enterprise combination I), or with any larger labor force (enterprise combination A); however, net returns are highest with the two-man labor force.

The same optimum enterprise combinations continue to recur as size increases (and the size of the labor force increases), although not necessarily to the same extent in areas including maximum net returns. For example, smaller amounts of enterprise combinations A and F are produced as size of the labor force increases.

The advantage of the variable programming procedure, in terms of generating data for aggregation, can now be illustrated from figure 1 and table 1. Assume that, with standard programming, 160 acres is selected to represent all farms between 100 and 250 acres in size, and that 640 acres is selected to represent all farms over 250 acres in size. Enterprise combination A, consisting of cotton, corn, and noncropland pasture, is the optimum enterprise combination for the 160-acre farm. But, if this program were inflated and made to represent all farms of 100 to 250 acres, it would overstate the importance of cotton and corn, understate the importance of beef cattle, and ignore soybeans and wheat altogether. Enterprise combination A is also the optimum combination for 640 acres of cropland. But enterprise combination A is even less representative of farms over 250 acres than of those below 250 acres in size. On the other hand, it would be possible to reduce aggregate bias considerably by increasing the number of intervals aggregated. This can be done by expanding from the midpoints of each of the maximum net return line segments in figure 1.

Treatment and Effect of Fixed Costs

Any relevant fixed or overhead cost, whether it enters as a single indivisible increment or varies with farm size, can be built into the analysis.

Because of recent interest in the effect of land charges and of changes in factor prices in general on certain relationships, such as minimum requirements for specified income levels, fixed costs will be discussed in terms of land charges.

The data in table 1 and figure 1 were based on the assumption of zero land charges. Now assume that clay soils are valued at $100 per acre, mixed soils at $200 per acre, and sandy soils at $300 per acre, and that rates of 5 percent of these values are used as land charges.

If the mixed land farm is reprogrammed, using these land charges as an additional cost, the results will be exactly the same as those shown in table 1, *except* that net revenues will be reduced at each optimum by the amount of the total land charge applicable at that point. If these new net returns data were charted, it would be seen that the optimum enterprise combination and the optimum labor force for a farm of any given size remain unchanged.

The effect of adding a single fixed cost that remains unchanged over all ranges of size would be the same as that indicated for a cost that varies with size. Proportionate reduction in income would, of course, decrease as size increased, but neither optimum enterprise combination nor optimum labor force would change for a given farm. This could be demonstrated by adding a fixed cost of (reducing net returns by) $4,000 at 100 acres and recharting the data, from table 1.

According to cost theory, this is exactly the way that fixed costs are supposed to operate. The effects of fixed costs are frequently misinterpreted,

[7] It is assumed that the first man is the operator, therefore no charge is made for his labor; that the two-man farm uses one hired man and has a total labor cost of $2,000; that the three-man farm uses two hired men and has a hired labor cost of $4,000, and so on.

however. It is particularly easy for erroneous effects to be attributed to fixed costs when conventional linear programming is done at a few discrete size levels and at various levels of fixed costs. With variable land programming any level of fixed costs can be conveniently added at any point with the effects, or lack of effects, more easily seen.

Semifixed costs.—Certain costs might be characterized as semifixed. That is, they are added at a given size and remain unchanged over a range of sizes whether or not the services they represent are fully utilized. But at some size level it may become profitable to add an increment. Cost for regular hired labor, as it has been used to this point, displays these characteristics.

There is no difference between the effects of these costs and those discussed above *if* it can be assumed that each increment of input for items of this nature has the same cost, and that changes in this cost affect each increment equally. For example, it was assumed in figure 1 that all or any part of the services of each additional resident laborer was hired at a cost of $2,000. If it were assumed that the cost of each laborer increased by $3,000 the only effect on figure 1 would be a reduction in net returns for any given farm.

It may not always be valid, however, to assume that more increments of these inputs can be added at the same cost. Instead of the simple assumption that each addition to the labor force costs $2,000, assume that the resident labor force grows as follows: [8]

Effective resident labor force	Hired labor	Labor cost
1	None (operator works)	None
2	1 (operator also works)	$2, 000
3	3 (operator now supervises, keeps books, repairs machinery).	6, 000
4	5 (including bookkeeping and some supervision).	11, 000
5	7 (including additional supervision and shop work).	17, 000

[8] This example introduces an element of diminishing returns to labor by requiring increasing amounts of, and more expensive, labor to perform a given amount of work. Six men, including the operator, constitute a four-man effective labor force (six times as many men are needed to do four times as much work as one man). Labor costs also rise as supervisory and other specialized labor is hired.

These new labor costs will have no effect on the enterprise combination as programmed for a given size (effective) labor force. They will, however, affect the size of farm at which it becomes profitable to hire additional laborers, and consequently will affect the range over which the various enterprise combinations are most profitable.

The new labor costs can be subtracted from the net returns shown in table 1 to get new return figures. For example, under these assumptions enterprise combination E on a three-man farm would now have a net return of $24,543, or ($10,181 ×3) −$6,000. New net returns obtained by this procedure are charted in figure 2.

Comparison of figures 1 and 2 indicates that, while optimum enterprise combinations are unchanged, the increase in labor costs has reduced net returns for farms over 425 acres in size, resulted in larger farms for a given effective labor force, and changed the relative importance of the various enterprise combinations. Enterprise combination E, for example, is now produced almost exclusively over the entire range of sizes above 550 acres, whereas combinations A, B, C, and D were produced in considerable quantities at these sizes under the old cost structure.

Different Levels of Use of Resources and Prices

Apart from interest in aggregation, variable resource programming can be useful for examining the effects, over a range of a particular resource, of changes in resource requirements, resource situations, or prices. An illustration will be presented in terms of changes in acreage allotments and prices. Others could be used to reflect changes in tenure, technology, or any other change in the basic situation.

To this point it has been assumed that cotton was limited to 34.5 percent of total cropland, which has been the approximate average level of Delta cotton acreage allotments for several years. With cotton acreage allotments changed to 24.5 percent of cropland the optimum enterprise combinations and corresponding net returns are as shown in table 2.

Net returns at all levels of size (again assuming that additional laborers are hired at a cost of $2,000 as it becomes profitable to do so) are charted for the 34.5 and 24.5 percent cotton restrictions in figure 3. Cotton price remains at 31.2 cents per pound of lint for the two allotment levels.

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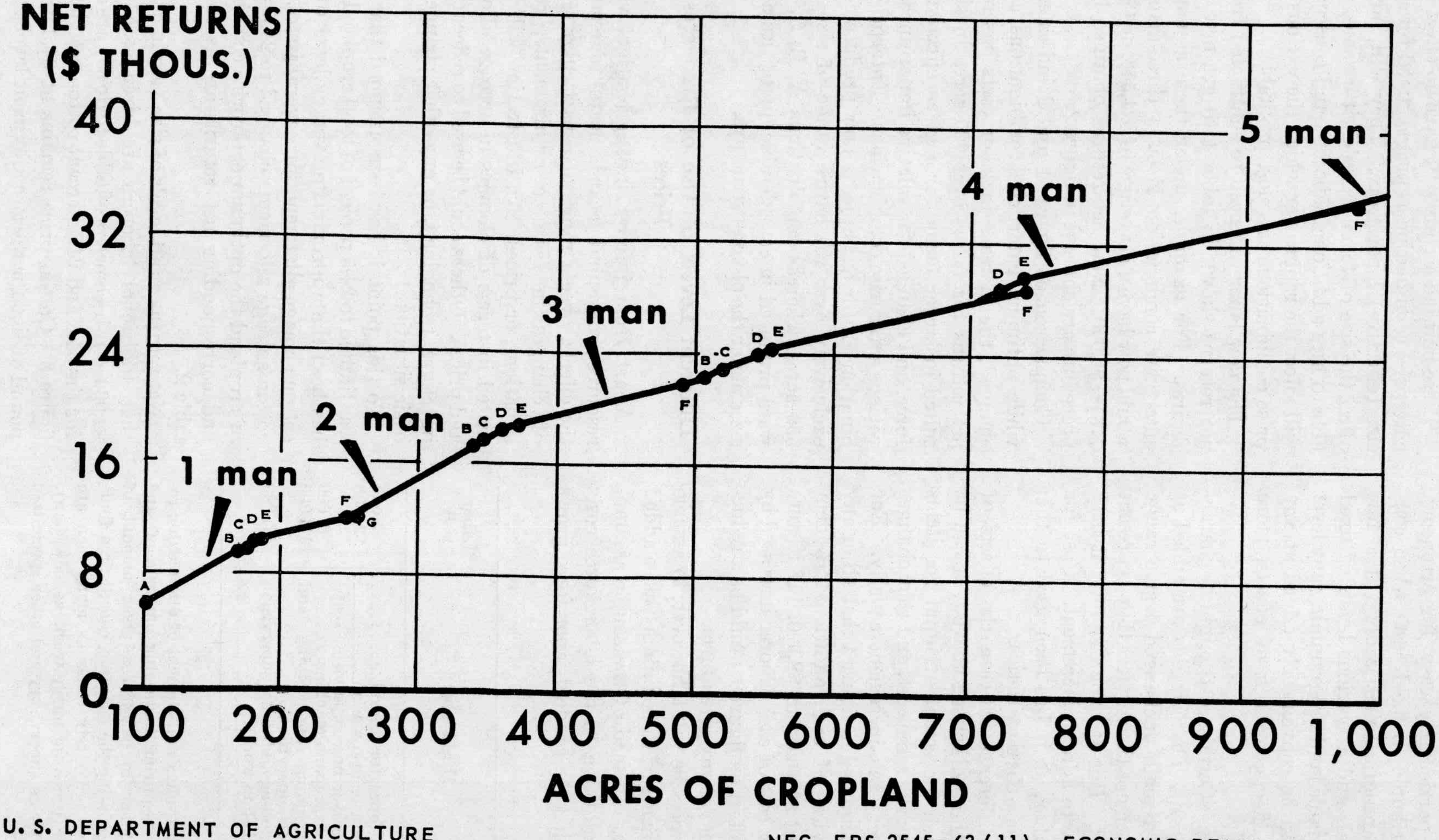

FIGURE 2.—*Net returns under conditions of increasing labor costs, by size of farm and size of labor force, owner-operated mixed land farms in the Mississippi River Delta area.*

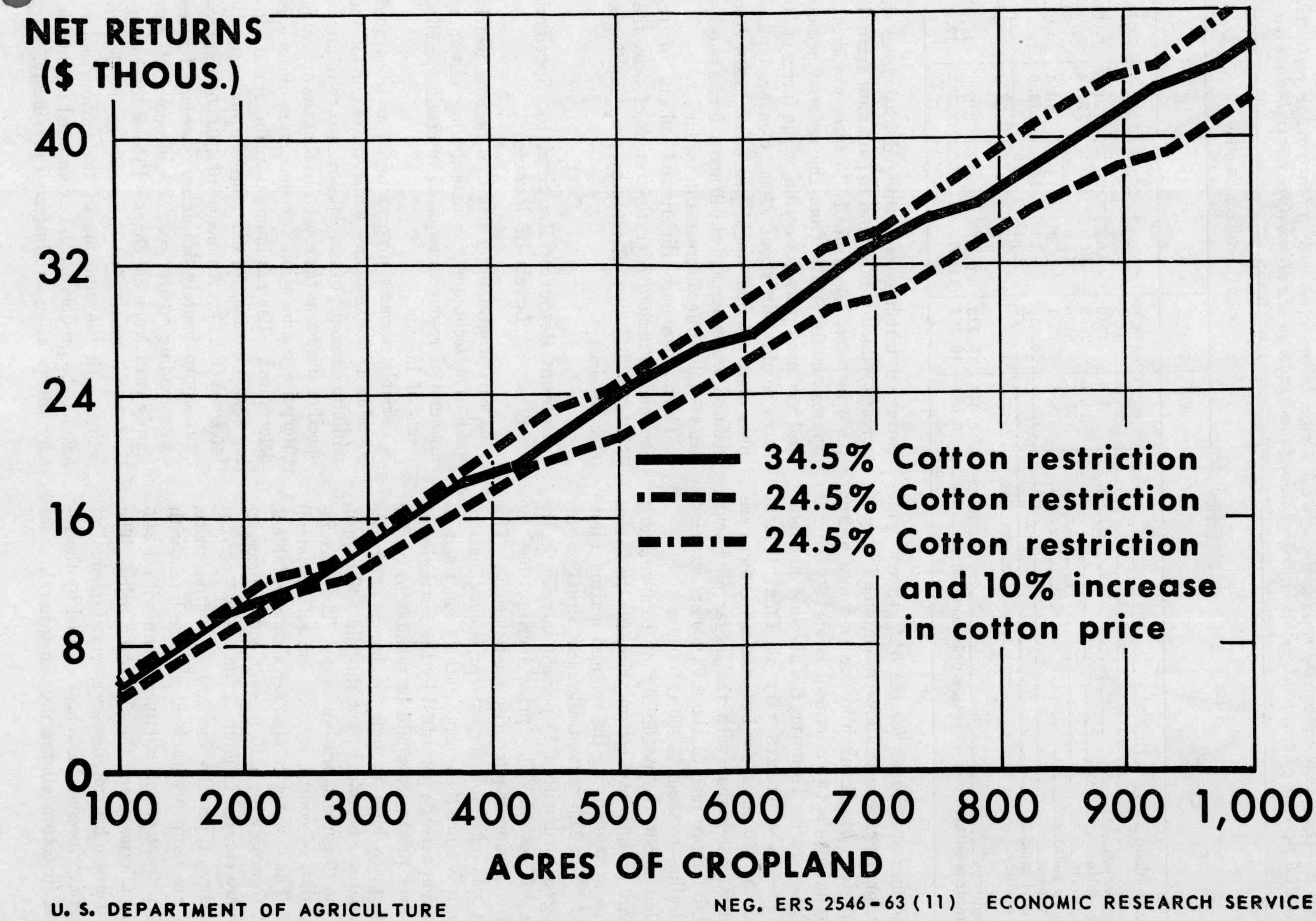

FIGURE 3.—*Net returns with different levels of cotton acreage restrictions and cotton prices, owner-operated mixed land farms in the Mississippi River Delta area.*

TABLE 2.—*Optimum enterprise combinations with 1-man labor force and cotton acreage restriction at 24.5 percent of cropland, owner-operated mixed land farm in the Mississippi River Delta area*

Item	Enterprise combination					
	A	B	C	D	E	F
Total cropland____acres__	100. 0	182. 8	206. 0	209. 3	220. 5	245. 0
Clay corn____do____	35. 2	64. 1	20. 3	-------	-------	-------
Mixed cotton____do____	9. 8	17. 9	20. 2	20. 5	21. 6	11. 5
Sandy cotton____do____	14. 7	26. 9	30. 3	30. 8	32. 4	36. 0
Mixed corn____do____	31. 5	57. 6	64. 9	65. 9	69. 5	89. 7
Noncrop pasture____do____	8. 8	16. 1	18. 1	18. 4	19. 4	21. 6
Clay wheat____do____	-------	-------	. 1	14. 0	14. 6	-------
Clay soybeans____do____	-------	. 2	52. 1	59. 6	-------	-------
Clay pasture____do____	-------	-------	-------	. 1	63. 0	86. 2
Net returns____dollars__	5, 047	9, 225	10, 367	10, 513	10, 999	11, 555
Net returns with 10 percent cotton price increase____do____	5, 681	10, 384	11, 672	11, 839	12, 396	12, 832

Incomes are higher for the 34.5 percent level than for the 24.5 percent level of cotton allotments except for a small range in size (net returns are the same for the two allotment levels between 220 and 245 acres). However, the absolute and relative income differences vary at different farm sizes. At 600 acres, for instance, net returns are about $1,200 higher with the larger allotment. This difference rises to about $3,200 at 700 acres, but declines to about $2,200 at 800 acres.

What about the possibility of compensating, through an increased cotton price, for the loss of income accompanying the reduced acreage allotment? The 24.5 percent allotment situation was reprogrammed with a 10 percent increase in the price of cotton. The price increase had no effect on optimum enterprise combinations. This result was inevitable for enterprise combinations through E since these combinations contained all the cotton acreage permitted by the restriction at the lower price. It would be possible to set the cotton price high enough to change enterprise combinations beyond E, but this did not happen with the 10 percent price increase. The price increase did, of course, increase net returns at all sizes. The new net returns are shown in table 2.

Net returns with a 10 percent cotton price increase are charted in figure 3 for the 24.5 percent allotment. With the increase in cotton price, farms are more profitable at all size levels with a 24.5 percent cotton allotment than with a 34.5 percent allotment and the old cotton price. The price increase has not, however, served to equalize the relative income differences created by the reduction in cotton allotments. In general, those farms on which income suffered least from the acreage reduction now tend to gain most from the price increase. A farm of 640 acres would gain approximately $2,400 from the reduced acreage and increased price for cotton, while farms at 500 acres would gain about $400. Conversely, if a price were set that would just offset losses from reduced cotton acreage at 640 acres, farms at other sizes would suffer decreases in income.

Thus, there are differential effects of the changed situation, over the range of size, that would be difficult to develop by programming at discrete sizes.

Minimum Resources Required for Specified Levels of Income

Linear programming has also become widely used as a technique for determining minimum amounts of resources required to attain specified levels of income.

Variable resource programming, as illustrated in table 1, accomplishes a determination of the minimum amount of cropland necessary to attain specified income *at the same time* that the optimum enterprise combination for maximum income is determined. The minimum cropland for attaining $8,000 income, for example, is approximately 145 acres (fig. 1). An income of $16,000 would require approximately 325 acres. Acreage figures corresponding to the specified income level are simply read from the chart. Precise total cropland requirements for these income levels, together with the amounts of the various enterprises to be produced, can be computed from table 1 by interpolation as illustrated previously.

This procedure has the same advantages for minimum resource programming as for optimum enterprise combination programming: the minimum amount of cropland or other resources required can be determined for any income level in contrast to one or a few finite levels, and some insight is furnished as to the stability of the program for a particular income level, i.e., over how wide a range of the varied resource it applies. The technique can also be used to appraise the effects on minimum resource requirements of changing resources, technology, product prices, factor prices, or other variables.

Evaluation of Uses and Limitations

It has been demonstrated that variable resource programming has certain advantages over conventional programming, at least for the type of problems and resource restrictions considered here. The increase in computing time is far less than proportional to the increase in information produced. If it is intended to examine both minimum resource and maximum income aspects of a problem, and at different levels of product and factor prices, variable resource programming requires less computing time than conventional programming.

The framework of problems and assumptions used in this report has, of course, been ideal for the use of this technique. First, it was assumed that farm size is an extremely important variable. This assumption was implicit in the S–42 procedure on which the data used were based.

Second, it was assumed that, while there are multiple labor restrictions, the quantities of labor available during different periods are embodied in indivisible individuals, and that additional labor must be added in these indivisible increments, i.e., all labor is performed by the operator or by regular hired laborers. Some labor is, or could be, hired on a seasonal or piece-rate basis, but this poses no problem. In fact the data used assumed that certain labor was hired on a seasonal basis, and the cost of this labor was simply subtracted from enterprise net returns. Alternatively, a labor hiring activity could have been added to hire additional seasonal labor, confined to specific enterprises and operations if desired.

The use of unpaid family labor, other than the operator, would present a problem. Assume a given quantity of unpaid family labor available in a particular restriction period. This would change the optimum enterprise combinations for any of the examples used in this report. But the quantity of this labor obviously would not double when the second man is added to the labor force. If this labor were a close substitute for seasonally hired labor it could be handled by adding seasonal wage rates for its use to net returns. But, if it were available during periods or for operations for which seasonal, piece-rate, or part-time labor normally cannot be used (milking cows for 2 hours per day, for instance), it would cause difficulty. Land still could be varied up to the limit of the available initial labor restriction, of course, but labor could not be simultaneously varied without considerable modification of the system.

Third, unlimited capital was assumed. For most of the examples used this was not a particularly bad assumption. The initial S–42 work has been in terms of farms operated by owners with high equity in their property. In this case it is not unreasonable to assume that adequate capital can be obtained to finance operating expenses and desired improvements. If capital were restricted at some given level, say $5,000, variable land programming could still be done to the limits imposed by initial labor and capital restrictions. But it would not be possible to move to the two-man labor force unless it could be assumed that the initial capital level doubled for a two-man farm.

It does not seem reasonable to assume that capital remains fixed as size increases. That is, it would be expected that a going farm of 300 acres would have access to more capital than one of 100 acres, independent of equity considerations. Therefore, a capital restriction that varies in some way with size would seem to be a more reasonable assumption than a fixed sum of capital over a range of sizes. What level of capital restriction should be used? If a particular capital availability is known to exist, there is no problem; it should be used. But no one can specify a completely valid capital restriction for a group of farms, or even for a single farm, with any degree of certainty. This leaves an alternative of programming at various levels of capital availability to gain some insight into the effect of capital on optimum plans. But, again, what levels should be chosen?

The program can be used to determine the amount of capital required for each optimum plan under the assumption of unlimited capital. Capital requirements so determined (based on operating capital requirements) are shown in table 1. It can be seen that the largest amount of capital required for any optimum combination is $64.76 per acre. Capital available in excess of $64.76 per acre is not used over all ranges of size. There is no interest in any capital restriction above this figure.

A small amount of variable capital programming, with land held constant, indicated that any capital restriction below $40.71 per acre forces some land into non-use over all ranges of size in which we are interested (enterprise combinations A to F). In view of the importance given to land in this problem there would be little interest in capital restrictions below this figure.

Capital restrictions, then, should lie between $40.71 and $64.76 per acre. Different levels of capital within this range will definitely have various effects on the optimum enterprise combinations. The specific restrictions chosen between these limits would depend upon the area, the problem, and the judgment of the investigator.

The method used in this report rests essentially on the fact that multiple resource restrictions have been reduced to two absolute restrictions. Restrictions on land of different qualities, on cotton acreage, and implicitly on capital, have been made to vary with total cropland. Multiple restrictions on labor have been allowed to operate as individual restrictions, but have been at the same time considered as components of a larger fixed labor increment, i.e., one man. In this way *simultaneous variable programming* has been accomplished, in effect, for land and for labor.

Had it been necessary to add a third absolute restriction the system would not have worked past the limit in size imposed by the original level of restrictions. For instance, if hogs had been considered as an alternative and hog housing were included as a restriction, it would not be possible to double all quantities when the quantity of labor doubled. In this case one could reject this method or make a reappraisal of hog housing to determine whether it actually is an absolute restriction, or whether additional hog housing would be forthcoming if hogs were profitable. If the latter view were taken, a cost for hog housing could be entered in the hog budget, with its capital requirements drawing against the total capital restriction.

It is possible that there are a number of problems in which land, labor, and capital, per se, could be considered as the relevant restrictions, with various subrestrictions of these three items related to them in definite quantities or proportions. If capital can then be related to size, variable land programming, as it has been illustrated here, can be used.

Suppose that the above assumptions cannot be made; that there are indeed additional resources that must be considered to exist in fixed quantities over an infinite range of farm sizes. This would neither rule out the possibility nor reduce the usefulness of performing variable land programming in conjunction with varying levels of hired labor. It would simply require more programming time. Reprogramming would now be necessary as each additional man is added to the labor force, but the results of these separate programs could be tied together to yield the same type of relationships as those shown in this report.

tal requirements so determined (based on operating capital requirements) are shown in table 1. It can be seen that the largest amount of capital required for any optimum combination is $64.76 per acre. Capital available in excess of $64.76 per acre is not used over all ranges of size. There is no interest in any capital restriction above this figure.

A small amount of variable capital programming, with land held constant, indicated that any capital restriction below $40.71 per acre forces some land into non-use over all ranges of size in which we are interested (enterprise combinations A to F). In view of the importance given to land in this problem there would be little interest in capital restrictions below this figure.

Capital restrictions, then, should lie between $40.71 and $64.76 per acre. Different levels of capital within this range will definitely have various effects on the optimum enterprise combinations. The specific restrictions chosen between these limits would depend upon the area, the problem, and the judgment of the investigator.

The method used in this report rests essentially on the fact that multiple resource restrictions have been reduced to two absolute restrictions. Restrictions on land of different qualities, on cotton acreage, and implicitly on capital, have been made to vary with total cropland. Multiple restrictions on labor have been allowed to operate as individual restrictions, but have been at the same time considered as components of a larger fixed labor increment, i.e., one man. In this way *simultaneous variable programming* has been accomplished, in effect, for land and for labor.

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