AGRICULTURAL AND ECONOMIC DEVELOPMENT

Cost Functions in Relation to Farm Size and Machinery Technology in Southern Iowa

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SUMMARY

This study was designed to (a) estimate the relationship between farm size and per-unit crop production costs for selected machinery combinations and farm situations in a southern Iowa area and (b) compare certain of the empirical results of this study with the agricultural structure of the study area. Budgeting techniques were used to estimate the relationship between crop acreage and crop production costs.

Estimates of average costs per dollar of crop product were made for five machinery combinations and for crop acreages varying from 40 to 640 acres on three different soil mixtures in the Shelby-Grundy-Haig soil association area. These three soil mixtures are referred to as hilly, average and upland farms. Cropland, as a proportion of total land, increases from approximately 30 percent on the hilly farm to 70 percent on the upland farm. Two budgeting models were considered. In model I, only cropland was considered. In model II, pasture production marketed through a beef-cow enterprise was considered along with cropland. Changing from model I to model II had relatively little effect upon the basic budgeting results or cost relationships.

A schedule of the time during which each crop operation can be performed without yield loss and a schedule of the time required for each field operation were derived for each crop. Revenue and yield reductions from crop field operations performed after scheduled time periods also were considered for each crop. A high efficiency level, high fertilization rates, specific field operations for each crop and rotations containing the highest proportion of row crops consistent with suggested soil conservation standards were assumed in each budgeting model.

The budgeting analysis suggests that substantial reductions in average total cost per dollar of crop product can be obtained by using larger machinery combinations on larger crop acreages when custom operations are not considered. Unit cost declines rapidly as crop acreage increases, and minimum unit cost is achieved at about 320 crop acres on each farm. Since the proportion of cropland in the three soil mixtures differs widely, the total land required to achieve minimum unit cost ranges from 1,061 acres on the hilly farm to 453 acres on the upland farm. Resource combinations that attain a unit cost within 5 percent of minimum cost achieve the major share of the cost economies available in crop production. Hence, unit costs within 5 percent of minimum costs are considered constant. The budgeting results indicate that a 2-man, 2-tractor machinery combination and 196 to 232 crop acres are required to achieve constant unit cost when custom operations are not considered.

Small machinery combinations have the lowest unit cost for small acreages (160 crop acres or less), but these costs are high relative to minimum unit cost. Total and average fixed costs for small machinery combinations are less than for large machinery combinations on small acreages. Small machinery combinations lack the capacity to operate efficiently on large crop acreages, and, as crop acreage increases, untimely field operations result in yield and revenue losses. Hence, the average fixed cost per dollar of crop product for small machinery combinations never declines to the low level achieved with larger machinery combinations on large acreages. In addition, the yield and revenue losses cause average variable cost per dollar of crop product for the small machinery combinations to increase rapidly as acreage increases.

Custom operations can be used to reduce total and average fixed cost per dollar of crop product and to increase the capacity of small machinery combinations. To estimate the effect of custom operations on the relative efficiency of small and large machinery combinations, custom harvesting operations for the 1-man, 1-tractor machinery combinations were considered on the average farm. Custom operations increase the relative efficiency for the 1-man, 1-tractor machinery combinations and make these small machinery combinations as efficient on small acreages as are the larger machinery combinations on larger acreages. Minimum average total cost per dollar of crop product is achieved at 152 crop acres with custom operations. The budgeting results suggest that most of the cost economies available in crop production on the average farm can be achieved with (a) a 1-man, 1-tractor combination and 152 to 288 acres of cropland and (b) a 2-man, 2-tractor combination and 288 or more acres of cropland. However, cost reductions associated with custom operations would be overestimated if there were extensive waiting periods for custom operations. Machinery sharing arrangements were not considered, but such agreements would have the same effect on unit cost as custom operations.

Estimates of average total cost per dollar of crop product were calculated with and without land rent. When land rent is included, total variable cost and unit cost increase substantially. Including land rent also causes a re-

duction in the minimum crop acreage required to achieve constant unit cost, but this reduction is less than 40 acres. Corn prices of $1.21, $1.23 and $0.96 are required to cover all crop production costs on the hilly, average and upland farms, respectively, when land rents are included and when land and machinery combinations are organized to provide minimum unit costs of crop production.

How many of the farms in the study area have the resource combinations necessary to attain the cost economies available in crop production? At least 160 crop acres and a 2-man, 2-tractor combination are required to attain constant unit crop production cost without custom operations, and at least 120 crop acres, a 1-man, 1-tractor combination and $731 or more of custom work are required to achieve constant unit cost with custom operations. Less than 50 percent of the farms in the study area have 160 acres of cropland and sufficient labor and machinery for a 2-man, 2-tractor machinery combination. Approximately half the farms in the study area do not have sufficient cropland to attain constant per-unit crop production costs even when custom operations are considered. Thus, the budgeting results indicate that the resource combinations on many farms in the study area must be enlarged to attain the major cost economies possible in crop production with currently available machine technology.

Increases in the acres of land and cropland per farm generally cause a reduction in the number of farms within an area. Hence, the budgeting results also suggest that attempts by farmers to reduce unit crop production costs will probably lead to a continued future reduction in farm numbers within the study area. Large changes in farm numbers and size within a relatively short time could cause land prices and rents within the study area to increase. Changes in relative factor prices affect, not only the optimum plans for individual farms, but also the agricultural structure derived from these plans. Hence, the present analysis should be extended to determine the effects of aggregate adjustments within an area upon individual farm adjustments.

products sold per farm in south-central Iowa is further evidence of the area's farm income problem. About 85 percent of all farms in Iowa had agricultural product sales of $2,500 or more in 1959 (table 2). Only 70.5 percent of the farms in south-central Iowa had agricultural product sales of $2,500 or more in the same year. Relatively few farms in the study area have a large sales volume. In 1959, 44.6 and 17.1 percent of the farms in Iowa had agricultural product sales of $10,000 or more and $20,000 or more, respectively. Only 19.2 and 4.5 percent of the farms in the study area had agricultural product sales in these two categories.

Table 2. Percentage distribution of farms by class for Iowa and south-central Iowa, 1959.[a]

Class	Annual sales of agricultural products	South-central Iowa	Iowa
I	$40,000 or more	1.0	4.7
II	20,000 to 39,999	3.5	12.4
III	10,000 to 19,999	14.7	27.5
IV	5,000 to 9,999	27.8	27.1
V	2,500 to 4,999	23.5	13.5
VI	50 to 2,499	7.4	3.2
VII	Part-time[b]	11.8	6.7
VIII	Part-retirement[c]	10.3	4.9
All		100.0	100.0

[a]A farm is defined as a place (a) of 10 acres or more if the estimated annual sale of agricultural products was $50 or more or (b) of less than 10 acres if the estimated annual sale of agricultural products was $250 or more. Source: U. S. Census of Agriculture: 1959. Counties, Vol. 1, Part 16. 1961.
[b]Operator under 65 years of age, and working off farm 100 or more days or with income from other sources greater than annual sales of agricultural products, and annual sales of agricultural products of $50 to $2,499.
[c]Operator 65 years old or over and annual sales of agricultural products of $50 to $2,499.

Farm reorganization has proceeded more rapidly in south-central Iowa than in other areas of the state. From 1928 to 1959, the average acreage per farm in the area increased about 30 percent (table 3). During the same period, the average acreage per farm in Iowa increased at a rate only half as great. Farm population in the study area declined rapidly as farm size increased. From 1948 to 1957, the number of people on farms in the study area decreased by 14.5 percent.[3] The value of land and capital inputs per farm worker in south-central Iowa has increased substantially as farm employment has declined.[4] However, labor inputs form a larger proportion of total inputs in the study area than in other areas within the state.[5]

Table 3. Average acreage per farm in Iowa and south-central Iowa for selected years.[a]

Year	Iowa	South-central Iowa
1928	162	162
1938	164	167
1948	172	183
1958	185	202
1960	192	211

[a]Source: Iowa Department of Agriculture. Annual farm census. 1928 through 1960.

Even with the farm reorganization that has already occurred in south-central Iowa, the relatively low income, the small sales per farm and the existing input combination indicate that further adjustments are needed to improve farm income. The adjustment problems are difficult since there are relatively few nonfarm employment opportunities in the study area.[6] As suggested previously, the agricultural adjustment problems in south-central Iowa are not unique, but they are more severe than in other areas in Iowa.

Soil Association Areas

Initially, this study was outlined to cover two major soil association areas in south-central Iowa, the Shelby-Grundy-Haig soil association area and the Shelby-Seymour-Edina soil association area. The first soil association area comprises most of Ringgold and Clarke counties and portions of Union, Decatur, Lucas and Monroe counties. The second soil association area includes most of Wayne and Appanoose counties and part of Davis County.

The physiography of the Shelby-Grundy-Haig and Shelby-Seymour-Edina soil association areas is quite similar. In each soil association area, there are now three rather distinct topographic divisions: (a) level to undulating upland, (b) irregular areas of rolling to hilly land along streams and drainageways and (c) narrow strips of level bottomland bordering the streams.[7] Although the second

[3]Iowa Department of Agriculture. Annual farm census. 1928 through 1960.

[4]M. W. Trautwein. Differential rates of resource adjustment within Iowa agriculture, 1940 to 1954. Unpublished M.S. thesis. Iowa State University Library, Ames, Iowa. 1958.

[5]Robert Allen Ausenhus. Productivity and income of Iowa farms. Unpublished M.S. thesis. Iowa State University Library, Ames, Iowa. 1959; James A. Seagraves. Productivity of agricultural resources in Iowa from 1950 census data. Unpublished M.S. thesis. Iowa State University Library, Ames, Iowa. 1952.

[6]Clark C. Bloom and Clifford M. Baumback. Nonagricultural industries and businesses in southern Iowa. In, Seminar on adjustment and its problems in southern Iowa. Center for Agricultural and Economic Adjustment Report 4. Iowa State University of Science and Technology. 1959. Pages 47-66. (Mimeo.)

[7]Roy W. Simonson, F. F. Riecken and Guy D. Smith. Understanding Iowa soils. Wm. C. Brown Company, Dubuque, Iowa. 1952.

topographic division is the largest, a combination of all three topographic divisions, in varying proportions, is found on almost every farm.

The heterogeneous topography in each soil association area makes the analysis of farming alternatives in the study area more difficult. The organization of a farm, especially the cropping plan, is affected by the topography of the soil mixture. It is impossible to analyze the farming alternatives for all the topography-soil mixture combinations in the study area. Consequently, three specific soil mixtures in each soil association area were considered for analysis. However, the analysis of this study is limited to three farm situations on Shelby-Grundy-Haig soils alone.

Soil Mixtures and Definitions of Farms

The selection procedure and the soil mixtures selected are described in Appendix A. In subsequent discussions, the three soil mixtures will be referred to as (a) the hilly mixture or hilly farm, (b) the average mixture or average farm and (c) the upland mixture or upland farm. The "hilly farm" consists primarily of rolling to hilly upland, with smaller amounts of bottomland and level to undulating upland. The "upland farm" is composed predominantly of level to undulating upland, with lesser amounts of bottomland and rolling to hilly land. Finally, the "average farm" consists largely of rolling upland, with smaller amounts of hilly and level upland. The land-use constraints assumed and the crop rotations considered for each farm are presented in Appendix A.

METHOD OF ANALYSIS

This section is concerned with the economic models used to achieve the objectives of the study. The major objective in this report is concerned with cost economies of crop production for different machinery sizes and acreages. Budgeting models or procedures are developed to provide estimates of short-run average cost curves for each machinery size. Long-run average cost curves or envelope curves also are derived. These curves are estimated to determine the size of farms necessary on specific soil types to realize the major unit cost and income advantages of modern machine technology and to provide more favorable family income in south-central Iowa.

Two budgeting models are considered in this study and are applied to the three types of farms in the Shelby-Grundy-Haig soil area. Preliminary calculations indicated that application of the budgeting models to the three farm types in the Shelby-Seymour-Edina soil area would produce relatively little change in the results obtained for the Shelby-Grundy-Haig soil area.

Budgeting Model I

In this model, budgets are constructed for a series of land-labor-machinery combinations. Several simplifying assumptions are made in the construction of the budgets: (1) The farm operator can acquire control over only one soil mixture at a given time. (2) One specific crop plan is considered for each farm. This crop plan consists of the most intensive crop rotations recommended under existing soil conservation standards. Only one level of fertilizer use is considered. (3) The farm operator possesses a high level of efficiency. The input-output coefficients used are numerical expressions of the efficiency level assumed. (4) The farm operator pays current market prices for all inputs not produced on the farm. The farmer can sell corn for $1 per bushel (a consideration relaxed in subsequent analyses in this report). Long-run average price relationships between corn, other farm products and farm-produced inputs are used to adjust the prices of other farm products and farm-produced inputs to a $1 corn price level. (Hence, the final results depend more on normal, or historic, price relationships than on a $1 corn price.) (5) The ratio of tractor operators to tractors is fixed; i.e., one man to one tractor and two men to two tractors. However, seasonal labor is available for haying and other operations. (6) A specific annual distribution of time available for field operations in the study area was based on the time distribution, adjusted to climatic differences, used by McKee.[8] (7) As the ratio of land to labor and machinery increases, the total hours required to perform a given field operation increase. A farmer with a fixed amount of labor and machinery has two alternatives as his acreage increases. He can allow some land to lie idle, or he can continue to perform all field operations on all land. Only the latter alternative is considered in this study. (8) All machines in a given machinery combination are owned, with these exceptions: The corn sheller is hired on a custom basis, and, for the hilly farm, the machinery ownership assumption is relaxed to allow custom operations for the 2-plow and 3-plow machinery combinations.

Field operations can reduce yields in two ways. A field operation may be accomplished

[8] Dean E. McKee. Scale associated with decreasing and increasing costs in cash grain farming. Unpublished M.S. thesis. Iowa State University Library, Ames, Iowa. 1953.

during the optimum time period—but be executed improperly or inadequately such that yields are reduced. Examples, such as those resulting from improper machine adjustments, are numerous. In this study, proper execution of field operations is considered a function of a farmer's efficiency level. Consequently, how adequately the field operations are performed is already reflected in the yields used. Field operations that are executed properly but are performed either too early or too late also reduce yields.

On the basis of existing agronomic data, optimum or no-loss time periods are derived for each crop's major field operations. In this study, it is assumed that a given field operation cannot begin early but can continue after the no-loss time period has passed; i.e., it can be late. Hence, yield-loss functions are derived only for late field operations.

Different combinations and sizes of machinery can perform a given field operation. Five machinery combinations are considered in this study. The size of the machinery combination is indicated by the size of the moldboard plow that a tractor can pull under average field conditions. The machinery combinations, and corresponding tractor units, considered are:

1. 2-plow
2. 3-plow
3. 2-plow, 2-plow
4. 2-plow, 3-plow
5. 3-plow, 3-plow.[9]

Given a land mixture, a cropping plan and a labor-machinery combination, a series of budgets is constructed with increasing amounts of land for each machinery combination. The minimum farm size considered is 40 acres, and farm size is assumed to increase in increments of 40 acres. Yields, total production, total cost and total revenue are calculated for each acreage or farm size for a given combination of machinery.

Total cost is divided into two components, fixed and variable costs. Total fixed cost consists of machinery depreciation, interest, taxes, housing and insurance costs. Total variable cost consists of expenditures for seeds and insecticides, fertilizer, machinery fuel and oil, machinery repair, machinery depreciation caused by more than normal use, land, labor and corn shelling. Total revenue consists of income from crop sales (corn, soybeans, oats and hay).

A short-run average cost curve for each of the five machinery combinations is derived from the budgets. The long-run cost or envelope curve for the five short-run average cost curves on each farm is derived similarly.

Budgeting Model II

In model I, all crops except permanent pasture are sold and contribute to the farm's total revenue; an increase in permanent pasture acreage increases total cost but does not affect total revenue in model I. (Permanent pasture must go with cropland in land purchases or rentals, and, hence, its costs are necessarily linked with that of cropland quantities.) In model II, permanent pasture contributes to both total cost and total revenue. This contribution by permanent pasture to total revenue is the basic difference between the two models. Consideration of revenue from pasture provides a more realistic situation in comparision of unit costs with revenue but, as shown later, has little effect on the shape of the cost curves.

In the study area, there are three alternative ways for a farmer to obtain revenue from his permanent pasture. First, the pasture can be used to produce grass seed. Second, the permanent pasture can be rented to another farmer. Third, the pasture can be used to produce feed for the farmer's own livestock enterprises. Only the third alternative is considered in this model. It is assumed that the farmer has a beef-cow herd producing feeder calves. The beef-cow enterprise uses all available permanent pasture.

DATA

The data used in the budgeting analysis are presented and discussed in this section. Pertinent basic data are presented in the two appendixes.

Summaries of the three soil mixtures on farms selected are presented in table 4. The rotations associated with each farm are presented in table 5. The proportion of row crops in each rotation is the highest recommended under existing soil conservation standards. It is assumed that terraces and contour cultivation are used when needed and that some of the cropland on each farm is devoted to grass waterways. For the hilly, average and upland farms, respectively, 5, 6 and 7 percent of the cropland is required for waterways.[10] Consequently, 136.67, 72.07 and 56.67 acres of the hilly, average and upland land mixtures, respectively, are needed to obtain 40 acres of cropland.

[9] The last three machinery combinations include two tractors.

[10] Estimates based on: F. W. Schaller, K. K. Barnes, W. D. Shrader, J. M. Scholl and A. L. McComb. Land use and crop production potentials and alternatives. In, Seminar on adjustment and its problems in southern Iowa. Center for Agricultural and Economic Adjustment Report 4. Iowa State University of Science and Technology. 1959. Pages 151-178. (Mimeo.)

Table 4. Percentages of land classes for the hilly, average and upland farms.[a]

Land class	Hilly farm	Average farm	Upland farm
Cropland A	32.42	40.23	74.31
Cropland B[b]	---	18.81	---
Permanent pasture	45.23	37.81	22.54
Forest land	17.26	---	---
Gullies	1.94	---	---
Roads, farmstead, etc.	3.15	3.15	3.15

[a] Soils for each of these farm situations are described in greater detail in Appendix A.
[b] Cropland B consists of soils that cannot support rotations containing as high a proportion of row crops as cropland A if annual soil losses are to be maintained at 4 tons or less per acre.

The high level of efficiency assumed results in yields approaching the economic maximum that farmers in the study area can presently attain (table 5). The fertilization rates assumed are the rates believed necessary to raise the soil fertility level specified in average soil tests to the level needed to produce the yields assumed under high-efficiency conditions.

Table 5. Estimated average crop and permanent pasture yields[a] for selected rotations[b] and farms.

Farm, cropland and rotation	Yields[c]						
	First-year corn	Second-year corn	Soybeans	Oats	First-year meadow	Second-year meadow	Unimproved permanent pasture
Hilly farm							1.14
Cropland A CCOMM	48.1	48.1	---	34.6	2.0	2.0	
Average farm							1.03
Cropland A CCOM	58.3	58.3	---	37.2	2.1	---	
Cropland B CCOMM	42.3	42.3	---	39.0	1.6	1.6	
Upland farm							0.85
Cropland A CCSb	59.3	59.3	25.6	---	---	---	

[a] Estimated fertilizer nutrient requirements for each crop are presented in tables B-4, B-5 and B-6, Appendix B.
[b] C, Sb, O and M represent corn, soybeans, oats and meadow, respectively.
[c] Yields for corn, oats and soybeans are given in bushels; meadow and pasture yields are in tons.

The hours available by selected periods for specific field operations are presented in table 6. It is assumed that certain field operations must be performed during optimum or no-loss time periods to achieve the yields presented in table 5. The no-loss time periods were derived from county extension directors' estimates of the beginning date for each field operation and from data on yield losses. Crop yield-loss functions for specific field operations are presented in table 7.

Table 6. Estimated average number of hours available by no-loss periods for specific field operations.

Period	Hours available	Field operation
March 8-25	32.5	
March 26-April 8	78.7	Oats seeding
April 9-May 2	161.9	
May 3-11	57.5	Corn planting
May 12-23	81.2	Soybean planting
May 24-26	21.3	
May 27-29	21.3	Corn hoeing
May 30-June 1	19.8	
June 2-8	45.0	Soybean cultivation
June 9-12	26.5	Hay cutting
June 13	6.6	
June 14-20	46.3	Corn cultivation
June 21-27	48.2	Soybean cultivation
June 28-30	22.3	
July 1-7	53.6	Corn cultivation
July 8-9	15.8	
July 10-14	32.8	Oats harvest
July 15-21	53.7	Hay cutting
July 22-Aug. 17	216.7	
Aug. 20-28	68.6	Hay cutting
Aug. 29-Oct. 2	269.6	
Oct. 3-7	37.4	Soybean harvest
Oct. 8-20	100.4	
Oct. 21-27	55.5	Corn harvest
Oct. 28-Dec. 26	317.7	
Total	1,896.9	

Five machinery combinations are considered in the two budgeting models.[11] The time required to perform the field operation per acre of cropland depends upon the effective capacity of the machinery combination, the crops included in the rotation and the sequences of operations assumed. Tables 8, 9 and 10 indicate the estimated hours required by each machinery combination to perform certain groups of field operations on the hilly, average and upland farms.

Total variable cost for the first 40 acres of cropland by farm and machinery combination is presented in table 11. Annual repair and service cost for each machine is calculated as a percentage of retail price. Then the annual repair and service cost is divided by normal

[11] See tables B-8 through B-12 for a list of the machines included in each machinery combination.

Table 7. Estimated average crop losses per acre from untimely field operations.

Field operations	Date losses begin	Crop losses per acre per day late	
1. Oats seeding[a]	April 9	First 21 days	1.00 bu.
		Remaining days	2.00 bu.
2. Corn planting[b]	May 12	First 16 days	0.40 bu.
		Next 14 days	0.84 bu.
		Remaining days	1.40 bu.
3. Soybean planting[c]	May 24		0.45 bu.
4. Corn hoeing[d]	May 30		0.50 bu.
5. Corn cultivation[d]			
First	June 21		0.25 bu.
Second	July 8		0.25 bu.
6. Soybean cultivation[e]			
First	June 9		0.50 bu.
Second	June 28		0.25 bu.
7. Hay harvesting[f]			
First	June 13		2.9%
Second	July 22		1.7%
Third	Aug. 29		1.3%
8. Oats harvesting[g]	July 15		1.3%
9. Soybean harvesting[g]	Oct. 8		1.3%
10. Corn harvesting[g]	Oct. 28		0.6%

[a] S. C. Wiggans and K. J. Frey. Your oats—how early—what rate? Iowa Farm Science 11:468-470. 1957.

[b] Ronald Dean Krenz. Farm size and cost in relation to farm machinery technology. Unpublished Ph.D. thesis. Iowa State University Library, Ames, Iowa. 1959.

[c] C. R. Weber. Guide to higher soybean yields. Iowa Coop. Ext. Serv. Pamph. 202. 1953.

[d] Krenz, **op. cit.**

[e] Same as corn cultivation losses.

[f] Based on: J. R. Dawson. Yield, composition and feeding value for milk production of alfalfa hay cut at three stages of maturity. U. S. Dept. Agr. Tech. Bul. 739. 1940.

[g] Based on: David Alan Link. Farm machinery selection from system economics. Unpublished M.S. thesis. Iowa State University Library, Ames, Iowa. 1958.

annual use to obtain repair and service cost per service unit.[12]

Fuel and oil costs for each field operation and seed, insecticide and fertilizer costs were derived in detail for each farm situation. Land rents per acre consist of interest and taxes. In calculating labor costs, wage rates of $1.35 an hour for operator and regular hired labor and $1 an hour for seasonal haying labor are assumed.

Custom corn shelling is assumed for every machinery combination and farm size. The custom corn-shelling cost is $0.03 a bushel.

[12] A service unit is an hour for a tractor and an acre for other machines.

Table 8. HILLY FARM: hours per 40 acres of cropland required by selected machinery combinations to perform specific field operations.[a]

Field operations	Machinery combinations				
	2-plow	3-plow	2-plow, 2-plow	2-plow, 3-plow	3-plow, 3-plow
Oats seeding[b]	13.20	10.96	6.60	5.68	5.48
Spring plowing[c]	33.04	23.84	16.52	13.44	11.92
Corn planting[d]	21.68	15.20	10.84	7.98	7.60
Corn harrowing	2.24	1.92	1.12	1.04	0.96
Corn hoeing	4.32	2.40	2.16	1.54	1.20
Corn cultivation					
First	7.68	4.16	3.84	2.69	2.08
Second	5.44	2.88	2.72	1.89	1.44
Hay harvest[e]					
First	33.28	33.28	16.64	16.64	16.64
Second	33.28	33.28	16.64	16.64	16.64
Third	33.28	33.28	16.64	16.64	16.64
Oats harvest[e]	11.36	9.44	5.68	4.72	4.72
Corn harvest[e]	40.00	21.44	20.00	10.72	10.72
Total	238.80	192.08	119.40	99.62	96.04

[a] Derived from: Kenneth K. Barnes. Ames, Iowa. Estimated effective capacity in hours per acre for performing selected field operations. (Private communication.) 1959.

[b] Includes seedbed preparation and seeding of legumes.

[c] Includes fertilizer spreading and disking cornstalks for corn and soybeans following corn.

[d] Includes seedbed preparation.

[e] Includes hauling.

Other custom operations also are considered for the 2-plow and 3-plow machinery combinations on the hilly farm. Custom combining and picking costs of $4.30 and $4.15 an acre, respectively, and custom bailing costs of $0.11 a bale are assumed.[13]

Machinery depreciation is considered as both a fixed and a variable cost in this study.[14] Normal annual machine use is assumed to result in a fixed annual depreciation cost for each machine. Machine use beyond normal use increases the annual depreciation cost. Variable depreciation cost per service unit for each machine was calculated in accumulating total depreciation for each machine combination.

The annual fixed costs for each machinery combination are presented in table 12. Minimum annual depreciation for each machine

[13] Ray E. Armstrong. Farm custom rate guide for 1959. Iowa Farm Science 13:159-160. 1959.

[14] For a discussion of machinery depreciation as a fixed and variable cost see: S. M. Aijan Husain. Cost relationships in farm machinery use. Unpublished M.S. thesis. Iowa State University Library, Ames, Iowa. 1949.

Table 9. **AVERAGE FARM:** hours per 40 acres of cropland required by selected machinery combinations to perform specific field operations.[a]

Field operations	2-plow	3-plow	2-plow, 2-plow	2-plow, 3-plow	3-plow, 3-plow
	Machinery combinations				
Oats seeding[b]	15.46	12.84	7.73	6.65	6.42
Spring plowing[c]	38.70	27.92	19.35	15.74	13.96
Corn planting[d]	25.39	17.80	12.70	11.25	8.90
Corn harrowing	2.62	2.25	1.31	1.22	1.12
Corn hoeing	5.06	2.81	2.53	1.80	1.40
Corn cultivation					
First	9.00	4.87	4.50	3.14	2.44
Second	6.37	3.37	3.18	2.22	1.68
Hay harvest[e]					
First	24.79	24.79	12.40	12.40	12.40
Second	24.79	24.79	12.40	12.40	12.40
Third	24.79	24.79	12.40	12.40	12.40
Oats harvest[e]	13.31	11.06	6.65	5.53	5.53
Corn harvest[e]	46.85	25.11	23.42	12.56	12.56
Total	237.13	182.40	118.47	97.31	91.21

[a] Derived from: Barnes, **op. cit.**

[b] Includes seedbed preparation and seeding of legumes.

[c] Includes fertilizer spreading and disking cornstalks for corn and soybeans following corn.

[d] Includes seedbed preparation.

[e] Includes hauling.

Table 10. **UPLAND FARM:** hours per 40 acres of cropland required by selected machinery combinations to perform specific field operations.[a]

Field operations	2-plow	3-plow	2-plow, 2-plow	2-plow, 3-plow	3-plow, 3-plow
	Machinery combinations				
Spring plowing[b]	86.11	62.26	43.06	35.20	31.13
Corn planting[c]	36.12	25.33	18.06	13.29	12.66
Soybean planting[c]	21.59	15.33	10.80	8.13	7.66
Corn harrowing	3.73	3.20	1.86	1.70	1.60
Soybean harrowing	1.87	1.60	0.94	0.85	0.80
Corn hoeing	7.20	4.00	3.60	2.56	2.00
Soybean cultivation					
First	6.40	3.47	3.20	2.24	1.74
Second	4.53	2.40	2.26	1.57	1.20
Corn cultivation					
First	12.80	6.94	6.40	4.48	3.47
Second	9.06	4.80	4.53	3.14	2.40
Soybean harvest[d]	18.93	15.73	9.46	7.86	7.86
Corn harvest[d]	66.65	35.72	33.32	17.86	17.86
Total	274.99	180.78	137.49	98.88	90.38

[a] Derived from: Barnes, **op. cit.**

[b] Includes fertilizer spreading and disking cornstalks for corn and soybeans following corn.

[c] Includes seedbed preparation.

[d] Includes hauling.

Table 11. **Variable costs for the first 40 acres of cropland by machinery combination and farm.**

Machinery combination	Machine repair	Fuel and oil	Feed, insecticide and fertilizer	Land rent	Custom corn shelling	Labor[a]	Total[b]
Hilly farm							
2-plow	$129.24	$ 96.02	$371.88	$620.90	$23.09	$386.70	$1,627.83
3-plow	126.64	84.60	371.88	620.90	23.09	323.63	1,550.74
2-plow, 2-plow	129.24	96.02	371.88	620.90	23.09	386.70	1,627.83
2-plow, 3-plow	122.25	86.07	371.88	620.90	23.09	333.30	1,557.49
3-plow, 3-plow	126.64	84.60	371.88	620.90	23.09	323.62	1,550.73
Average farm							
2-plow	125.05	93.78	412.57	616.20	30.13	368.05	1,645.78
3-plow	119.89	81.65	412.57	616.20	30.13	294.16	1,554.60
2-plow, 2-plow	125.05	93.78	412.57	616.20	30.13	367.78	1,645.51
2-plow, 3-plow	116.05	83.38	412.57	616.20	30.13	310.88	1,569.21
3-plow, 3-plow	119.89	81.65	412.57	616.20	30.13	294.18	1,554.62
Upland farm							
2-plow	127.54	103.73	413.60	817.75	47.42	371.24	1,881.28
3-plow	113.41	87.19	413.60	817.75	47.42	244.05	1,723.42
2-plow, 2-plow	127.54	103.73	413.60	817.75	47.42	371.22	1,881.26
2-plow, 3-plow	110.53	91.44	413.60	817.75	47.42	266.98	1,747.72
3-plow, 3-plow	113.41	87.19	413.60	817.75	47.42	244.02	1,723.39

[a] Wage rates are $1.35 per hour for operator and regular hired labor and $1 per hour for seasonal hay harvesting labor.

[b] Does not include variable depreciation cost or the cost for the beef-cow enterprise.

Table 12. Annual fixed machinery costs by machinery combinations.[a]

Machinery combinations	Minimum annual depreciation	Interest	Taxes, housing and insurance	Total
2-plow.	$1,107	$477	$270	$1,854
3-plow.	1,245	568	321	2,134
2-plow, 2-plow . . .	1,392	637	362	2,391
2-plow, 3-plow . . .	1,530	728	413	2,671
3-plow, 3-plow . . .	1,636	786	445	2,867

[a] The fixed costs in this table are for the hilly and average farms. The hay baler and rake are not included in the machinery combinations for the upland farm. Hence, the annual fixed costs for the five machinery combinations on the upland farm are $1,368, $1,707, $1,905, $2,244 and $2,440.

is calculated as retail price, minus salvage value, divided by estimated life in years. Salvage value for each machine is assumed to be 10 percent of its retail price. Machinery interest costs are based on average machinery values and an interest rate of 6.8 percent. The estimated tax cost for each machine is 1.1 percent of its retail price. This tax charge is based on a tax rate of 68.54 mills and an assessment rate of 30 percent of average value. Housing and insurance costs are calculated as 0.75 and 0.25 percent of retail price, respectively.[15]

BUDGETING RESULTS

This section contains the results for budgeting models I and II. Average total cost curves for each of the five machinery combinations are derived for each land mixture. The long-run average cost curve for each land mixture also is presented. This section includes a discussion of the effects of including land rent in the estimates of total cost. Estimates of product and factor prices that equate total revenue and total cost also are presented. Finally, the results for the budgeting models are summarized and compared with the factor combinations that exist in the study area.

Model I

The results for model I on the average, hilly and upland farms follow. Custom operations are considered only on the average farm.

Average farm

For this model, total variable cost increases at a nearly constant rate as acreage increases. Hence, average variable cost per acre is a constant. Total fixed cost consists of certain machinery costs that remain unchanged as acreage varies. Thus, average fixed cost per acre declines continuously as acreage increases. Since average total cost per acre is the sum of average variable and average fixed cost, the former also declines continuously as acreage increases.

Short-run average total cost per acre. Average total cost curves per acre (per unit of land input) for the five machinery combinations on the average farm are presented in fig. 1.

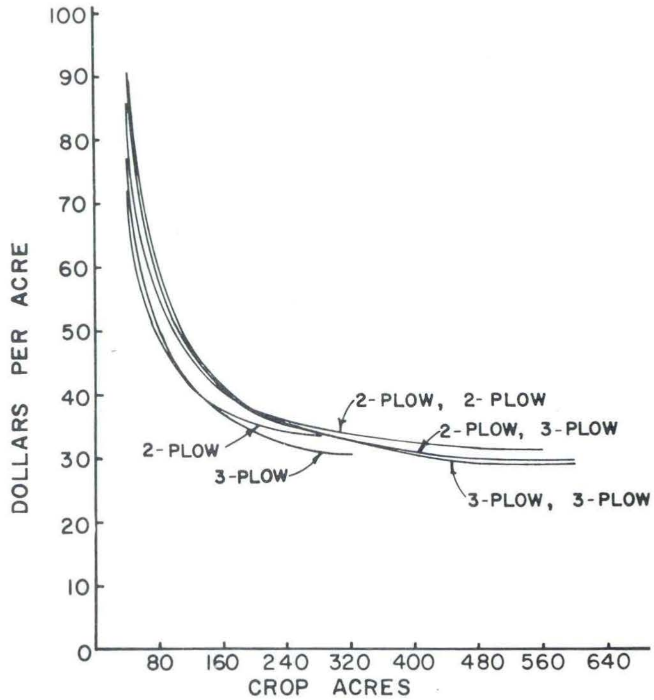

Fig. 1. Average total cost per crop acre with no crop losses for selected machinery combinations on the average farm.

These cost curves indicate that average total cost per crop acre declines sharply as crop acres increase, but cost reductions for farms with 320 or more crop acres are negligible. Although the term average total cost per acre is used here, land costs are not considered. The omission of a land charge from the total cost neither greatly alters the shapes nor materially affects the relative positions of the cost curves. Consequently, land costs are not considered in the derivation of cost curves in this section.

Total cost per unit is usually considered as a function of the quantity of output (cost per unit of product) in the conventional construction of cost curves.[16] Fixed cost per unit of output falls steadily as output increases. Variable cost per unit of output declines initially as output increases and then increases as diminishing returns occur. Hence, the average total cost curve per unit of output typically passes through stages of decreasing, constant and increasing

[15] Leo M. Hoover. Farm machinery—to buy or not to buy. Kan. Agr. Exp. Sta. Bul. 379. 1956.

[16] James M. Henderson and Richard E. Quandt. Micro-economic theory. McGraw-Hill Book Co., Inc., New York. 1958.

cost. However, as in fig. 1, cost curves for farm machinery are often plotted against acres rather than output. Output and total revenue are not considered in the construction of such cost curves, or it is implicitly assumed that output and revenue per acre are constant.

Figure 2 indicates that output and total

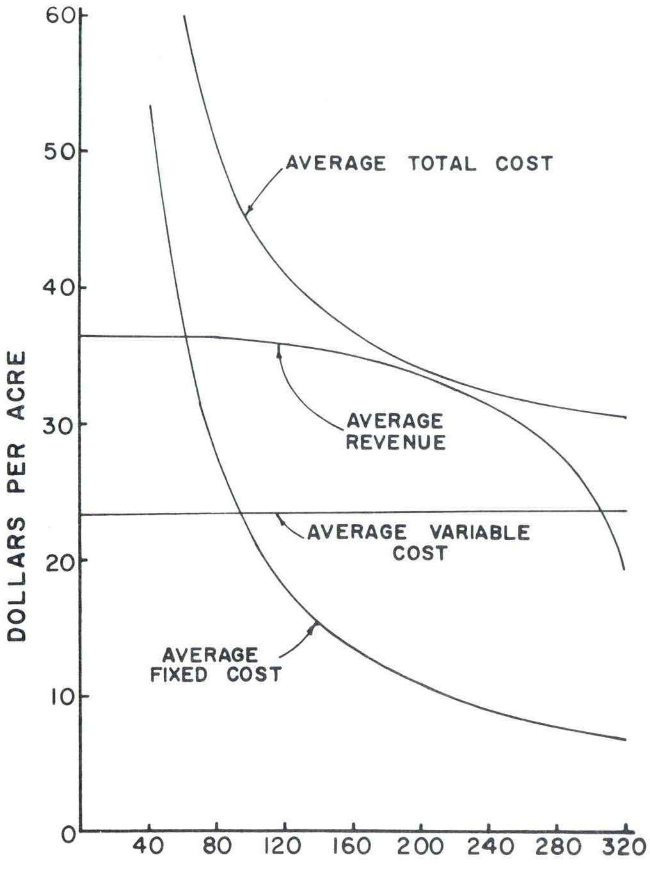

Fig. 2. Average costs and revenue per crop acre for the 3-plow machinery combination on the average farm.

revenue per crop acre are not constant when the size of machinery is fixed. Since crop operations become untimely as acreage increases, yields and average revenue per acre decline sharply as crop acres increase. Consequently, fig. 1 presents only a portion of the desired information; i.e., the relationship between acreage and cost per acre. A method for presenting all three of the important variables (cost, output or revenue and acreage) in one figure is needed. The method used in this study is to present the ratio of average total cost to average revenue on the vertical axis and acreage on the horizontal axis. Cost curves of this type are presented and discussed later.

Short-run average total cost per dollar of crop product. Figure 3 contains the average total cost curves for the five machinery combinations on the average farm when crop losses

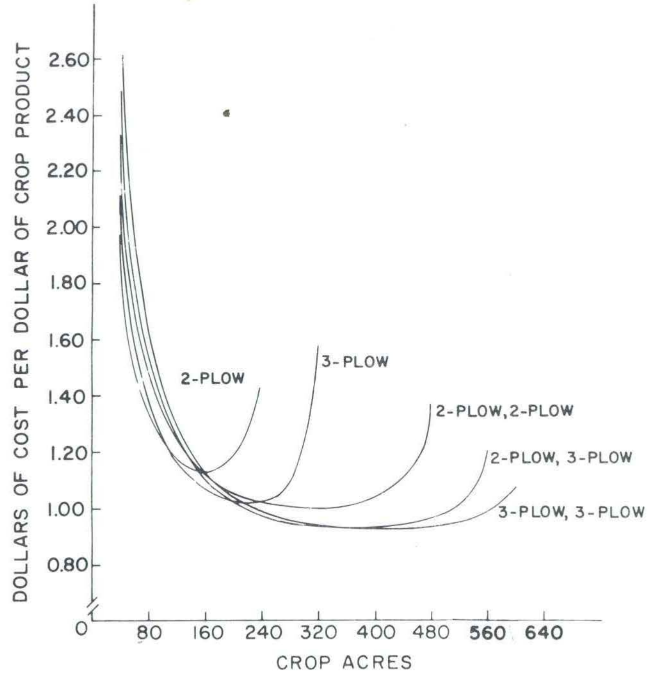

Fig. 3. Average total cost per dollar of crop product by farm size for selected machinery combinations on the average farm.

are considered. The cost curves in fig. 3 and fig. 1 differ considerably in shape and relative position. All curves in fig. 3 pass through three stages of average total per-unit costs— decreasing, constant and increasing. The curves in fig. 1 pass through only the first stage of cost. If crop losses are ignored, the 2-plow, 2-plow and the 2-plow, 3-plow machinery combinations are never the most efficient; i.e., never have the lowest average cost for a given acreage. When crop losses are considered, however, the 2-plow, 3-plow combination has the lowest average cost from 192 to 400 crop acres. The 2-plow, 2-plow combination remains relatively inefficient even when crop losses are considered.

Small machinery combinations are the most efficient for small acreages. For example, the 2-plow combination is the most efficient of the five machinery combinations from 0 to 96 crop acres (table 13). The high average variable cost of the 2-plow combination is more than offset by its low average fixed cost for small acreages. As acreage increases, the 2-plow combination's advantage in fixed cost is canceled by its high variable costs which become a large proportion of total cost. Untimely field operations (hay harvesting, corn cultivation, corn harvesting and corn planting) also cause total revenue to increase at a slower rate as acreage rises. Thus, the 2-plow combination reaches its minimum cost point at 160 crop acres, and cost per unit rises sharply beyond 160 acres.

Table 13. Cost per dollar of crop product for selected machinery combinations on the average farm.

Machinery combination	Range in crop acreage with lowest average cost[a]	Minimum average cost crop acreage	Minimum average cost
2-plow.	0- 96	160	$1.13
3-plow.	96-192	240	1.02
2-plow, 2-plow	---	280-320[b]	1.00
2-plow, 3-plow	192-400	320-400[b]	0.93
3-plow, 3-plow	360-600	360-440[b]	0.93

[a]Acreage range within which this machine combination has lower average costs than any other machine combination.
[b] Although cost is not absolutely constant over this range, rounding cost to the nearest cent results in the same magnitude.

Unit costs exceed $1 for all minimum cost acreages and machine combinations except the last three in table 13. Since costs include a charge for operator and family labor, the results suggest that, for the other combinations and acreages, the operator cannot realize the market rate of return on his labor, although he may still have positive net income. Also, addition of income from livestock using permanent pasture causes costs per dollar unit of output to be less than the stated revenue.

Although the 2-plow combination reaches its minimum cost point at 160 acres, it is not the most efficient combination for that acreage. A farmer with 160 crop acres could reduce his costs by shifting from a 2-plow to a 3-plow combination. The 3-plow combination is the most efficient of the five machinery combinations from 96 to 192 crop acres.

Table 13 indicates the range in crop acres for which the 2 -plow, 3-plow and the 3-plow, 3-plow combinations are the most efficient. The 2-plow, 3-plow combination has lower average fixed costs and higher average variable costs than the 3-plow, 3-plow combination. However, average cost per dollar of crop product for these two machinery combinations differs only slightly between 360 and 440 crop acres. (In whole cents, the cost rounds to the same magnitude over this range.) A farmer with 360 to 440 crop acres could choose either of these two machinery combinations without materially affecting unit cost. For crop acreages greater than 440 acres, however, the yield losses for the 2-plow, 3-plow combination more than offset its fixed cost advantage over the 3-plow, 3-plow combination.

Although the 2-plow and the 3-plow combinations are the most efficient combinations for small acreages, they are high-cost combinations. Minimum unit costs for (a) 80, (b) 160 and (c) 320 crop acres illustrate this point. The (a) 2-plow, (b) 3-plow and (c) 2-plow, 3-plow combinations are the most efficient for these acreages, and unit costs for these acreages and machinery combinations are (a) $1.35, (b) $1.07 and (c) $0.93. Thus, even with the most efficient machinery combination for each, unit costs for 80 and 160 acres are, respectively, 45 and 15 percent greater than for 320 crop acres.

What causes these differences in unit cost? Average variable cost for the (a) 2-plow, (b) 3-plow and (c) 2-plow, 3-plow machinery combinations differs only slightly, but average fixed costs for the 2-plow and 3-plow combinations are 167 and 62 percent greater than for the 2-plow, 3-plow combination; hence, the differences in average total costs. Total fixed cost for the 2-plow, 3-plow machinery combination is greater than for the other two combinations. Low average fixed cost is obtained by spreading the larger total fixed cost over more units of output. Thus, a farmer with 80 or 160 crop acres cannot reduce his unit cost by using a 2-plow, 3-plow machinery combination.

Short-run average total cost with custom operations. No custom operations, other than corn shelling, were considered in deriving the cost curves for fig. 3. Farmers with 2-plow or 3-plow machinery combinations may consider custom operations, but it is difficult to include such operations in the budgeting models. If custom machines are not available to the farmer when he needs them, untimely field operations and yield losses may occur. The availability of custom machines is not easily estimated. To obtain some estimate of the effects of custom operations upon crop production costs, however, custom machines are assumed immediately available to farmers using them.

Custom machinery operations lower unit cost by reducing fixed cost per unit, untimeliness losses, or both, but custom operations also cause average variable cost to rise. Three machines in the 2-plow combination have relatively large total fixed costs. The combine, corn picker and hay baler represent 43 percent of the total investment for the 2-plow combination. If these machines are replaced by custom operations, total fixed cost declines by 50.3 percent. These three machines are also involved in the untimeliness losses for the 2-plow combination. Even for small acreages, untimely haying causes yield losses and delays corn cultivation. There also are some yield losses from untimely corn harvesting. Since these three machines affect both losses and fixed costs, custom combining, hay baling and corn picking are assumed for the 2-plow combination.

Only custom combining and hay baling are assumed for the 3-plow combination. Fixed costs for the combine, corn picker and hay baler represent 45.7 percent of total fixed cost for the 3-plow combination. However, yield losses from untimely corn harvesting are relatively small. Hence, custom corn picking would result in only small reductions in unit cost and is not considered for the 3-plow combination.

The shapes of the average cost curves for the 2-plow and 3-plow combinations with custom operations are remarkably stable (fig. 4). The minimum cost acreages for the two

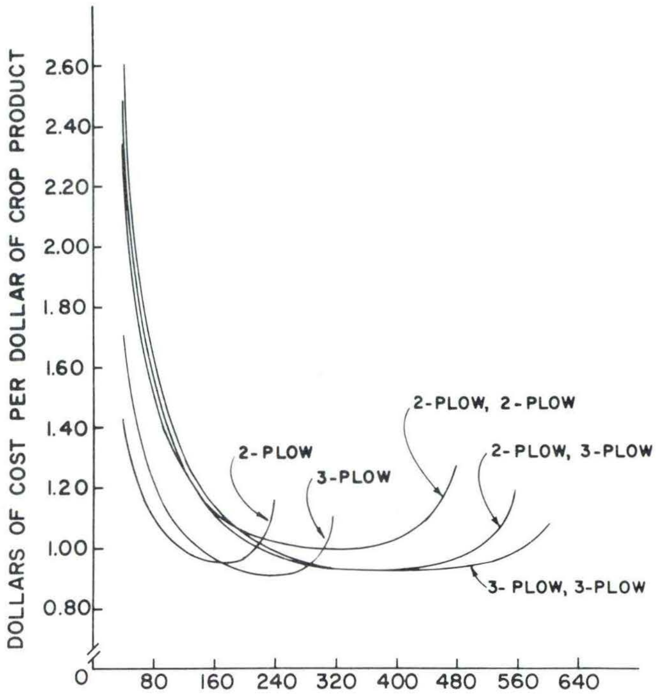

Fig. 4. Average total cost per dollar of crop product by farm size for selected machinery combinations and custom operations on the average farm.

machinery combinations are unchanged at 160 and 240 crop acres (table 14). Minimum average cost is expected to occur at smaller acreages with custom operations because (a) total fixed cost and fixed cost per unit decline and (b) total variable cost and variable cost per unit increase. However, the average variable cost curve pivots, instead of shifting vertically. Custom operations increase variable cost per unit for small acreages but decrease variable cost per unit for large acreages by reducing yield losses from untimely field operations. Hence, custom operations cause the average total curves for the 2-plow and 3-plow combinations to shift vertically but not horizontally.

The relative efficiency of both 1-man, 1-tractor combinations increases tremendously when custom operations are assumed (table 14). The acreage range at which the 2-plow

Table 14. Cost per dollar of crop product for selected machinery combinations and custom operations on the average farm.

Machinery combination	Range in crop acreage with lowest average cost[a]	Minimum average cost crop acreage	Minimum average cost
2-plow, custom	0-168	160	$0.95
3-plow, custom	168-288	240	0.91
2-plow, 2-plow	---	280-320[b]	1.00
2-plow, 3-plow	288-400	320-400[b]	0.93
3-plow, 3-plow	360-600	360-440[b]	0.93

[a] Acreage range within which this machine combination has lower average costs than any other machine combination.

[b] Although cost is not absolutely constant over this range, rounding cost to the nearest cent results in the same magnitude.

and 3-plow combinations are most efficient increases with custom operations. Consequently, the acreage range at which the 2-plow, 3-plow combination has the lowest average cost declines. In addition to increasing the relative efficiency of both the 2-plow and 3-plow combinations, custom operations reduce unit cost for small acreages. Custom operations lower costs for the smaller acreages by reducing fixed cost per unit.

To estimate the effect of custom operations upon cost, custom machines are assumed available whenever needed. However, farmers might sometimes have to wait for custom machines to complete field operations on other farms. Consequently, untimely operations and yield losses might occur. Under such circumstances, the cost curves for both the 2-plow and 3-plow combinations in fig. 4 underestimate unit cost. Since the custom machines are used only for harvesting, some of the yield losses can be reduced by salvaging grain left in the field. Farmers often use their livestock to glean fields, and losses from untimely custom operation may be reduced considerably in this way.

Farmers also can use machinery exchange agreements to spread fixed costs and to reduce cost per unit. However, farmers do not obtain any additional labor during critical time periods with machinery exchange agreements. Consequently, such agreements may lead to larger yield losses and smaller cost reductions than will the custom operations considered.

Long-run average total cost without custom operations. The long-run average cost curve for the average farm without custom operations is presented in fig. 5. This envelope or planning curve provides estimates of the cost economies that can be attained when both acreage and machinery size are considered variable. Although minimum cost is achieved with 320 to 440 crop acres, unit cost varies only 1 percent from 272 to 496 crop acres. Average cost rises rapidly for acreages outside this range.

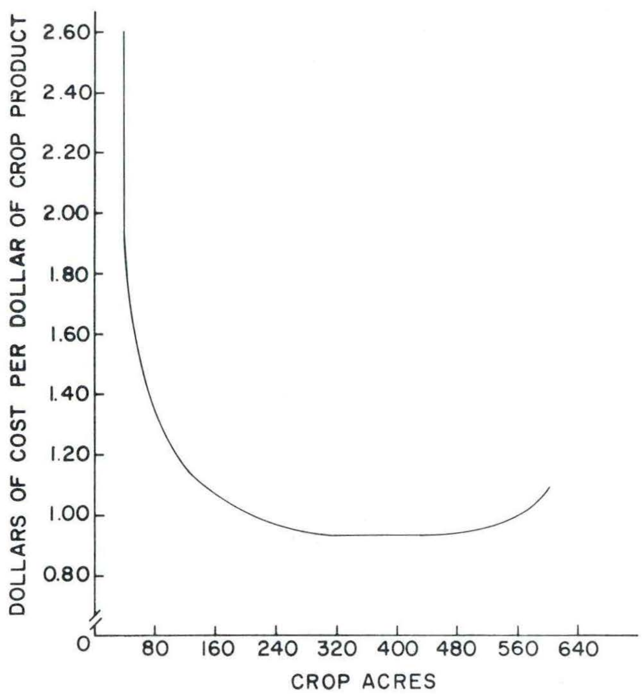

Fig. 5. Long-run average cost curve for crop production on the average farm.

Unit cost on the average farm varies 5 percent or less from minimum cost between 232 to 548 crop acres. Hence, unit cost can be considered approximately constant for this range of cropland acreage. The 2-man, 2-tractor combinations (the 2-plow, 3-plow and the 3-plow, 3-plow combinations) are the most efficient between 232 and 548 crop acres (table 13 and fig. 3). Thus, the long-run average total cost curve in fig. 5 indicates that a 2-man, 2-tractor combination and 232 to 548 acres of cropland are required to achieve the major share of the cost economies available on the average farm without custom operations. Since approximately 1.8 acres of the average soil mixture are required to obtain 1 acre of cropland, 418 to 987 acres of average land are required to obtain 232 to 548 acres of cropland.

Long-run average total cost with custom operations. The envelope curve in fig. 6 indicates the cost economies that can be achieved with custom operations on the average farm when acreage and machine size are considered variable. Custom operations cause the long-run average cost curve to shift left and down

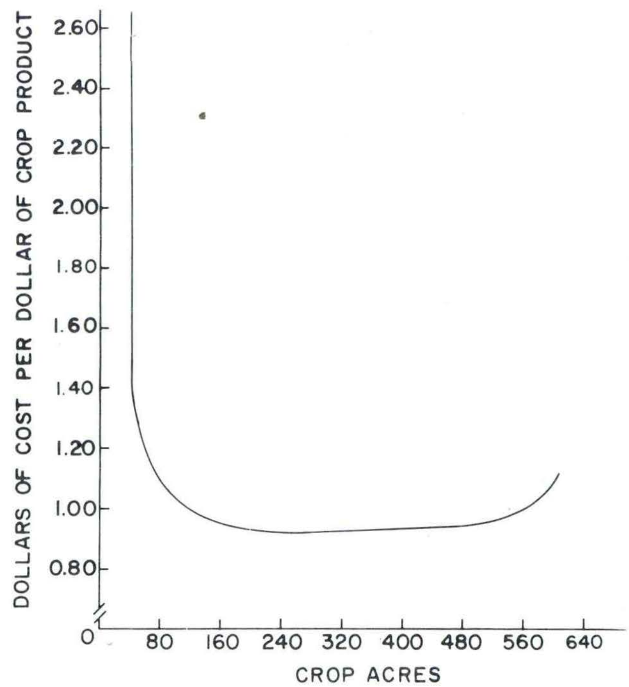

Fig. 6. Long-run average cost curve for crop production with selected custom operations on the average farm.

slightly. The minimum-cost acreage changes from 320-440 crop acres (577-649 total acres) without custom operations to 240 crop acres (432 total acres) with custom operations. Thus, custom operations reduce the acreage required to achieve minimum cost by 25 percent. Unit cost for the minimum-cost acreage also is reduced 2 percent with custom operations.

Unit cost varies 5 percent or less from minimum cost between 152 and 520 crop acres with custom operations and can be considered approximately constant for this range in acreage. Hence, when custom operations are considered, the major share of the cost economies available on the average farm can be achieved with four combinations of land, labor and machinery. They are: (a) the 2-plow machinery combination with $996-$1,100 of custom work and 152-168 acres of cropland, (b) the 3-plow machinery combination with $731-$1,215 of custom work and 168-288 acres of cropland, (c) the 2-plow, 3-plow machinery combination and 288-400 acres of cropland and (d) the 3-plow, 3-plow machinery combination and 360-520 acres of cropland. The first two input combinations are 1-man, 1-tractor combinations, whereas the last two input combinations are 2-man, 2-tractor combinations. Note that custom operations reduce the minimum acreage necessary to achieve constant cost but increase the range in acres for which constant cost is achieved.[17]

[17] The minimum acreage required declines from 232 to 152, and the range in acreage increases from 316 to 386.

Short-run and long-run cost curves for the average farm indicate that most of the cost economies available on the average farm can be achieved with either a 1-man, 1-tractor operation and custom operations on a smaller acreage or a 2-man, 2-tractor operation on a larger acreage. The crop production costs considered apply only to the average land mixture. Crop rotations, yields, field operations and costs change as the land mixture changes.

Hilly farm

The hilly land mixture contains a lower proportion of cropland and a higher proportion of permanent pasture, forest and wasteland than the average land mixture (table 4). Consequently, more acres of hilly land than of average land are required to obtain a given acreage of cropland. The rotation on the hilly farm also has a lower proportion of row crops and a higher proportion of forage and small grain crops (table 5). As the rotation changes, the field operations that are untimely and cause yield losses also change. Untimely hay harvesting and corn cultivation cause the largest yield losses on the hilly farm. However, untimeliness losses per acre per day are smaller on the hilly farm than on the average farm, because yields of the hilly farm are generally lower and untimeliness yield losses are calculated as a proportion of maximum yield.

Short-run average total cost. The cost curves for the five machinery combinations on the hilly farm are presented in fig. 7. The 2-plow and 3-plow machinery combinations are again

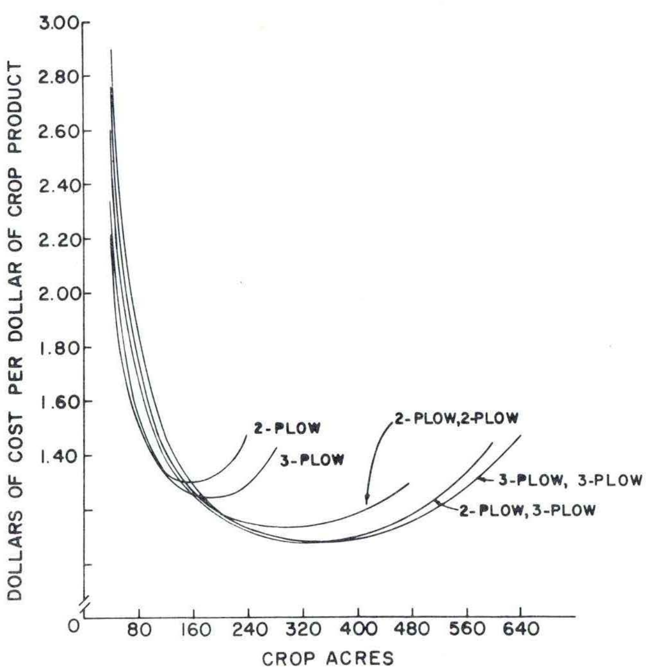

Fig. 7. Average total cost per dollar of crop product by farm size for selected machinery combinations on the hilly farm.

the most efficient machinery combinations for small acreages, while the two larger machinery combinations are the most efficient for larger acreages (table 15). The 2-plow, 2-plow combination remains relatively inefficient except for a very small range in acreage, 156-160 crop acres.

Table 15. Costs per dollar of crop product for selected machinery combinations on the hilly farm.

Machinery combination	Range in crop acreage with lowest average cost[a]	Minimum average cost crop acreage	Minimum average cost
2-plow	0-120	160	$1.30
3-plow	120-156	200	1.24
2-plow, 2-plow	156-160	280-320[b]	1.14
2-plow, 3-plow	160-400	320	1.08
3-plow, 3-plow	340-640	320-360[b]	1.09

[a] Range in crop acreage over which the specified machine combination gives lowest cost per unit.

[b] Although cost is not absolutely constant over this range, rounding cost to the nearest cent results in the same magnitude.

Even though the smaller machinery combinations (the 2-plow, the 3-plow and the 2-plow, 2-plow) are the most efficient for small acreages, they are high-cost combinations relative to larger machinery combinations on larger acreages. These three combinations, together with the 2-plow, 3-plow combination, are the most efficient machinery combinations for 80, 120, 160 and 320 crop acres, respectively. However, minimum unit cost for 80, 120 and 160 crop acres is 69, 21 and 14 percent larger, respectively, than for 320 crop acres. The differences in average total cost result from differences in average fixed cost.

The shapes of the cost curves for the hilly and average farms are similar. With lower yields and proportionately smaller untimeliness losses per acre per day, the cost curves for the hilly farm do not rise as rapidly, after reaching minimum cost, as the curves for the average farm. Hay harvesting and corn cultivation untimeliness losses begin at relatively small acreages on the hilly farm. Since these losses exceed the decline in average fixed cost associated with larger acreages, the hilly farm's cost curves effectively do not attain minimum unit cost for a wide range in acreage.

The relative positions, rather than the shapes, of the cost curves are affected by the changes in land mixtures. The 2-plow and 3-plow combinations have the same hay harvesting capacities. Thus, the efficiency of machinery combinations containing the 2-plow tractor relative to the combinations containing the 3-plow tractor is greater for the hilly farm than for the average farm. The location of the cost curves for the (a) 2-plow, (b) 2-plow, 2-plow and (c) 2-plow, 3-plow combinations is shifted down relative to the location of the curves for the 3-plow and the 3-plow, 3-plow combinations. The cost curves for the (a) 2-plow and (b) 2-plow, 2-plow combinations are shifted vertically, since their minimum cost acreages are the same on the average and hilly farms. The cost curves for the (a) 3-plow, (b) 2-plow, 3-plow and (c) 3-plow, 3-plow combinations are shifted to the left, because the minimum cost acreages for the hilly farm are smaller than for the average farm.

The vertical shifts in cost curves increase the range in crop acreage for which the 2-plow and the 2-plow, 3-plow combinations are most efficient. The change in soil mixtures reduces the range in crop acreage for which the 3-plow combination is most efficient.

Cost per dollar of crop product on the hilly farm is larger than on the average farm for each acreage and for each machinery combination. Minimum average total cost on the hilly farm ranges from 14 to 20 percent higher than on the average farm (tables 13 and 15). What causes these differences in unit cost for the two farms? Total variable crop production cost for 40 crop acres for each machinery combination differs only slightly on the two farms (table 11). Total fixed crop production costs are not affected by changes in soil mixtures (table 12). Consequently, total crop production cost for 40 acres for the two farms is the same.[18] Differences in total revenue for 40 crop acres cause the cost differences per dollar of crop product between the two farms. The hilly farm has lower yields and a smaller grain acreage than the average farm. Hence, with no untimeliness losses, total revenue for 40 crop acres for the hilly farm is 10 percent smaller than for the average farm.

Long-run average total cost. The long-run average cost curve for the hilly farm is presented in fig. 8. Changing from an average to a hilly soil mixture does not reduce the crop acreage required to achieve minimum unit cost but does reduce the range in acreage associated with minimum unit cost. Minimum long-run average cost is achieved at 320 crop acres (1,061 total acres) on the hilly farm versus 320-440 crop acres (577-793 total acres) on the average farm.

Unit cost on the hilly farm varies 5 percent or less from minimum cost between 210 and

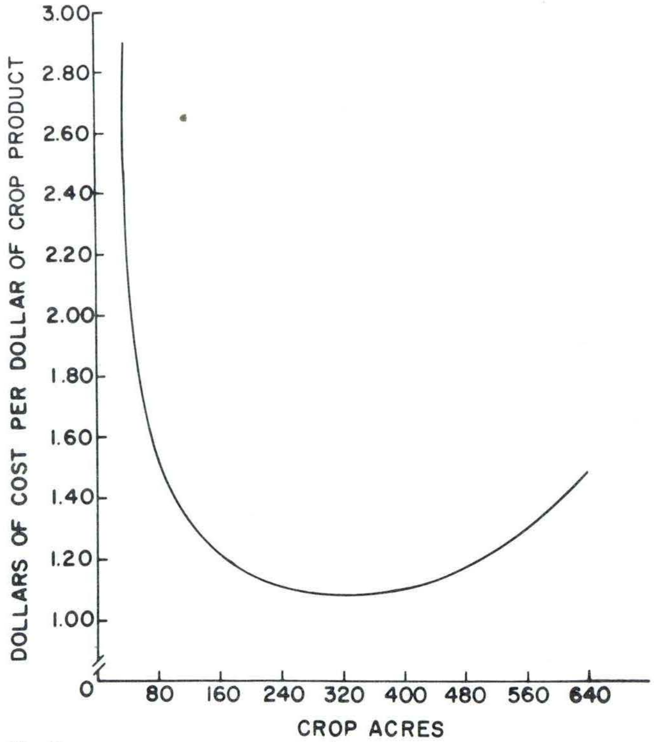

Fig. 8. Long-run average cost curve for crop production on the hilly farm.

456 crop acres (697-1,512 total acres) and can be considered constant for this range in acreage.[19] Both the minimum crop acreage required to achieve constant costs and the range in crop acreage with constant costs for the hilly farm are smaller than for the average farm. Increases in the relative efficiency of the 2-plow, 3-plow combination reduce the minimum acreage required to achieve constant costs on the hilly farm. Revenue losses from untimely hay harvesting and corn cultivation on the hilly farm shift the cost curves for the (a) 2-plow, 3-plow and (b) 3-plow, 3-plow combinations toward the cost axis. These shifts reduce the range in crop acreage for which costs are constant.

The budgeting results for the hilly farm without custom operations suggest that a 2-man, 2-tractor combination and 210 to 456 acres of cropland (697 to 1,512 total acres) are required to attain most of the cost economies available in crop production. Two machinery combinations, the 2-plow, 3-plow and the 3-plow, 3-plow, are the most efficient for this range in acreage (table 15).

Upland farm

Total fixed machinery cost for the upland farm is less than for the average and hilly farms, because somewhat different machinery combinations are involved (table 12). There

[18] Total crop production cost does not include land rent.

[19] To achieve constant costs on the average farm requires 232-548 cropland acres or 418-987 total land acres.

are no hay harvesting operations on the upland farm since the rotation, CCSb, does not contain hay crops. Neither a hay baler nor a rake are included in the machinery combinations for the upland farm. In addition to supporting a rotation consisting entirely of row crops, the upland soil mixture contains the highest proportion of cropland—74.31 percent (table 4). Hence, only 56.67 acres of the upland soil mixture are required to obtain 40 acres of cropland.

Short-run average total cost. The shape of the short-run average total cost curves for the upland farm (fig. 9) differs slightly from the shape of the curves for the average farm (fig. 3).[20] Changes in the soil mixture and the accompanying changes in rotations and yields cause this change in shape.

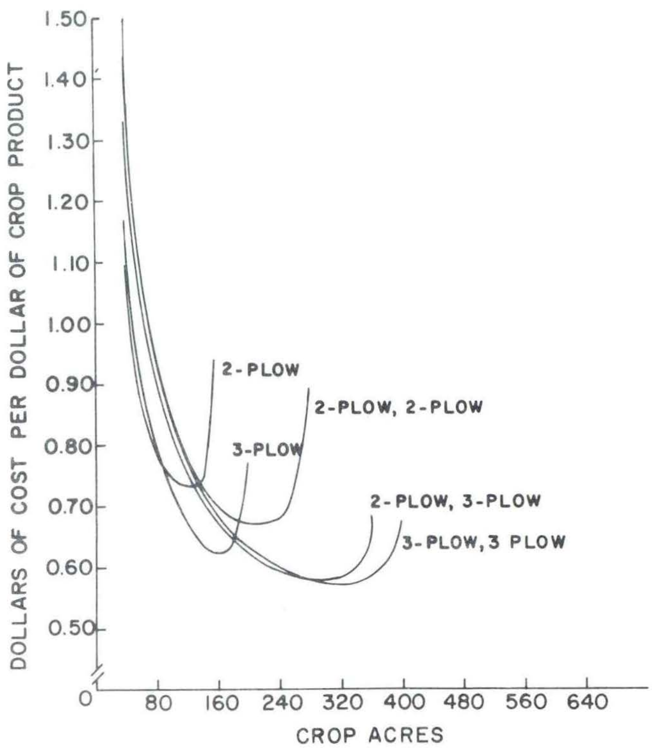

Fig. 9. Average total cost per dollar of crop product by farm size for selected machinery combinations on the upland farm.

Unit cost for 40 acres of cropland is relatively low on the upland farm. Hence, the decline in unit cost from 40 crop acres to the minimum-cost crop acreage also is relatively small. For acreages greater than the minimum-cost acreage, unit cost rises more rapidly on the upland farm than on the average farm. Crop production on the upland farm is more specialized than on the other farms, since the rotation consists of two similar row crops—corn and soybeans. Time requirements for specialized row-crop production are large during the no-loss period for planting and hoeing. Large revenue losses from untimely planting and hoeing operations cause the cost curve to rise sharply after reaching the minimum-cost acreage.

Changing from an average to an upland soil mixture shifts the cost curve for each machinery combination down toward the acreage axis and left toward the cost axis. Minimum average total cost for each machinery combination on the upland farm is lower and is achieved at smaller acreages than on the average farm (table 13 and 16). Total crop production cost for 40 acres of cropland is smaller on the upland farm, and total crop revenue for 40 acres of cropland is larger.[21] Hence, unit cost for each machinery combination and each acreage on the upland farm is lower than on the average farm. Lower total and average and fixed costs cause minimum average total cost to be achieved at smaller acreages.

Changing from the average to the upland soil mixture also affects the relative position of each cost curve and, hence, the relative efficiency of each machinery combination (table 16). The relative efficiency of combinations containing the 2-plow tractor declines, and the relative efficiency of the combinations containing the 3-plow tractor increases. The 2-plow and the 3-plow machinery combinations have the same capacity in hay-harvesting operations, but the 2-plow combination has considerably less work capacity in row-crop operations. For example, the 2-plow combination's work capacity in plowing, planting, hoeing, cultivating and corn picking operations ranges from 33 to 47 percent less than for the 3-plow machinery com-

Table 16. Costs per dollar of crop product for selected machinery combinations on the upland farm.

Machinery combination	Range in crop acreage with lowest average cost[a]	Minimum average cost crop acreage	Minimum average cost
2-plow.	0- 80	120	$0.73
3-plow.	80-180	160	0.62
2-plow, 2-plow	------	200	0.67
2-plow, 3-plow	180-280	280-320[b]	0.58
3-plow, 3-plow	280-400	320	0.57

a Acreage range within which this machine combination has lower average costs than any other machine combination.

b Although cost is not absolutely constant over this range, rounding cost to the nearest cent results in the same magnitude.

20 Note that the scale used on the vertical axis in fig. 9 differs from the scale used in figs. 7 and 8.

21 Total crop production cost does not include a charge for land.

bination. The 2-plow combination's smaller work capacity for planting and cultivating operations causes, for larger acreages, untimely operations, reduced yields, revenue losses and reductions in relative efficiency.

Although the 2-plow machinery combination declines in relative efficiency on the upland farm, it remains the most efficient combination for 80 crop acres or less. From 80 to 160 crop acres, the 3-plow combination is the most efficient. Although the 2-plow and 3-plow combinations are the most efficient for small acreages, unit costs are relatively high. Thus, the minimum unit cost for 80 and 160 crop acres is 38 and 9 percent larger than for 320 crop acres.

Long-run average total cost. Changing from the average to upland soil mixture has the same effect upon the short-run and long-run average total cost curves. Thus, long-run average total cost for each acreage on the upland farm is lower than on the average farm (figs. 5 and 10). The smallest crop acreage required

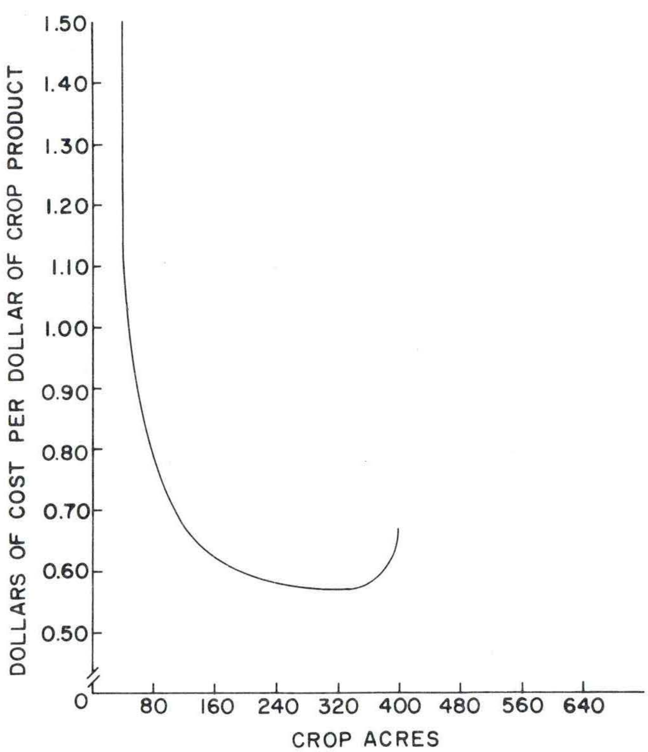

Fig. 10. Long-run average cost curve for crop production on the upland farm.

to achieve minimum average total cost on the upland farm remains unchanged at 320 crop acres, but fewer total acres of land (453) are required.

The long-run cost curve for the upland farm indicates that a 2-man, 2-tractor combination and 196-380 crop acres (278-538 total acres) are required to achieve most of the cost economies available in crop production. Average total cost varies 5 percent or less from minimum cost between 196 and 380 acres. Two machinery combinations, (a) the 2-plow, 3-plow and (b) the 3-plow, 3-plow, are the most efficient combinations between 196 and 380 crop acres (table 16).

Model I results compared

The three farms considered in model I have different soil mixtures, rotations, yields, field operations, etc. Despite these differences, the results for model I are quite similar. Minimum long-run average total cost is achieved at the same crop acreage (320) on each farm. The machinery combinations and crop acreages necessary to attain most of the cost economies available on each farm also are similar. It is assumed that resource combinations achieving unit cost within 5 percent of minimum cost attain constant unit cost and, hence, most of the cost economies available. Either a 2-plow, 3-plow or a 3-plow, 3-plow machinery combination and 196 to 232 acres of cropland are necessary to achieve constant cost (table 17).

Table 17. Machinery combinations and crop acreage necessary to achieve unit cost within 5 and 10 percent of minimum unit cost for selected farms without custom operations.

Farms	5 percent		10 percent	
	Machinery combinations	Range in crop acreage	Machinery combinations	Range in crop acreage
Hilly	2-plow, 3-plow 3-plow, 3-plow	210-456	2-plow, 3-plow 3-plow, 3-plow	170-504
Average	2-plow, 3-plow 3-plow, 3-plow	232-548	3-plow 2-plow, 3-plow 3-plow, 3-plow	192-576
Upland	2-plow, 3-plow 3-plow, 3-plow	196-380	3-plow 2-plow, 3-plow 3-plow, 3-plow	148-394

Thus, the results for model I suggest that a 2-man, 2-tractor combination is necessary to achieve most of the cost economies available in crop production on each farm.[22]

Estimates of the effects of custom operations upon unit cost are made for only the average farm. Custom operations reduce the acreage required to achieve minimum long-run average total cost and constant unit cost. With custom operations, the 2-plow and 3-plow combinations are able to attain most of the cost economies available. Both of these combinations involve only one man and one tractor. The effects

[22] One also could contend that unit cost should be considered constant and that most of the cost economies had been achieved if unit cost were within 10 percent of minimum cost. Then, constant unit cost could be achieved with a 1-man, 1-tractor combination on the average and upland farms (table 17).

of custom operations upon unit cost are expected to be similar for all three farms. Machinery exchange agreements among farmers are not considered, but the effects of such agreements upon unit cost should be similar to the effects of custom operations.

The estimates of minimum long-run average total cost obtained for the three farms differ considerably. Minimum unit cost on the hilly and average farms is greater than on the upland farm. The total cost of crop production for the minimum cost acreage is similar for the three farms, but total crop revenue for the minimum cost acreage is greater on the upland farm than on the average and hilly farms. A charge for land is not included in the estimates of total cost, and the revenue from permanent pasture production is not included in the estimates of total revenue. (A different land rent per acre is assumed later for each farm.) Permanent pasture acreages and yields also differ for the three farms. Hence, one would expect the estimates of minimum long-run average total cost for the three farms to differ. The effects of permanent pasture production upon total revenue and unit cost and the effects of land rents upon total cost and unit cost are considered in the two sections that follow.

Model II

In model II, the farmer is assumed to have a beef-cow herd that produces feeder calves, and the permanent pasture crop is processed through this livestock enterprise. The beef-cow herd utilizes all the permanent pasture available on each farm. Revenue and expenses from the beef-cow enterprise are included in the total revenue and total variable cost of the farm. The size of the beef-cow herd depends upon the quantity of available permanent pasture rather than on the stock of hay produced on the farm. Permanent pasture production on the hilly, average and upland farms is sufficient (in terms of the mix of soil types and the proportion of pasture to cropland in each) to support 19.2, 7.9 and 3.05 beef-cow units, respectively, per 40 acres of cropland.

Total variable cost and total revenue for crop production alone are not affected by the addition of the beef-cow enterprise to the budgeting model. Hence, total variable cost and total revenue, with beef cattle included in both costs and revenue, per 40 crop acres in model II will be greater than in model I. However, average total cost per dollar of product in model II may be greater than, equal to, or less than unit cost for model I. The effect of model II upon unit cost, relative to model I, depends upon the relationship between the unit cost of beef production and crop production.

Short-run average total cost

The shapes of the average total cost curves, taken separately, for beef and crop production are not identical, but they are similar. The average total cost curve for the beef-cow enterprise passes through stages of decreasing and increasing cost. Labor requirements per head, and, hence, unit costs decline as acreage and the size of the beef-cow herd increase. Large acreages also lead to untimely hay harvesting losses and reductions in hay production. As farm size increases, hay consumption generally exceeds hay production, and increasing quantities of hay must be purchased. Hence, unit beef production costs generally increase for very large acreages.

Short-run average total cost curves, with crops and beef combined in the value of production or output unit, for the machinery combinations on the average, hilly and upland farms are presented in figs. 11, 12 and 13, respectively.[23] Changing from model I to model II causes only a small change in the minimum average cost acreage and in the relative efficiency for any machinery combination. The range in crop acreage for which a specific machinery combination has the lowest average cost remains nearly the same in the two models (tables 13, 15, 16 and 18). Thus,

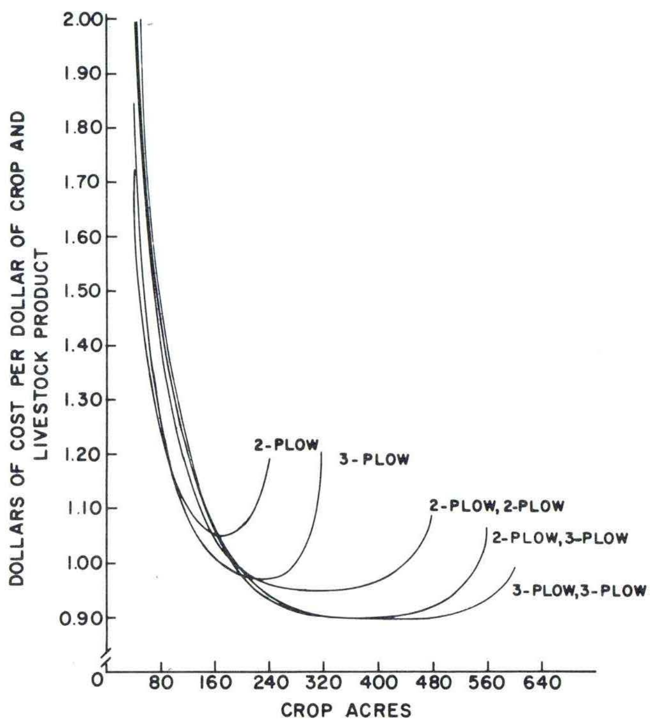

Fig. 11. Average total cost per dollar of crop and livestock product by farm size for selected machinery combinations on the average farm.

[23] Total cost is defined as all the costs of beef and crop production except land rent.

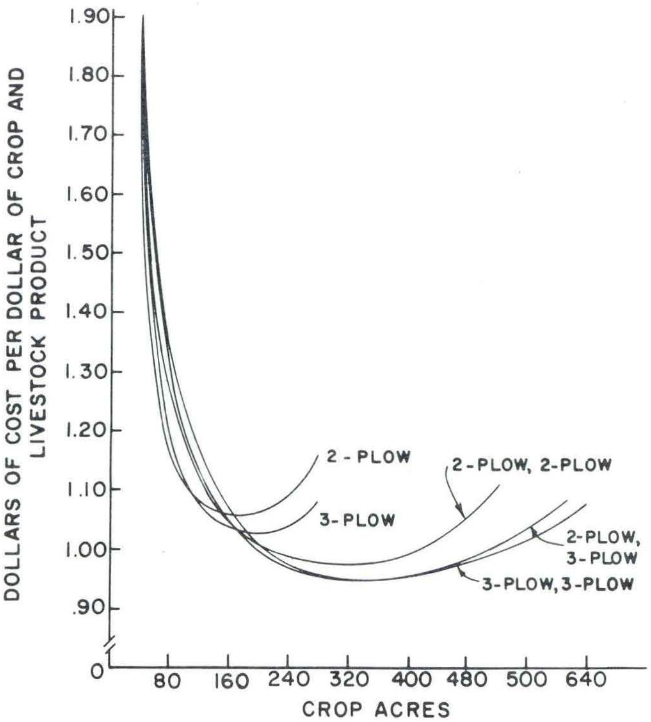

Fig. 12. Average total cost per dollar of crop and livestock product by farm size for selected machinery combinations on the hilly farm.

Table 18. Costs per dollar of crop and livestock product for selected machinery combinations and farms.

Farm and machinery combination	Range in crop acreage with lowest average cost[a]	Minimum average cost crop acreage	Minimum average cost
Hilly			
2-plow	0-104	160-200[b]	$1.06
3-plow	104-160	200	1.03
2-plow, 2-plow	----	280-360[b]	0.98
2-plow, 3-plow	160-360	320-360[b]	0.95
3-plow, 3-plow	320-640	320-360[b]	0.95
Average			
2-plow	0-100	160	1.05
3-plow	100-192	240	0.97
2-plow, 2-plow	----	280-360[b]	0.95
2-plow, 3-plow	192-400	320-440[b]	0.90
3-plow, 3-plow	320-600	320-480[b]	0.90
Upland			
2-plow	0- 72	120	0.75
3-plow	72-180	160	0.66
2-plow, 2-plow	----	200	0.70
2-plow, 3-plow	180-280	280	0.62
3-plow, 3-plow	280-400	280-320[b]	0.62

[a] Acreage over which the specified machinery combination results in the lowest cost.

[b] Although cost is not absolutely constant over this range, rounding cost to the nearest cent results in the same magnitude.

the change in budgeting models causes only small horizontal shifts in the short-run average total cost curves.

Changing from model I to model II causes the short-run average total cost curves to shift vertically. The cost curves for the hilly and average farms shift down toward the acreage axis, because the unit cost of beef production is less than the cost of crop production (figs. 3, 7, 11 and 12). Hence, unit cost for each acreage and each machinery combination in model II, with cost measured against both beef and crop output, is smaller than in model I (where cost is measured only against crop output). Similarly, changing from model I to model II causes the cost curves on the upland farm to shift upward, because the unit cost of crop production is less than the cost of beef production (figs. 9 and 13).

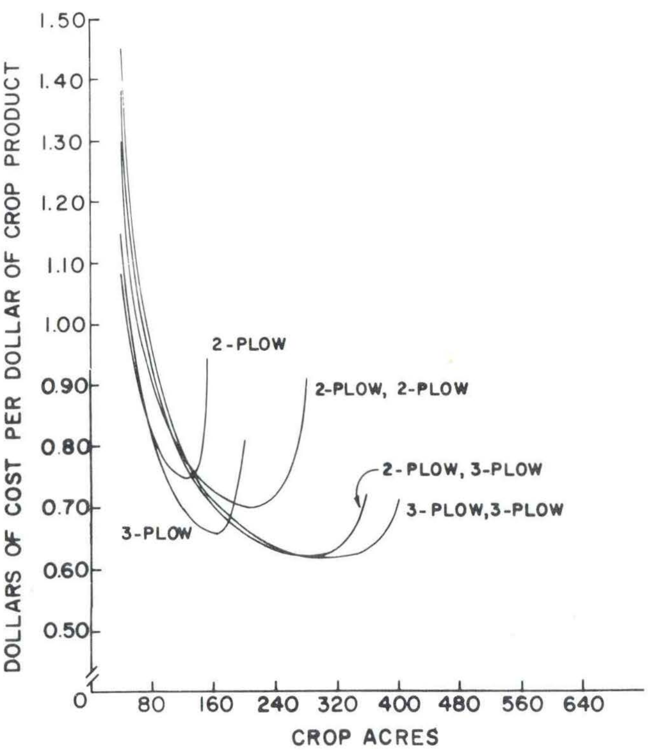

Fig. 13. Average total cost per dollar of crop and livestock product by farm size for selected machinery combinations on the upland farm.

Long-run average total cost

The effects of changing from model I to model II are similar for the short-run and long-run cost curves (figs. 14, 15 and 16). The cost curves shift vertically rather than horizontally, because minimum cost is achieved at approximately the same crop acreage. Changing from model I to model II reduces, but does not eliminate, the differences in unit cost among farms. With model I, minimum unit cost for the hilly and average farms is 89 and 63 percent greater, respectively, than on the upland farm. With model II, minimum unit cost for the hilly and average farm is only 53 and 45 percent larger, respectively, than on the upland farm.

Changing from model I to model II has relatively little effect upon the resource combination necessary to achieve most of the cost

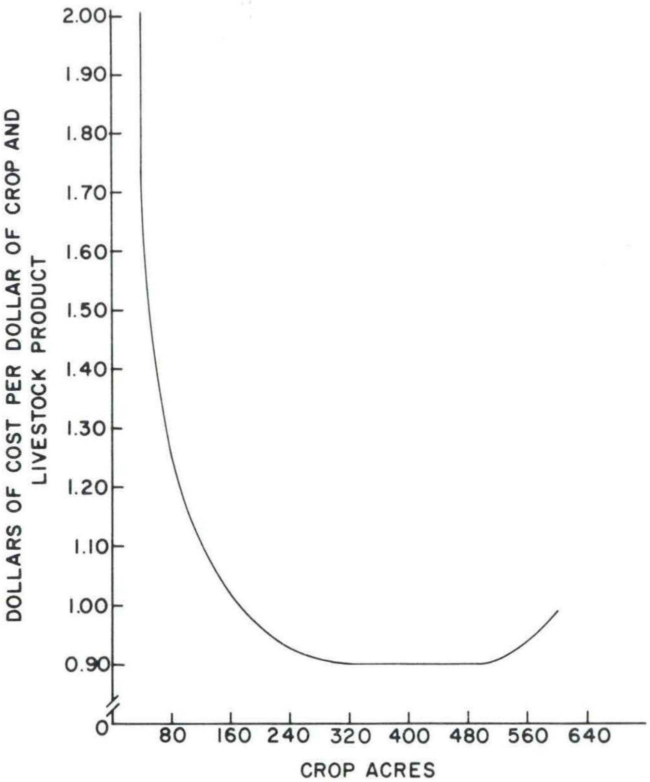

Fig. 14. Long-run average cost curve for crop and livestock production on the average farm.

economies available. To attain constant unit cost and, hence, most of the cost economies available, a resource combination's unit cost must fall within 5 percent of minimum cost. A

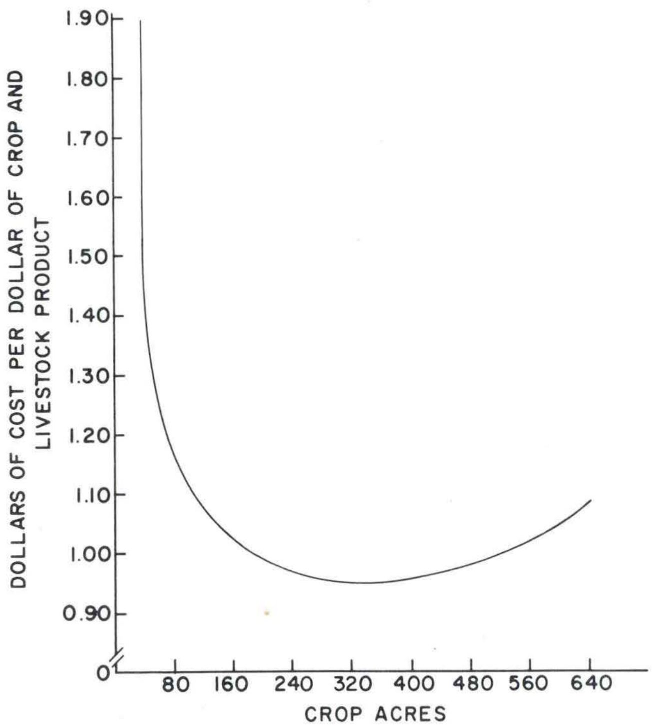

Fig. 15. Long-run average cost curve for crop and livestock production on the hilly farm.

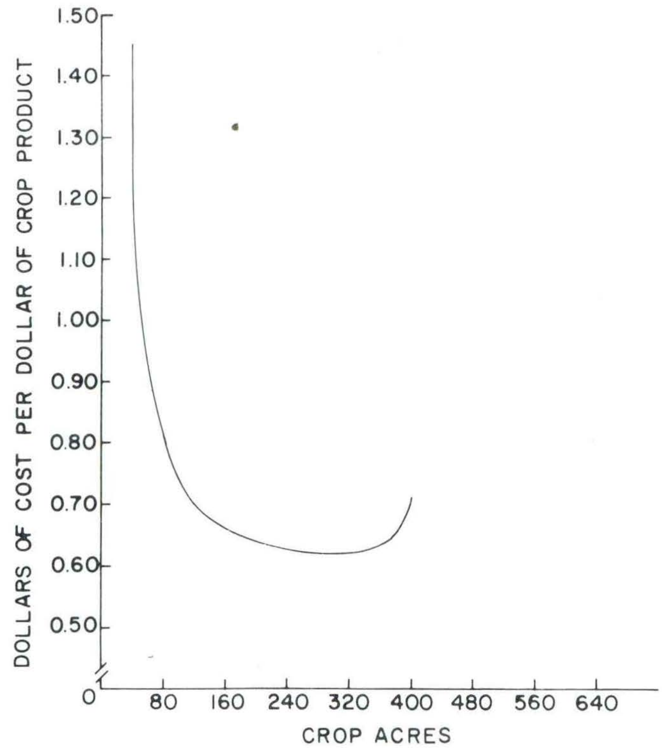

Fig. 16. Long-run average cost curve for crop and livestock production on the upland farm.

2-plow, 3-plow or a 3-plow, 3-plow machinery combination and 180 to 220 crop acres are required to achieve constant unit cost (table 19).[24] Either a 2-plow, 3-plow or a 3-plow,

Table 19. Machinery combinations and crop acreages necessary to achieve a unit cost within 5 and 10 percent of minimum unit cost for selected farms with model II.

Farms	5 percent		10 percent	
	Machinery combinations	Range in crop acreage	Machinery combinations	Range in crop acreage
Hilly	2-plow, 3-plow 3-plow, 3-plow	200-524	2-plow, 3-plow 3-plow, 3-plow	144-600
Average.	2-plow, 3-plow 3-plow, 3-plow	220-568	3-plow 2-plow, 3-plow 3-plow, 3-plow	176-600
Upland.	2-plow, 3-plow 3-plow, 3-plow	180-380	3-plow 2-plow, 3-plow 3-plow, 3-plow	106-396

3-plow machinery combination and 196 to 232 crop acres, are required to attain constant costs in model I.

Land Rent

A charge for land resources is included in

24 One could also contend that unit cost should be considered constant and that most of the cost economies available had been achieved if unit cost were within 10-percent of minimum cost. Given this contention, the resource combination necessary to achieve constant cost would remain similar for the two models.

the estimates of total cost in this section, and the effects of this budgeting change upon the cost curves for each farm are considered. The charge for land, consisting of an interest and tax charge upon the land price assumed, will be referred to as a land rent.[25] Land rent is assumed constant per acre. Total variable cost and average total cost per dollar of product for any acreage increase when land rent is considered. The average variable cost curve for each machinery combination shifts upward and away from the acreage axis. An upward shift in the average variable cost curve causes the average total cost curve to shift upward and may cause minimum average total cost to occur at a smaller acreage.

Effects of land rent

Including a charge for land in total cost has only a slight effect on the shape and relative position of the short-run average total cost curves for the three farms. Adding land rent into total cost also causes relatively small horizontal shifts in the average total cost curves. The minimum average total cost crop acreage is reduced for some machinery combinations, but these acreage reductions are less than 40 acres (table 20, for crops only; table 21, for crops and livestock combined). The changes in the crop acreage for which each machinery combination is most efficient also are relatively small.

[25] Land rents are not included in the estimates of total cost presented in the previous section. See Appendix B, table B-2, for the land rents used.

Table 20. Cost per dollar of crop product for selected machinery combinations and farms when total cost includes a land rent.

Farm and machinery combination	Range in crop acreage with lowest average cost[a]	Minimum average cost crop acreage	Minimum average cost
Hilly			
2-plow	0-112	120	$1.82
3-plow	112-144	160	1.77
2-plow, 2-plow	144-148	240	1.65
2-plow, 3-plow	148-400	280	1.61
3-plow, 3-plow	320-640	320	1.61
Average			
2-plow	0- 96	120-160 [b]	1.60
3-plow	96-164	200-240 [b]	1.51
2-plow, 2-plow	---	240-280	1.45
2-plow, 3-plow	164-360	320	1.38
3-plow, 3-plow	280-600	320	1.38
Upland			
2-plow	0-72	120	1.12
3-plow	72-180	160	1.00
2-plow, 2-plow	---	200	1.05
2-plow, 3-plow	180-280	280	0.95
3-plow, 3-plow	280-400	280-320 [b]	0.95

[a] Acreage range for which the specified combination results in lowest unit costs.

[b] Although cost is not absolutely constant over this range, rounding cost to the nearest cent results in the same magnitude.

Table 21. Cost per dollar of crop and livestock product combined for selected machinery combinations and farms when total cost includes a land rent.

Farm and machinery combination	Minimum average cost crop acreage	Minimum average cost
Hilly		
2-plow	160	$1.32
3-plow	160-200 [a]	1.29
2-plow, 2-plow	280	1.23
2-plow, 3-plow	280-360 [a]	1.21
3-plow, 3-plow	320-360 [a]	1.21
Average		
2-plow	160	1.39
3-plow	240	1.32
2-plow, 2-plow	240-320 [a]	1.29
2-plow, 3-plow	320	1.23
3-plow, 3-plow	320	1.23
Upland		
2-plow	120	1.11
3-plow	160	1.00
2-plow, 2-plow	200	1.05
2-plow, 3-plow	280	0.96
3-plow, 3-plow	280-320 [a]	0.96

[a] Although cost is not absolutely constant over this range, rounding cost to the nearest cent results in the same magnitude.

It was assumed earlier that, for practical purposes, resource combinations achieving a unit cost within 5 percent of minimum cost can produce at constant unit cost and that these resource combinations achieved most of the cost economies of size available. Adding land rent to total cost reduces the minimum acreage required to achieve constant unit cost. When land rent is considered, at least 160 to 200 crop acres and the (a) 3-plow, (b) 2-plow, 3-plow or (c) 3-plow, 3-plow machinery combination are required to attain constant cost without custom operation.[26] At least 192 to 232 crop acres and either (a) the 2-plow, 3-plow or (b) the 3-plow, 3-plow combination are required to achieve constant cost when land rents are not considered (tables 17 and 19). Thus, including land rent in total costs reduces the minimum acreage required to achieve constant cost by less than 40 crop acres; this indicates that constant cost can be achieved with a 1-man, 1-tractor combination on the upland farm.

The effect of both land rent and custom operations is considered on only the average farm. If custom operations are assumed, adding land rent to total cost has little effect upon the minimum cost acreage for any machinery com-

[26] The upper limit for crop acreage ranges from 376 to 520 acres. The 3-plow combination can achieve constant cost on only the upland farm.

bination or upon the range in acreage for which each machinery combination is most efficient. However, the minimum acreage required to achieve constant unit cost declines from 152 to 120 crop acres. The effects of land rent and custom operations are expected to be similar for other farms.

The primary effect of including land rent in total cost is a vertical shift of the cost curve for each machinery combination. Average total cost per dollar of product for each acreage and machinery combination increases sharply. The size of the vertical shift can be ascertained by examining the change in minimum average total cost per farm. The increases in minimum average total cost per farm range from 48 to 67 percent in model I (tables 13, 15, 16 and 20). In model II the increases in minimum average total cost per farm range from 27 to 55 percent (tables 18 and 21).

Cost differences among farms

Cost differences among farms in model I are reduced, but not eliminated, by considering model II. The remaining differences in average total cost among farms are reduced further by including land rent in total cost, since the level of land rent tends to vary directly with the magnitude of income per $1 of cost (or inversely with the magnitude of costs per $1 of income). Minimum average total cost on the hilly and average farms is 69 and 45 percent greater, respectively, than on the upland farm when land rents are not included in model I. Minimum unit cost for the hilly and average farm is only 26 and 28 percent greater, respectively, than on the upland farm when land rents are included in model II. Thus, considering model II and including land rent in total cost reduces, but does not eliminate, the differences in unit cost among farms.

What causes the difference in unit cost relative to value of output, including rent as a cost, among farms? These cost differences may be caused by a disequilibrium in the land market. Land prices in the study area rose 172 percent from 1940 to 1960.[27] During this period, the price of high-grade land rose more rapidly (185 percent) than the price of low-grade land (150 percent) or medium-grade land (164 percent). These changes in the relative price of different grades of land are not inconsistent with the hypothesis that some grades of land, particularly less productive land, are overpriced relative to other grades. The changes in relative prices of grades of land may merely indicate a price response to differential changes in productivity.

[27] Dwight Maxon Gadsby. Iowa land values sag in 1960. Iowa Farm Science 15:639-640. 1961.

Not only are there differences in minimum unit cost among farms when land rents are considered, but total cost exceeds total revenue for every acreage and every machinery combination on the hilly and average farms. The budgeting results do not indicate that the farm actually operates at a loss but, rather, that market rates of return are not received for all resources. If the market wage rate were just realized, along with the market rent for land, the cost per unit ($1) of value output would equal $1 also. Thus, the budgeting results suggest that the market rates of resource returns cannot be achieved on the hilly and average farms.

It is difficult to suggest any single factor that would cause total cost to exceed total revenue on the hilly and average farms. With the product and factor prices assumed, it may be impossible to find a combination of resources that draws total cost down to the level of returns when labor is used so abundantly and land is priced at existing levels. Estimates of the changes in (a) the factor price level, (b) land rents and prices and (c) the product price level that are required to equate total revenue and total cost are derived as follows. These estimates will be made only for the resource combinations that attain minimum long-run average total cost in model II.

Factor price level. Factor prices would have to decline by 17 and 19 percent to equate total revenue and total cost (cost per $1 of output equal to $1) on the hilly and average farms, respectively, if the product price level remained unchanged. To equate total revenue and total cost on the upland farm would require a 4-percent increase in factor prices. The index of prices paid by farmers in the United States has risen steadily since 1955.[28] Farmers must compete with other sectors of the economy for mobile resources, such as capital and labor. Hence, in an expanding economy, the prices of capital and labor resources used by farmers are not likely to decline even if farm product prices decline.

The prices for resources used primarily on farms may decline as prices received by farmers decline. More than 90 percent of the land in the study area was in farms in 1959.[29] Land price movements in the study area during the 1954-60 period are not inconsistent with the findings from the budgeting model; namely, that a $1 corn price level cannot support existing land prices under the structure of farm sizes existing in the area. Estimated land prices for the study area increased from 1954 through

[28] Prices of Iowa farm products (1930-1960). Iowa Farm Science 15:656. 1961.

[29] U. S. Census of Agriculture: 1959. Counties, Vol. 1, Part 16. 1961.

1959 despite a general decline in the level of prices received. However, in 1960, after 3 years of product prices approaching those assumed in the budgeting model, estimated land prices for the study area fell by 4.24 percent.

Residual land prices. Estimates of land prices that equate total revenue and total cost (i.e., allow costs per $1 of product to fall to $1) are derived by capitalizing the land rents obtained when a charge for land is not considered.[30] Only one estimate of land price, the maximum land price possible if total revenue and total cost are to be equal, is derived for each farm type. Residual land prices of $14, $40 and $251 per acre, assuming the optimum or least-cost size of farm in each case, are obtained for the hilly, average and upland farms, respectively.[31] These prices are average for the soil mixes, including permanent pasture and cropland, assumed for each farm situation. The residual land prices for the hilly and average farms, respectively, are only 19 and 30 percent as much as the prices used in this study. The residual land price for the upland farm is 13 percent greater than the assumed price. These residual land prices are not presented as estimates of the value of land but merely as land prices that equate total cost and total revenue (allow cost per $1 of product to fall to $1) in budgeting model II.

Product price level. Corn price levels of $1.21, $1.23 and $0.96 are required to equate total revenue and total cost on the hilly, average and upland farms, respectively, if total cost and land price remains unchanged in each case. (The minimum-cost acreage is assumed in each case.) The break-even price level for the upland farm is 4 percent less than the corn price level assumed. Comparisons between the break-even corn price levels just estimated and the actual price level for agricultural products cannot be made, but the break-even corn prices can be compared with historic corn prices and with recent government corn support prices.

The average annual corn price per bushel in Iowa during the periods 1945-60, 1950-60 and 1955-60 was $1.33, $1.29 and $1.14, respectively. Government corn support prices for only the period 1958-60 are considered here. In 1958 the minimum national average corn support price per bushel was $1.36 for farmers complying with acreage allotments and $1.06 for noncomplying farmers. The corn support price per bushel declined to $1.12 in 1959 and to $1.06 in 1960.

The break-even corn prices (the level allowing costs per $1 of product to be $1) for all the farms are less than the average corn prices for the 1945-60 and 1950-60 periods. Only the break-even corn price for the upland farm is less than average price for the 5 years, 1955-60. The break-even corn prices for the hilly and average farm exceed all the government support prices considered except the 1958 support price for complying farmers. Again, only the upland farm's break-even corn price is smaller than all the corn support prices cited.

The level of unit cost in the budgeting models is influenced by the price level assumed. Use of the average corn price level for either the 1945-60 period or the 1950-60 period would have caused a substantial reduction in the level of unit cost for each farm. With these two price levels, total revenue would exceed total cost for some acreage on each farm, or the minimum long-run average total cost for each farm would be less than $1. Corn price levels greater than $1, such as the support prices and the average price for the 1955-60 period, would reduce the level of cost per unit (per $1) on each farm. Any corn price level less than $1 would increase the level of cost per unit (per $1) on each farm.

It would be misleading to place great emphasis upon the cost differences among farms or upon the unprofitableness of crop production on the hilly and average farm. The objective in the budgeting models is to estimate the cost economies and the least-cost farm sizes associated with varying combinations of machinery and land. The relative stability in shape and minimum-cost acreages of the cost curves under changing conditions support this contention. The short-run cost curves indicate the acreages that minimize cost for a given machinery combination. The long-run cost curves indicate the combinations of resources that attain most of the cost economies available in crop production. In the section which follows, an attempt is made to compare the resource combinations that attain most of the cost economies available in crop production with the resource combinations used by the farmers in the study area.

Budgeting Results and the Study Area

Any resource combination with unit cost falling within 5 percent of minimum cost is assumed to achieve constant unit cost and, hence, most of the cost economies available in crop production. If custom operations are not considered, the resource combinations that achieve constant unit cost are: 176-210 or more crop acres and (a) the 2-plow, 3-plow or (b) the 3-plow, 3-plow machinery combination on the hilly farm; 200-232 or more crop

[30] An interest rate of 4.44 percent is assumed.

[31] The value of farm buildings is not included in the residual land price but is included in the land price assumed for the study area.

acres and (a) the 2-plow, 3-plow or (b) the 3-plow, 3-plow machinery combination on the average farm; 160-196 or more crop acres and (a) the 3-plow, (b) the 2-plow, 3-plow or (c) the 3-plow, 3-plow machinery combination on the upland farm. All these machinery combinations, except the 3-plow combination, involve two men and two tractors. The acreages cited are minimum acreages required to achieve constant unit cost.

Custom operations were considered for only the average farm, but their effects upon unit cost are expected to be similar for the other farms. It was assumed that custom operation would be available immediately at a constant price whenever needed.[32] At least 120 to 160 crop acres are required to achieve constant unit cost on the average farm with custom operations. The four machinery combinations achieving constant unit costs are: the 2-plow combination and $996-$1,100 of custom work; the 3-plow combination and $731-$1,215 of custom work; the 2-plow, 3-plow combination; and the 3-plow, 3-plow combination. The first two machinery combinations involve one man and one tractor, while the last two combinations involve two men and two tractors.

What proportion of the farmers in the study area have the resource combinations necessary to attain constant costs? There is no precise answer for this question since available data do not allow classification of farmers in the study area by combination of resources. Farms in the area are classified by acreage, but quality of land is not considered in this classification. Estimates of the numbers of specific machines are available, but these estimates do not consider age and size of the machines or classify farms by numbers of machines per farm. Estimates of the total number of farm workers for a year or for special periods are also available, but farms are not classified by number of workers per farm. In addition, useful estimates of the farm work force's composition and its work load are not available.

Total acres of land per farm in the study area have increased sharply during the past few decades. The number of acres of cropland per farm also has increased.[33] From 1954 to 1959, the average cropland acreage per farm increased from 111 to 128 acres.[34] The data required to estimate the distribution of farms by acres of cropland are not available for the study area. However, the censuses of agriculture for 1954 and 1959 classify farms by acres of cropland harvested.[35] The distribution of farms reporting cropland harvested by acreage is presented in table 22. About 80 and 75 percent of the cropland in the study area was harvested in 1954 and 1959, respectively.[36] Hence, the measure of acres of cropland harvested per farm underestimates the acres of cropland actually available per farm. However, the number of acres of cropland harvested per farm is the best available estimator of total cropland per farm.

Table 22. Distribution of farms reporting cropland harvested by acreage for the study area, 1954 and 1959.[a]

Acres of cropland harvested	Proportion of farms reporting cropland harvested	
	1954	1959
Less than 100 acres	58.8	54.5
100 to 199 acres	32.3	32.8
200 or more acres	8.9	12.7

[a] Based on: U. S. Census of Agriculture: 1954 and 1959. **op. cit.**

A minimum of 160 acres of cropland is required to achieve constant unit cost if custom operations are not considered. Between 54.5 and 87.3 percent of the farms in the study area do not have the cropland resources necessary to attain constant unit cost. At least 120 acres of cropland are necessary to achieve constant unit cost when custom operations are considered. Approximately half the farms in the study area do not have sufficient cropland to attain constant unit cost, even when custom operations are considered.

Machine combinations involving two men and two tractors are required to achieve constant unit cost except on the upland farm when custom operations are not considered. The budgeting results with custom operations suggest that constant unit cost can be attained with a 1-man, 1-tractor operation. Most of the farms in the study area have or could have one worker per farm. How many farms in the study area have two or more workers? About 47 percent of the farms hired some labor in 1959, with an average labor hire expenditure per farm of $399, but only 3.6 percent of the farms reported one or more regular hired workers. Census economic class I, II and III farms averaged about two workers per farm during the week of Oct. 24-30, 1954.[37] Class I,

[32] This assumption may not be valid. The effect upon the cost estimates of a breakdown in this assumption was discussed earlier.

[33] Some of this increase in acres of cropland per farm can be attributed to the change in the census definition of a farm between 1954 and 1959.

[34] U. S. Census of Agriculture: 1954. Counties and state economic areas, Vol. 1, Part 9. 1956.

[35] U. S. Census of Agriculture: 1954 and 1959, op. cit.

[36] Total acres of cropland in the study area consist of cropland harvested, cropland used only for pasture and cropland not harvested or pastured.

[37] U. S. Census of Agriculture: 1954, op. cit.

II, and III farms are units on which the total value of all farm products sold is $5,000 or greater. Approximately 32 percent of the farms in the study area were class I, II or III farms in 1954. By 1959 about 54 percent of the study area's farms had farm product sales of $ 5,000 or more. [38] Thus, it seems reasonable to estimate that between 30 and 50 percent of the farms have sufficient labor for a 2-man operation.

How many farms have the machinery required for a 1-man, 1-tractor operation with $731 to $1,215 of custom work or a 2-man, 2-tractor combination with no custom operation? Slightly more than 85 percent of the farms had one or more tractors in 1959. [39] Only 54 percent of the farms reported expenditures for machinery hire, and the average expenditure per farm was $120 per farm. The paucity of data on machinery hire makes it difficult to estimate the number of farms that have or could obtain the custom operations necessary for constant unit cost with a 1-man, 1-tractor operation. In 1959 about 43 percent of the farms reported two or more tractors per farm. In addition, approximately 41, 54 and 40 percent of the farms in the area reported one or more combines, corn pickers and pickup balers or field forage harvesters per farm, respectively. Hence, it appears that slightly more than 40 percent of the farms have the machinery necessary for a 2-tractor combination.

The budgeting results for each farm suggest that a considerable reduction in unit cost can be obtained by adopting the combination of resources that achieves constant unit cost. [40] However, census data indicate that less than 50 percent of the farms in the study area have the resource combination necessary to achieve the cost economies available when custom operations are not considered. And only slightly more than half the farms have sufficient cropland to attain the cost economies available when custom operations are considered.

The resources on many farms in the study area must be enlarged to attain the cost economies estimated available in crop production. It will be impossible for all farms with a high-cost resource combination to attain the combination of land, labor and machinery that minimizes unit cost. Total land in farms and total acres of cropland in the study area have remained relatively stable in the past and are unlikely to increase in the future. Thus, increase in acres of land and cropland per farm can be achieved only through a reduction in the number of farms in the area. Hence, the budgeting results indicate that attempts by farmers to reduce unit crop production costs are likely to lead to a continued reduction in farm numbers within the study area.

APPENDIX A: SELECTION OF SOIL MIXTURES

This analysis of cost in relation to farm size is limited to the Shelby-Grundy-Haig soil association area. Within a soil association area, there are a large number of soil mixtures (combinations of particular soils). Since only a limited number of soil mixtures can be considered in this study, the specific mixtures for analysis must be selected so that budgeting results apply to as wide a range of soil mixtures as possible. Hence, we try to select those that represent the broadest possible strata of soil mixtures in the soil association area.

The source of detailed information on soil mixtures used in this study is the sample soil survey conducted by the Soil Conservation Service and the Iowa Agricultural and Home Economics Experiment Station to inventory soil conservation needs. [41] The sampling scheme for the soil survey included selection of three quarter-sections at random in each township. The sections selected were surveyed and mapped. Reports from this survey classify the land within each quarter-section selected by (1) soil type, (2) percent slope, (3) erosion class and (4) present land use. To each plot of land delineated by these four attributes, a land-capability class was assigned.

Certain soil mixtures occur more frequently than others within a soil association area. Therefore, a frequency distribution of soil mixtures is needed for the selection of specific soil mixtures that represent the largest area or portion of soils in a locality. Before a frequency distribution of soil mixtures can be estimated, a measure or attribute must be selected by which these soil mixtures can be ranked or classified. The single measure or attribute for a soil mixture used in this study is annual corn production per acre.

Annual corn production per acre for each plot of land is the product of two factors: (1) the estimated frequency in time that a plot of land can be used for corn (i.e., the number of years out of 5 that a plot is used for corn); (2) the estimated yield of corn when the plot of land is used for corn. Annual corn production per acre reflects the influence of all four factors

[38] U. S. Census of Agriculture: 1959, op. cit.

[39] Ibid.

[40] Unit costs for other resource combinations are 5 to more than 100 percent larger than for the resource combination that attains minimum long-run average cost.

[41] U. S. Soil Conservation Service and Iowa State University. Soil survey of statistical quarter section samples. Project 1191. Department of Agronomy, Iowa State University, Ames, Iowa. 1959. (Typewritten).

used in the soil survey to classify land. Present land use is considered, because only the cleared land falling in land-capability classes I, II, III and IV is classified as suitable for corn production. The percent slope and degree of erosion affect the frequency with which a plot of land can be used for corn. Finally, the estimated corn yield for a given plot of land is influenced by its soil type and degree of erosion.

Given a single soil mixture measure for each quarter-section, the next task is (1) to select class limits and (2) to establish the frequency distribution of the soil mixtures for the quarter-sections surveyed in the soil association area. The class limits and the frequency distribution, by annual corn production classes, are presented in table A-1 for quarter-sections surveyed in three counties in the Shelby-Grundy-Haig soil association area. This frequency distribution illustrates the variation in land mixtures within the soil association area.

Table A-1. Estimated annual corn production per acre for quarter-sections surveyed in the Shelby-Grundy-Haig soil association area of Clarke, Ringgold and Union counties.[a]

Soil mixture and estimated annual corn production per acre	Number of quarter-sections	Percent of total number of quarter-sections
Hilly	28	30.11
0 4.9	5	
5.0- 9.9	8	
10.0-14.9	15	
Average	56	60.21
15.0-19.9	14	
20.0-24.9	29	
25.0-29.9	13	
Upland	9	9.68
30.0-34.9	4	
35.0-39.9	4	
40.0-44.9	0	
45.0-49.9	1	
50.0-54.9	0	
Total	93	100.0

[a] Estimated mean annual corn production per acre for the 93 quarter-sections equals 19.9 bushels.

Specific quarter-sections were then selected for delineating each soil mix for analysis. Although the frequency distribution table has 11 classes, only three classes were considered in the selection of specific quarter-sections to provide the three farm situations for budgeting. They are:

1. 0 - 14.9 bu. corn per acre
2. 15.0-29.9 bu. corn per acre
3. 30.0 and more bu. corn per acre.

From quarter-sections falling in these three groups, the hilly, average and upland farm or soil situations mentioned in the text were formulated. A "typical quarter-section" was selected for each of these farms or situations. The soil composition of each quarter-section selected was used as the "standard mix" assumed when acreage per farm is varied against a given machine combination. In other words, the "mix" for 480 acres, for each farm or situation, is the same as that shown in tables A-2, A-3 and A-4 for the hilly, average and upland farms, respectively. The maximum intensity of cropping also was established for the major soil groupings on each farm and is shown in tables A-2, A-3 and A-4 along with the acreage and proportion of land assumed to remain in permanent pasture, timber, gullies and waste.

Table A-2. Description of soils for the hilly quarter-section in the Shelby-Grundy-Haig soil association area.

Areas and proposed land use	Soil components of new areas[a]	Acres	Percent of total	Maximum intensity rotation
Cropland		59.0	32.42	CCOMM
	65-10-2	9.6		
	65-10-3	3.3		
	65-12-2	1.9		
	131- 3-1	11.3		
	131- 6-2	8.9		
	131- 7-2	4.1		
	132- 4-2	7.7		
	132- 6-2	3.2		
	132- 7-2	2.8		
	132- 7-3	6.2		
Pasture		82.3	45.23	
	11- 3-0	18.2		
	24-16-2	9.3		
	65-14-3	7.2		
	65-15-2	7.6		
	65-16-3	2.1		
	65-17-3	4.0		
	65-20-2	8.6		
	65-20-3	3.1		
	103- 3-+	2.3		
	132- 7-4	2.8		
	192- 8-2	1.1		
	192- 8-3	2.1		
	192-10-2	8.6		
	192-10-3	3.4		
	192-11-2	1.9		
Timber		31.4	17.26	
	11- 3-0	8.3		
	65-20-1	22.1		
	192-10-1	1.0		
Gully		3.5	1.94	
Waste			3.15	

[a] The first number refers to soil type, the second to percent slope and the third to erosion class. For the soil type, the legend is: 11-Judson-Wabash, 24-Shelby, 65-Lindley, 93-Shelby-Adair, 103-Gravity, 131-Pershing, 132-Weller, 192-Adair, 222-Clarinda, 362-Haig, 364-Grundy, 593-thin solum Adair.

Six alternative rotations are considered in this study: (1) corn-corn-soybeans or CCSb, (2)

Table A-3. Description of soils for the average quarter-section in the Shelby-Grundy-Haig soil association area.

Areas and proposed land use	Soil components of new areas [a]	Acres	Percent of total	Maximum intensity rotation
Cropland		95.1	59.05	
A	11- 3-0	0.4		CCOM
	24-11-2	2.3		
	93-11-2	0.9		
	222- 7-2	2.0		
	364- 3-1	24.9		
	364- 7-2	31.6		
	593- 7-2	2.7		
B	93-11-2	20.0		CCOMM
	364- 7-1	0.8		
	364- 7-2	8.0		
	593- 7-3	1.5		
Pasture		60.9	37.81	
	11- 3-0	10.7		
	24-15-2	9.6		
	93-11-2	23.9		
	93-11-3	9.0		
	192- 7-2	2.3		
	364- 7-2	1.4		
	593- 7-2	4.0		
Waste			3.15	

[a] See table A-2.

corn-soybeans-corn-oats-meadow or CSbCOM, (3) corn-corn-oats-meadow or CCOM, (4) corn-corn-oats-meadow-meadow or CCOMM, (5) corn-oats-meadow or COM and (6) corn-oats-meadow-meadow or COMM. The rotation listed beside each cropland area in tables A-2, A-3 and A-4 is the maximum intensity rotation that can be applied to that cropland area and still restrict soil losses to approximately 4 tons or less per acre. Intensity is defined here as the proportion of row crops in the rotation. In table A-2, the rotation CCOMM is listed as the maximum intensity crop rotation. Hence, the CCSb, CSbCOM and CCOM rotations are not feasible alternatives for the cropland area on the hilly farm.

Table A-4. Description of soils for the upland quarter-section in the Shelby-Grundy-Haig soil association area.

Areas and proposed land use	Soil components of new areas [a]	Acres	Percent of total	Maximum intensity rotation
Cropland		122.0	74.31	CCSb
	192- 7-3	3.1		
	362- 1-1	36.8		
	364- 3-1	43.3		
	364- 6-2	38.8		
Pasture		37.0	22.54	
	11- 3-0	3.7		
	93-11-2	12.2		
	93-11-3	1.8		
	192- 7-2	3.3		
	192- 7-3	3.6		
	192- 8-2	12.4		
Waste			3.15	

[a] See table A-2.

APPENDIX B: SELECTED BUDGETING DATA

The basic data used in budgeting and cost function construction are too numerous for detailed presentation. However, a few data relating to particular aspects of the analysis are presented.

Table B-1. Estimated average number of hours per week available for field work by weeks in south-central Iowa. [a]

	Week	Hours
March	8-14	4.0
	15-21	12.4
	22-28	28.1
	29-April 4	40.2
April	5-11	46.3
	12-18	46.3
	19-25	51.1
	26-May 2	44.7
May	3- 9	43.1
	10-16	50.3
	17-23	45.3
	24-30	49.7
	31-June 6	44.5
June	7-13	46.3
	14-20	46.3
	21-27	48.2
	28-July 4	52.1
July	5-11	55.5
	12-18	53.4
	19-25	54.2
	26-Aug. 1	52.1
Aug.	2- 8	49.4
	9-15	52.6
Aug.	16-22	55.3
	23-29	52.4
	30-Sept. 5	52.2
Sept.	6-12	55.0
	13-19	56.3
	20-26	53.1
	27-Oct. 3	53.1
Oct.	4-10	52.2
	11-17	54.7
	18-24	54.4
	25-31	56.9
Nov.	1- 7	56.9
	8-14	54.7
	15-21	54.7
	22-28	48.8
	29-Dec. 5	30.9
Dec.	6-12	25.0
	13-19	11.8
	20-26	2.4
Annual total		1,896.9

[a] Basic data obtained from: Dean E. McKee. Scale associated with decreasing and increasing costs in cash grain farming. Unpublished M.S. thesis. Iowa State University Library, Ames, Iowa. 1953. Data were adjusted on the basis of climatological data from: Robert H. Shaw, H. C. S. Thom and Gerald L. Barger. Climate of Iowa. I. The occurrence of freezing temperatures in spring and fall. Iowa Agr. Exp. Sta. Spec. Report 8. 1954.

Table B-2. Estimated rent per acre of land mixtures in the Shelby-Grundy-Haig soil association area.

Item	Land mixtures Hilly	Average	Upland
Land price[a]	$72.07	$131.64	$222.09
Interest charge[b]	3.20	5.84	9.86
Tax charge[c]	1.48	2.71	4,57
Land rent	4,68	8.55	14.43

[a]Dwight M. Gadsby. Farm land prices in selected Iowa counties during 1958 and 1959. Unpublished M.S. thesis. Iowa State University Library, Ames, Iowa. 1959.
[b]Interest rate of 4.44 percent, adapted from: Wilellyn Morelle. Interest rates on farm loans. Federal Reserve Bulletin 43:259-268. 1957.
[c]Based on a survey of county treasures in the study area. Assessed values are 30 percent of the land prices, and the tax rate is 68.54 mills per dollar of assessed value.

Table B-3. Beef-cow, sell-calf enterprise: estimated revenue and costs per unit.[a]

Item	Revenue and costs
Total revenue	$82.36
Annual cash expenses	
Power	1.77
Shelter and equipment use	3.20
Breeding cost	7.00
Hauling	1.59
Veterinary and miscellaneous	6.74
Labor[b]	20.61
Total annual cash expense	40.91
Total interest charge	12.86
Housing depreciation cost	2.58
Total cost	56.35
Net revenue	26.01

[a]Based on: George David Irwin. Effect of pork production techniques on optimum farm resource use. Unpublished M.S. thesis. Iowa State University Library, Ames, Iowa. 1959; and Dale A. Knight and C. F. Bortfeld. Labor and power requirements by size of enterprise for beef cattle systems in eastern Kansas. Kan. Agr. Exp. Sta. Tech. Bul. 98. 1958. A unit equals a cow, calf and replacement stock.
[b]Annual labor requirements, and, thus, labor expenses per unit, vary with herd size. Labor requirements for herds with 0 to 19, 20 to 29, 30 to 109, and 110 or more units were 15.27, 14.22, 8.20 and 7.85 hours per year, respectively.

Table B-4. Shelby-Grundy-Haig association soils, hilly farm: estimated requirements per acre for nitrogen, phosphorus and potassium for selected crop rotations.[a]

Rotation and crop	Nitrogen (pounds)	Phosphorus (pounds)	Potassium (pounds)
CCOMM			
C	25	41	25
C	69	41	25
O	24	33	0
M	0	18	7
M	0	18	7

[a]Adapted from: W. D. Shrader, F. W. Schaller, J. T. Pesek, D. F. Slusher and F. F. Riecken. Estimated crop yields on Iowa soils. Iowa Agr. and Home Econ. Exp. Sta. Spec. Report 25. 1960.

Table B-5. Shelby-Grundy-Haig association soils, average farm, cropland A and B: estimated requirements per acre of nitrogen, phosphorus and potassium.[a]

Rotation and crop	Nitrogen (pounds)	Phosphorus (pounds)	Potassium (pounds)
Cropland A			
CCOM			
C	23	27	11
C	49	27	11
O	16	26	0
M	0	11	1
Cropland B			
CCOMM			
C	20	39	33
C	62	39	33
O	21	32	0
M	0	20	16
M	0	20	16

[a]Adapted from: W. D. Shrader, F. W. Schaller, J. T. Pesek, D. F. Slusher and F. F. Riecken. Estimated crop yields on Iowa soils. Iowa Agr. and Home Econ. Exp. Sta. Spec. Report 25. 1960.

Table B-6. Shelby-Grundy-Haig association soils, upland farm: estimated requirements per acre of nitrogen, phosphorus and potassium for selected crop rotations.[a]

Rotation and crop	Nitrogen (pounds)	Phosphorus (pounds)	Potassium (pounds)
CCSb			
C	63	26	11
C	63	26	8
Sb	0	11	0

[a]Adapted from: W. D. Shrader, F. W. Schaller, J. T. Pesek, D. F. Slusher and F. F. Riecken. Estimated crop yields on Iowa soils. Iowa Agr. and Home Econ. Exp. Sta. Spec. Report 25. 1960.