Farm Size Adjustments in Iowa and Cost Economies in Crop Production for Farms of Different Sizes

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Farm Size Adjustments in Iowa and Cost Economies in Crop Production for Farms of Different Sizes*

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The relation of cost economies to size of farm has been a subject of considerable speculation in Iowa. Farmers are interested in farms of different sizes because cost advantages or disadvantages have an important bearing on farm profits. Other segments of the population have also been interested in size and scale economies in farming. Many people put forth the hypothesis that modern farming methods give very great cost economies to the large acreage. The supposition is: "Mechanization results in very low per-acre costs for large units and a danger exists that these cost advantages will give rise to large-scale units which cause the liquidation of family-farm units." Whether or not a threat of this nature actually exists depends on the costs associated with farms of different sizes.

Discussion of farm size has gone on with very little knowledge of the cost economies realized in different types of agriculture. Certain aspects of cost are, however, evident: (1) Cost economies are likely greatest in grain and crop farming systems; mechanization has been developed particularly around these enterprises. Important changes have taken place in production of livestock. fruit and vegetable crops. However, the adaptation of mechanization to these enterprises has not been great. (2) If foods and fibers are to be produced efficiently, and farm families are to have favorable incomes, the size of the farm must be great enough to attain some of the efficiencies inherent in mechanization. Farms that are too small will result in low income.

Information is needed to suggest the nature of cost economies associated with farms of different sizes and to indicate the scale of operations which allow maximum farming efficiency. This report is one of several studies dealing with efficiency and productivity in relation to the quantity of resources employed and farm size. Subsequent reports will show the level and source of income and the marginal returns of resources for farms using different amounts of capital, labor and land.

This report deals specifically with farm size as measured in acres. Its specific objectives are these: (1) to briefly trace the pattern of adjustment in farm size over a period of time for different areas of the state, (2) to examine the nature of farming costs in crop production, (3) to examine the nature of risk and uncertainty and other forces which are determinants of farm size. Subsequent reports will deal with the nature of costs for different types of livestock production.

This study is based upon data from three sources: The first section of this study, dealing with historic adjustments in acres per farm, is drawn from the various federal census reports for Iowa. The second section outlines the logical models which underlie the empirical sections which follow. The third section, dealing with budget cost estimates. is based on information from engineering and farm management research. The fourth section, involving estimates of production and cost functions, is derived from random samples of farms in the years 1948 and 1951. The fifth section, based only on the 1948 sample survey, is an analysis of subjective estimates of farmers in relating farm size to risk or uncertainty.

HISTORIC PATTERN OF FARM SIZE ADJUSTMENT IN IOWA

Since growth of mechanization in Iowa has brought forth much speculation on "prospective" farm size changes, this section is devoted to historic trends in farm size. Numerous trends which have bearing on farm size have developed since 1920.[1] Some of these have been opposite in effect and perhaps others have not had full opportunity to become manifest. Nevertheless, some trends for the state as a whole are discernible.

Aside from temporary lulls in farm size adjustments, the noticeable trend for the state as a whole was toward consolidation and somewhat larger units between 1920 and 1930.[2] The average

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* Project No. 1135, Iowa Agricultural Experiment Station.

[1] For an analysis of farm sizes early in the history of Iowa agriculture, see Heady, Earl O. Pattern of farm size adjustments in Iowa. Iowa Agr. Exp. Sta. Res. Bul. 350. 1947.

[2] Such short-run forces as drouth and depression may act either as a stimulant or as an obstacle to farm size expansion. If incomes are already low in an area, a further decline may push returns to a level where farm expenses, debt payments and family living cannot be met. In this case, some operators will be forced to abandon farming. and the opportunity for others to consolidate will then exist. If incomes are considerably above the level necessary to meet fixed obligations, drouths or depression may slow down adjustments in farm size; income may not drop to the distress level, but the uncertainty and lower incomes of the period will hold people back on the farm. Likewise, the duration of the low-income period will be important in determining whether operators are forced from their farms and consolidation is encouraged. A comparison of the 5-year periods 1925-30, 1930-35 and 1935-40 suggests that, for the state as a whole, the severe de-

size of all farms over 19 acres in size increased from 165.3 acres in 1920 to 172.9 in 1940. As indicated in table 1, the number of farms in each of the size groups 20 to 49, 50 to 99 and 100 to 174 acres decreased from 1920 to 1950. The number in the group 175 to 259 acres increased between 1920 and 1930, decreased in the 1930-40 period and increased again in the period 1940-50. On the other hand, the number of farms over 259 acres in size increased in each of the 10-year periods. The greatest percentage change for any one group was in the size range of 500 acres and over (table 2). During World War II, and in the postwar period, the trends started after 1920 were continued for the state generally. The period was favorable to adjustment of farm size because it opened up opportunities of employment in other occupations.

PATTERN OF CHANGE BY TYPE-OF-FARMING AREAS

An examination of state figures alone fails to reveal some of the trends in farm size since an increase in one area offsets a decrease in another. Data by type-of-farming areas are included in tables 3 and 4. Adjustments in farm size vary considerably among areas of the state.

Less change in the total number and size of farms has taken place in the Northeast Dairy and Cash Grain areas than in other areas of the state. The greatest total change in number and size of farms has been in the Southern Pasture area. Between 1920 and 1950 the number of farms in this area over 49 acres in size decreased by 13.1 percent (table 4). In each of the 10-year periods, there was a decrease in the number of farms under 175 acres and an increase in the number over 260 acres (table 3). Numbers of small farms have decreased in the Eastern Livestock area; numbers of large farms have increased.

TABLE 1. NUMBER OF FARMS OF OVER 19 ACRES, BY SIZE DISTRIBUTION, IOWA, CENSUS YEARS 1910-50.

Size in acres	1910	1920	1930	1940	1950
20-49	15,678	13,117	12,178	12,003	*
50-99	38,712	35,959	32,209	32,146	25,925
100-174	80,121	85,549	84,722	82,393	77,486
175-259	40,304	41,414	42,615	41,452	42,281
260-499	25,861	23,865	25,546	26,119	28.110
500 and over	2,644	2,014	2,136	2,583	3,093
All farms over 19 acres	203,320	201,918	199,406	196,406	*
All farms over 49 acres	187,642	188,801	187,228	184,693	176,895

* Data not available.

TABLE 2. PERCENT DISTRIBUTION OF FARMS OVER 19 ACRES IN SIZE, IOWA, CENSUS YEARS 1910-50.

Size in acres	1910	1920	1930	1940	1950
20-49	7.7	6.5	6.1	6.1	8.4*
50-99	19.0	17.8	16.1	16.3	13.4
100-174	39.5	42.4	42.5	41.9	40.1
175-259	19.8	20.5	21.4	21.1	21.9
260-499	12.7	11.8	12.8	13.3	14.6
500 and over	1.3	1.0	1.1	1.3	1.6
All farms	100.0	100.0	100.0	100.0	100.0

* 10 to 49 acres and hence this class is not comparable for earlier years with 20 to 49 acres.

The wartime and postwar periods of full employment, with higher returns for many people in nonfarm employment than for those operating relatively small acreages, has tended to speed up the rate at which farms have been consolidated. While cost economies may have served, particularly in earlier years, as a force which "pushed" some operators from their units, the more favorable nonfarm opportunities in the last decade have served as an important force which has "pulled" people from farms, thus allowing an expansion by remaining units. Also, incomes of remaining farmers have been favorable in that they could accumulate funds and expand their units; some could add to their units as parcels or farms were offered for sale. "Pushing" in this sense may be as important or more important than "pushing" due to per-unit cost advantages. In terms of the cost data presented in a later section, we believe that these considerations are more important than cost differentials due to further mechanization. We also believe that extreme adjustments in farm size are not in sight but that recent trends will continue. Often the results will be beneficial—a low-income farm unit will vanish from the picture, its previous or prospective operator will have better economic opportunities elsewhere, and the person who combines it with his previous unit will have a more efficient farm.

Mechanization, a factor commonly mentioned, should have had some effect in bringing about adjustments over long periods. The number of tractors in Iowa increased from 20,000 in 1920 to 241,000 in 1950. The pattern of change in Iowa suggests that mechanization, while a factor favoring farm consolidation, has not been the only or the most important factor in bringing about farm size adjustments. For the state as a whole, consolidations have nowhere nearly kept abreast of mechanization. It is true that the effects of mechanization can only be gradual and will show up to a greater extent in the future. This does not account, however, for such wide differences as are evidenced between different parts of the state. On the basis of mechanization alone, the greatest amount of consolidation might be expected in an area such as the Cash Grain area, where grain is important relative to other products as a source of income and where the topography is favorable to large-capacity machines. Yet many highly mechanized counties of this area experienced little or no change in numbers of farms even during the 1930-50 period. In contrast, southern counties, which have the smallest

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pression and the drouth of the early 1930's tended to check expansion in farm size. The number of farms decreased slightly in both the first and third periods, but actually increased in the 1930-35 period. The greater rate of consolidation from 1935 to 1940 may also have been a result of the prolonged drouth and depression period. Whereas the initial effect may have been only to hold operators on farms by increasing uncertainties and decreasing the number of other opportunities, the prolonged effect was to crowd operators from their farms as incomes remained near the distress level over a period of several years.

TABLE 3. DISTRIBUTION OF FARMS BY SIZE, TYPE-OF-FARMING AREAS, 1920, 1930, 1940 AND 1950.

Area	Size group in acres						Total over 49 acres
	20-49	50-99	100-174	175-259	260-499	500 and over	
Northeast Dairy							
1920	2,198	6,348	16,329	8,049	3,962	252	34,940
1930	2,061	5,862	16,329	8,156	4,162	252	34,761
1940	2,068	6,138	16,332	8,159	4,065	304	34,998
1950	2,932*	5,130	15,920	8,182	4,356	345	33,933
Cash Grain							
1920	1,748	5,476	17,250	8,039	5,390	371	36,526
1930	1,806	4.990	17,249	8,327	5,903	392	36,861
1940	1,862	5,205	16,770	8.046	5,919	457	36,397
1950	2,895*	4,351	16,575	8,496	5,060	477	35,869
Western Livestock							
1920	2,155	6,815	19,118	9,646	6,071	486	42,136
1930	2,111	6,225	19,476	9,893	6,400	489	42,483
1940	1,962	5,972	18,657	9,460	6,636	670	41,395
1950	2,990*	4.659	17,328	9,756	7,076	826	39,645
Eastern Livestock							
1920	3,651	8,940	18,155	8,718	4,384	370	40,567
1930	3,205	7,895	17,798	9,066	4,556	396	39,711
1940	3,157	7,814	17,508	8,876	4,725	436	39,359
1950	4,051*	6,291	16,456	8,969	5,194	596	41,577
Southern Pasture							
1920	3,365	8,380	14,697	6,962	4,058	535	34,632
1930	2,995	7,237	13,874	7,173	4,525	607	33.416
1940	2,954	7,017	13,126	6.911	4,774	716	32,544
1950	3.647*	5,463	11.287	6,950	5,558	854	30,112

* 10 to 49 acres, and hence this class is not comparable for earlier years with 20 to 49 acres.

TABLE 4. PERCENTAGE CHANGE IN NUMBER OF FARMS BY TYPE-OF-FARMING AREAS IN IOWA, 1920 to 1950.

Area	Farms over 49 acres			
	1920 to 1930	1930 to 1940	1940 to 1950	1920 to 1950
Northeast Dairy	—0.5	+0.7	—0.2	— 2.9
Cash Grain	+0.9	—1.3	—0.1	— 1.8
Western Livestock	+0.8	—2.6	—2.1	— 5.9
Eastern Livestock	—2.1	—0.9	—3.8	— 7.5
Southern Pasture	—3.5	—2.5	—6.6	—13.1

degree of mechanization, show the greatest amount of consolidation.[3]

NATURE OF COSTS IN CROP PRODUCTION

In examining the effects of mechanization and farm size on cost economies, it is worthwhile to make this distinction: First output or size can be expanded in the pure scale manner. Scale adjustments refer to changes in size or output which are brought about by increasing all resources in constant and fixed proportions. Pure scale adjustments are involved if we start with 160 acres, 15 months of labor, a general-purpose tractor and $3,000 in annual expenses and increase the size of the unit, first, to 320 acres, 30 months of labor, two general-purpose tractors and $6,000 in operating expenses and, second, to 480 acres, 45 months of labor, three general-purpose tractors and $9,000 in operating expenses. If these adjustments result, as compared to the first combination, in exactly a doubling or tripling of the output, constant returns to scale exist; the cost per unit will be exactly the same for each of the three farm sizes; no farmer will have a cost advantage due to size. If output is more than doubled or tripled, increasing returns to scale exist; larger farms will realize lower per-unit costs than smaller farms. If output increases but is neither doubled or tripled for the two adjustments mentioned above, decreasing returns to scale exist; per-unit costs of production will favor the small farm.

The second type of adjustment in size involves a *disproportionate* increase in resources; some resources are held constant while others are increased. The result is a change in the proportion of resources as output of the basic plant is expanded. This type of adjustment is reflected when acreage is held constant at 160 acres while labor, feed and livestock are increased on this given area to provide a greater market product; it is reflected when the power unit and complement of machines is held constant while the acres, labor, tractor fuel and other expense items are increased to produce a greater product. Disproportionate resource adjustments in size lead to lower costs when fixed costs associated with the fixed resource (power and machinery in the example here) are large; as fixed costs are spread over more units of product, they decline because the constant outlay is divided by a greater output. Total costs per unit also will become lower if the decline in fixed costs per unit is sufficiently greater than any increase in variable costs per unit.

Questions of cost in relation to farm size revolve mainly, although not entirely, around expansion of the disproportionate type. Most farmers start out with a fixed acreage and, as their capital accumulates, add fertilizer, labor, livestock and other resources on this fixed acreage.

A conceptual illustration of these differences in size changes is useful for the analysis to follow

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[3] For the effect of income on farm size changes see Heady, op. cit.

and can be made in fig. 1.[4] Curve SAC_1 represents a short-run cost curve; it illustrates how per-unit costs change with different levels of output. It is a short-run curve because it represents a disproportionate adjustment wherein some resource is held fixed while others are increased in amount. Curve SAC_1 might be taken to represent the average cost for a farm which operates a variable number of acres with one set of small machines as fixed factors. This curve may decline with greater outputs, as increasing productivity is realized for the variable factor or as fixed costs are spread over a greater output. The costs per unit of product may eventually rise because enough acres are operated with the same machine unit to cause untimely planting, tillage and harvesting. Lower per-acre yields result. The curve of total costs per unit of product increases as soon as yield sacrifices become sufficiently great to offset further declines in fixed machine costs per unit of product.

Curve SAC_2 may represent a farm which includes fixed resources made up of two sets of small machines or one set of large machines. It, too, will have the characteristic "U" shape for the reasons mentioned for SAC_1. On small acreages, cost per unit will be greater for the large unit SAC_2 than for the small unit SAC_1; the greater fixed costs for the larger unit cannot be spread over a great enough number of units of output to result in per-unit cost advantages. For larger outputs, however, cost economies result in lower per-unit costs for the resource combination represented by SAC_2.

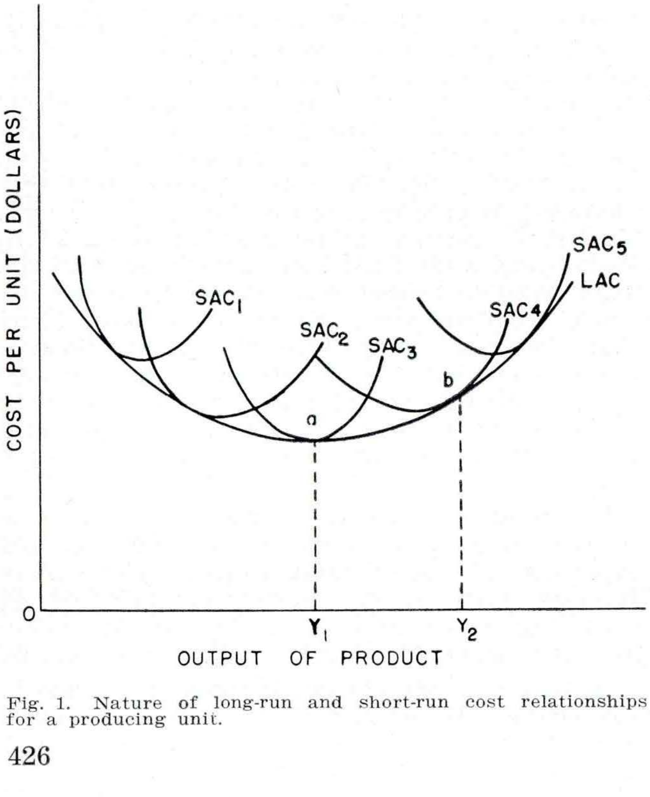

Fig. 1. Nature of long-run and short-run cost relationships for a producing unit.

A different short-run curve exists for each level at which identical factors may be held fixed (e.g., two or three tractors as compared to one) or for each possible form of fixed factors (e.g., a large Caterpillar tractor as compared to a small Ford tractor). Out of an entire family of short-run cost curves, one particular curve has a minimum point which is lower than that of any other curve. SAC_3, in fig. 1, represents such a cost curve. At the minimum point, *a*, the output OY_1 can be produced at a lower cost with the SAC_3 plant than with any other short-run plant. Using per-unit cost of production as the criterion, SAC_3 thus represents the optimum size of producing plant (although the optimum size may be larger under certain short-run price situations and when profit maximization is the criterion). If costs eventually increase (cost diseconomies) for firms of greater scale for any of the reasons already cited, higher short-run curves such as SAC_4 and SAC_5 come about. The cost of producing the output OY_1 is greater under SAC_4 than under SAC_3. However, for "very large" outputs such as OY_2, the per-unit cost is lower under SAC_4.

LONG-RUN COSTS AND PLANNING CURVES

The concept of long-run costs is probably more important to farm size problems than is the concept of short-run costs. A long-run cost curve (LAC in fig. 1) can be constructed for any family of short-run cost curves. The long-run cost curve is the "envelope" of the short-run cost curves; no single resource is fixed for it, as is true for the short-run curves. It is the single curve tangent to the entire family of short-run cost curves. It is tangent to only one point on each single short-run curve. The point of tangency is (a) to the left of the minimum cost point on short-run curves denoting firms of a size less than optimum and (b) to the right of the minimum cost point for plants greater than optimum in size. The point of tangency of the long-run cost curve (LAC) and the short-run curve denote that lowest possible long-run cost (LAC) is also the minimum short-run cost (SAC_3).

The long-run cost curve is actually a planning curve. A person starting farming, for example, might consider costs in the sense of LAC. He could then proceed to build a short-run plant indicated by a particular point such as *a* or *b* on the long-run curve. After the producing plant is constructed, the long-run curve becomes of historic interest only. The relevant decision-making cost curve is then of the short-run nature. Not all farmers can view long-run costs in the sense of a planning curve wherein they select the most profitable point and collect together the relevant set of resources. Instead the size of the unit in agriculture is partly a historical phenomenon wherein a beginning operator acquires a unit of a size determined by the limited resources he possesses.

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[4] These curves also relate to scale relationships if the increase in quantity of factors (the fixed factors represented by SAC_1, SAC_2, etc.) refer to factors which are homogeneous or are of the same form in all cases.

Following acquisition of the unit, additional inputs are added as capital accumulates. Opportunity in choice of the particular short-run plant is open to some farmers, however. This possibility exists for those who own or can borrow capital in large amounts. Similarly, it is open to the "financially able" tenant who can rent farms of various acreages or for corporations which might sell stock and operate on a large-scale basis. The concept of long-run cost curves is most meaningful in agriculture, however, to denote the nature of cost advantage for farms of different sizes.[5]

BUDGETED COSTS FOR FARMS WITH DIFFERENT MACHINE COMBINATIONS

The cost concepts outlined above are fundamental to all analyses of farm size. The particular nature of cost economies or diseconomies will help determine whether or not large farms can use mechanization to "squeeze out" small farms. The relationship of size to cost per unit will determine the profitability of farms with different acreages. This section is devoted mainly to providing the empirical counterpart of the short-run cost curves. An exception must be noted, however. Each short-run curve of this section represents a different technique or machine combination. Finally, a long-run cost curve is derived. This curve refers to cost economies for farms of different sizes using different machine combinations.

Source of Data and Methods of Analysis

The cost data in this section deal with costs associated with machine combinations of different sizes used on different acreages. For budgeting purposes, yields equal to the average of the north central Cash Grain area of Iowa have been used; labor and related inputs are based upon other studies of the Iowa Agricultural Experiment Station; machine repair, depreciation, fuel and similar items are based on engineering data and previous surveys.[6]

Per-acre Costs in Crop Production for North Central Iowa

The first data presented in this section are in terms of costs per acre, rather than costs per bushel or ton of product produced. Costs per acre decline over all acreages. This is because fixed costs per acre continue to decline as more acres are operated, while variable costs per acre such as fuel, seed and labor tend to be constant or increase only slightly.[7] As shown in the next section, however, costs per unit of product eventually increase, as more acres are operated with one machine combination, because of lack of timeliness in operations resulting in declines in per-acre yield. The estimates which follow are based on a corn-corn-oats-meadow rotation, the most common cropping pattern in north central Iowa. The physical yields employed are averages for the area over the previous 10 years. Product is expressed in value because three crops are included. Costs and investments are based on prices at 1949 levels. Subsequently, costs are computed per $100 value of crops produced with prices again at 1949 levels. The data presented in this section are "budget estimates." These data have been derived by setting down all of the operations in crop production, with size of operations considered, and computing the costs involved. The many industrial cost items have then been summed for different acreages; per-unit costs have been computed accordingly. The data best reflect cost structures on farms operated with a fairly high level of efficiency.[8]

MACHINE COMBINATIONS

The machine combinations, with the total investment for new machines, used as a basis of deriving per-acre costs are these:

1. One-plow tractor (15 horsepower), one-bottom (14-inch) mounted plow, 4-foot tandem disk, 20-foot drag harrow, endgate seeder, two-row corn planter, two-row cultivator, 7-foot tractor mower; harvesting operations hired on custom basis. (Required investment at 1949 prices, $2,875.)

2. Two-plow tractor (19 horsepower), two-bottom (14-inch) wheel plow, 8-foot tandem disk, 20-foot drag harrow, endgate seeder, two-row corn planter, two-row cultivator, 7-foot tractor mower, 8-foot 4-bar side delivery rake, 8-foot fertilizer spreader, 5-foot power-takeoff combine, one-row pull-type cornpicker, hay baling hired. (Required investment, $5,790.)

3. One-plow and two-plow tractor combination (each with horsepower indicated above), one-bottom (14-inch) mounted plow, two-bottom (14-inch) wheel plow, 8-foot tandem disk, 11.5-foot single disk, 20-foot drag harrow, endgate seeder, two-row planter, 2 two-row cultivators, 7-foot

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[5] Other alternatives in farm cost structure are outlined in Heady, Earl O. Economics of agricultural production and resource use. Prentice-Hall, New York. 1952.

[6] For a detailed description of the budgeting procedure, see McKee, Dean E. Scale associated with decreasing and increasing costs in cash grain farming. Unpublished M.S. thesis. Iowa State College Library, Ames, Iowa. 1953.

[7] The variable cost line shown in the following figures have slight increases due to the "transfer" of fixed depreciation costs to variable costs as more acres are covered. For details on this point see Husain, S.M. Cost relationships in farm machinery use. Unpublished M.S. thesis. Iowa State College Library, Ames, Iowa. 1949.

[8] Nearly all empirical analyses have limitations in terms of the inferences which can be based on them. This study is no exception. For limitations of budgeting techniques, see Heady, Earl O. and Jensen, Harald R. Farm management economics. Prentice-Hall, New York. 1954. Ch. 5. For limitations of production function analyses, see Heady, Earl O. Productivity and income of labor and capital on Marshall silt loam farms in relation to conservation farming. Iowa Agr. Exp. Sta. Res. Bul. 401. 1953.

tractor mower, 8-foot 4-bar side delivery rake, 8-foot fertilizer spreader, 6-foot power-takeoff combine, one-row pull-type cornpicker, baling hired. (Required investment, $8,555.)

4. Two two-plow tractors, 8-foot tandem disk, 15-foot single disk, 2 two-bottom (14-inch) wheel plows, 20-foot drag harrow, endgate seeder, four-row cornplanter, 2 two-row cultivators, 10-foot fertilizer spreader, 7-foot tractor mower, 8-foot four-bar side delivery rake, 7-foot power-takeoff combine, two-row cornpicker, power take-off baler. (Required investment, $11,724.)

5. Three-plow tractor (26 horsepower), three-bottom (14-inch) wheel plow, 10-foot tandem disk, 24-foot drag harrow, endgate seeder, four-row corn planter, four-row cultivator, 7-foot tractor mower, 8-foot four-bar side delivery rake, 10-foot fertilizer spreader, power-takeoff baler, 8-foot self-propelled combine, two-row mounted cornpicker. (Required investment, $11,792.)

6. Two-plow and three-plow tractors (with horsepower indicated above), two-bottom (14-inch) wheel plow, 10-foot tandem disk, three-bottom (14-inch) wheel plow, 18-foot single disk, 24-inch drag harrow, endgate seeder, four-row corn planter, two-row cultivator, four-row cultivator, 10-foot fertilizer spreader, 7-foot power mower, 8-foot four-bar side delivery rake, power-takeoff baler, 10-foot self-propelled combine, two-row cornpicker. (Required investment, $15,630.)

7. Two three-plow tractors, 2 two-bottom (14-inch) wheel plows, 10-foot tandem disk, 18-foot single disk, 24-foot drag harrow, endgate seeder, 10-foot fertilizer spreader, four-row cornplanter, 2 four-row cultivators, 7-foot power-takeoff mower, 8-foot four-bar side delivery rake, power-takeoff baler, 12-foot self-propelled combine, two-row cornpicker. (Required investment, $16,912.)

While numerous other machine combinations are possible, those described appeared to be most feasible in terms of farm operation. With the one-plow machinery combination, cornpicking, raking, baling and combining were assumed to be hired on a custom basis. Only baling was assumed to be entirely a custom operation with the two-plow and the one-plow, two-plow machinery combinations. While prices have gone up since 1949, the relative costs of different machine combinations are very much the same; the entire cost curve has moved up for all combinations. Constant per-acre costs for seed, fertilizer and hauling and transporting have been used over the entire range of acreages considered. Labor costs have been computed on a basis of a charge of $1.00 per hour of labor employed.

In separating costs, variable costs (those which depend on the number of acres operated and the production per acre) have been computed to include twine, baling wire, seed, fertilizer, transportation and hauling, custom work, fuel, grease, labor and all outlays of a similar nature. Fixed costs include machinery, housing, taxes, insurance, obsolescence, depreciation and interest on investment calculated as an average over the life of each machine. "Time" depreciation was included with fixed costs while "wear" depreciation was included with variable costs.

COSTS PER ACRE

Per-acre costs are shown in figs. 2 through 9 for the seven machine combinations. As in all graphs presented, the legends have these equivalents: ATC = average total costs; AVC = average variable costs; AFC = average fixed costs. Per-acre costs fall very rapidly for the first few acres. This sharp decline is due to the reduction in fixed costs per acre with variable costs remaining constant or nearly constant. However, the curves tend to flatten out for sufficiently large acreages. For the one-plow tractor combination, total costs per acre decline only slightly after 80 acres because variable costs constitute a much greater proportion of total costs than do fixed costs. Costs per acre are $25.60 for 80 acres and drop to only $23.39 for 120 acres, a decline of only 8 percent in per-acre costs for an increase of 50 percent in acreage. While the decline in per-acre costs is continuous and "one of degree" for all combinations, costs per acre continue to decline quite rapidly up to 200 acres for the two-plow tractor combination. At 200 acres the cost is $19.55, but it declines to only $18.79 at 240 acres. For a three-plow tractor outfit, per-acre costs decline quite rapidly up to 400 acres where they are $17.02; they fall to only $16.60 at 480 acres.

The decline over a larger acreage range for the large power and machine combinations is due to the fact that their fixed costs are high; a low per-acre cost can be attained only by large-scale operations. The curves begin to flatten out only when variable cost per acre becomes greater than fixed cost per acre. (Total per-acre cost approaches variable cost, as a mathematical limit, as operations are extended over an infinite number of acres.) Conversely, per-acre costs for small-scale operations are less with small power and machine units because they involve a greater proportion of variable costs and a smaller proportion of fixed costs.

As indicated in fig. 9, lowest costs are realized on extremely small acreages by the smallest machine and power combination. For 40 acres of cropland, costs per acre are $32.36 for the one-plow tractor outfit; next lowest for this same acreage is the two-plow outfit with costs of $41.77. A three-plow outfit gives costs of $69.90; the two three-plow outfits would have a cost of $95.45, an outlay entirely prohibitive for a farm of this size. The small outfit gives lowest per-acre costs up to approximately 118 acres; for larger acreages, the two-plow unit results in lower costs. The two-plow outfit is clearly the least costly from slightly below 120 acres, where its curve crosses the curve for the one-plow outfit, to slightly above 320, the estimated maximum feasible for the two-plow machine combination. The broken (vertical) lines in figs. 2-8 indicate the acreage capacity that engineers estimate to be feasible over a period of time with normal weather fluctuations for each machine combination. At 200 acres, a three-plow and

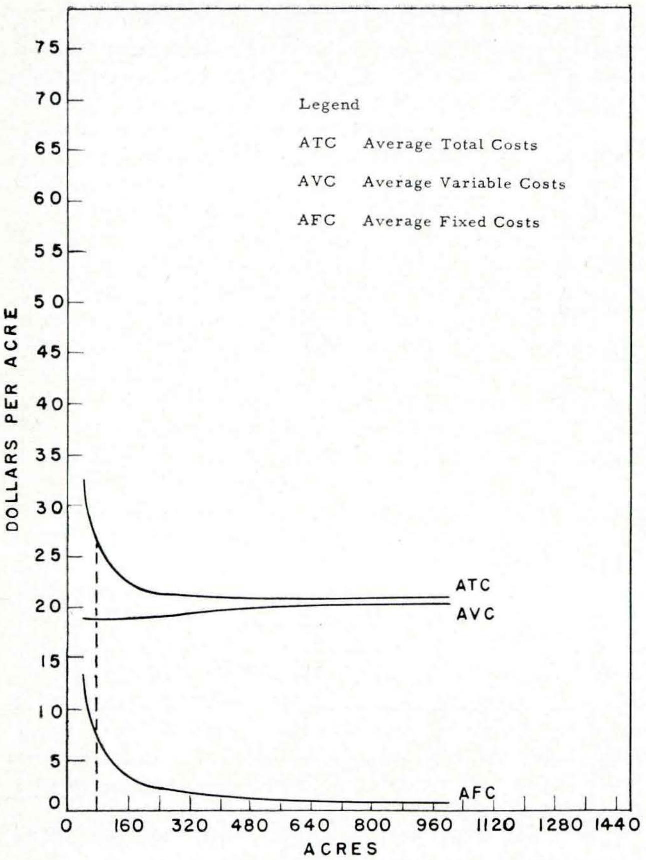

Fig. 2. Per-acre costs for the one-plow machinery combination.

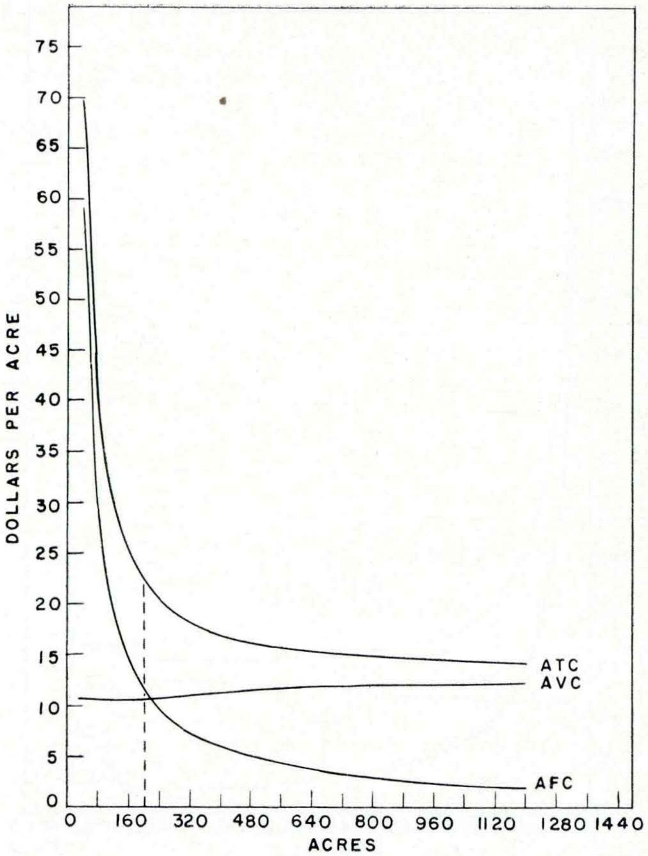

Fig. 4. Per-acre costs for the three-plow machinery combination.

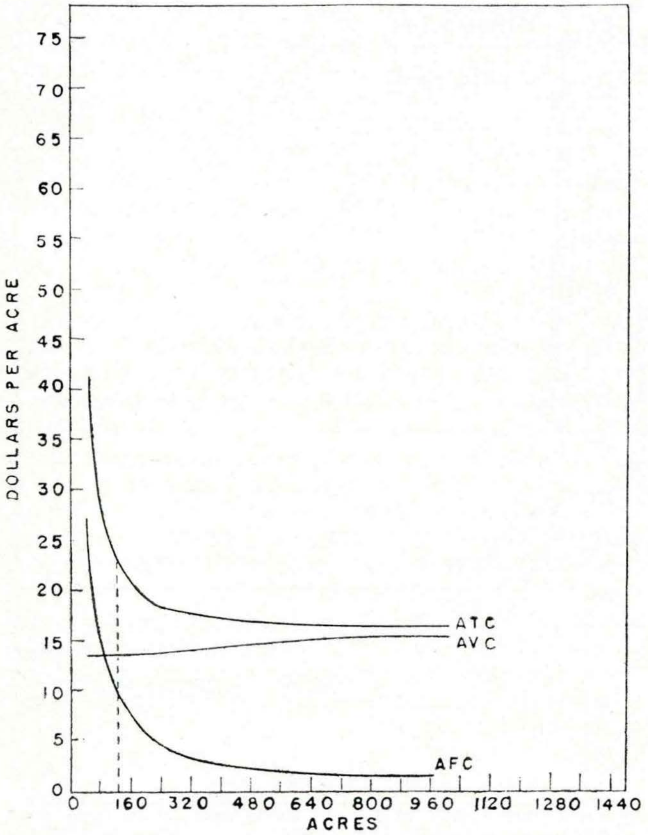

Fig. 3. Per-acre costs for the two-plow machinery combination.

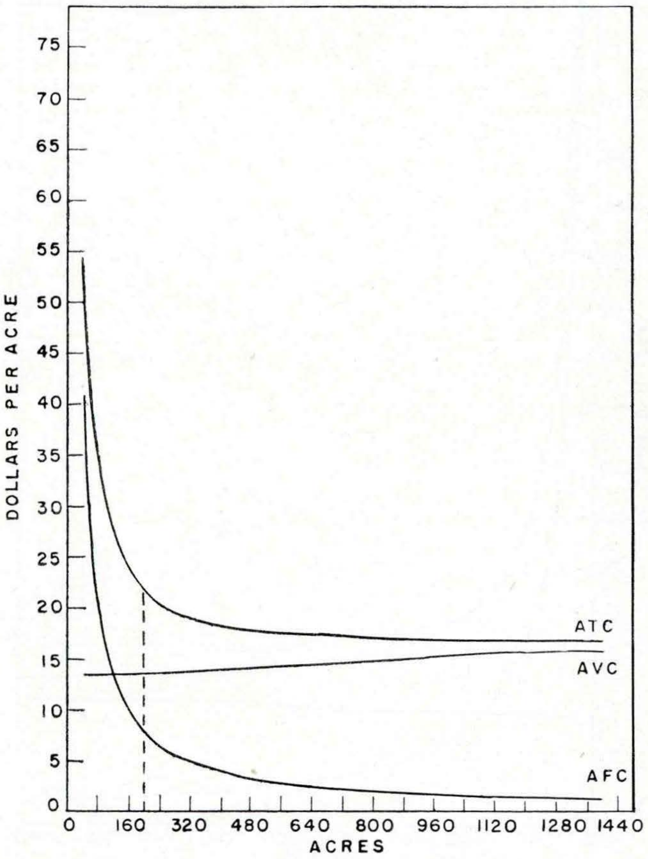

Fig. 5. Per-acre costs for the one plow, two-plow machinery combination.

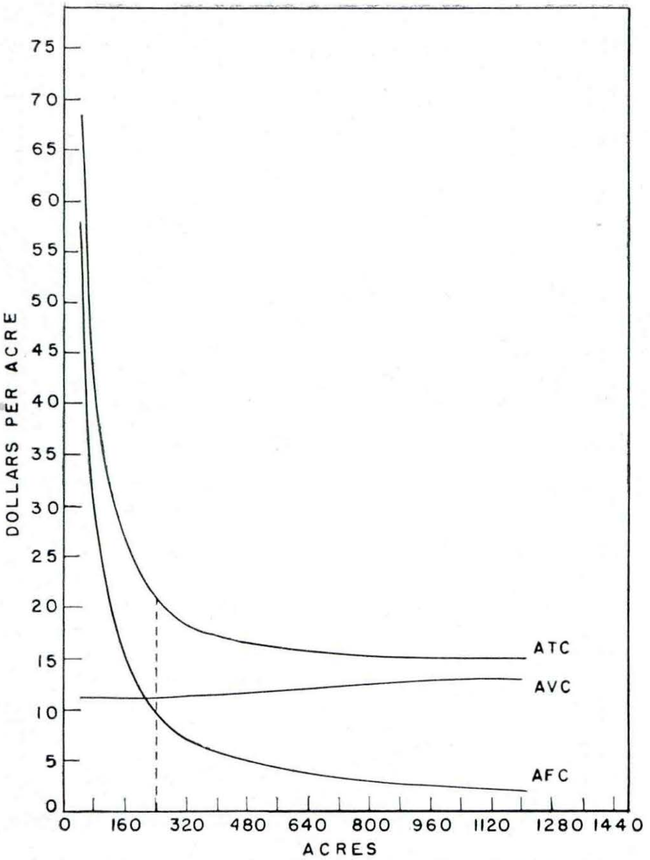

Fig. 6. Per-acre costs for the two-plow, two-plow machinery combination.

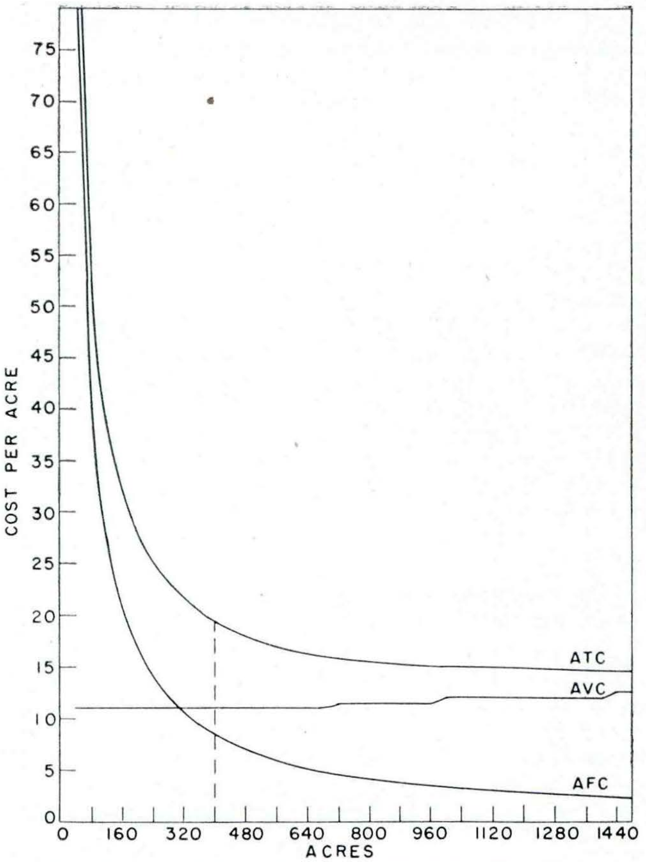

Fig. 8. Per-acre costs for the three-plow, three-plow machinery combination.

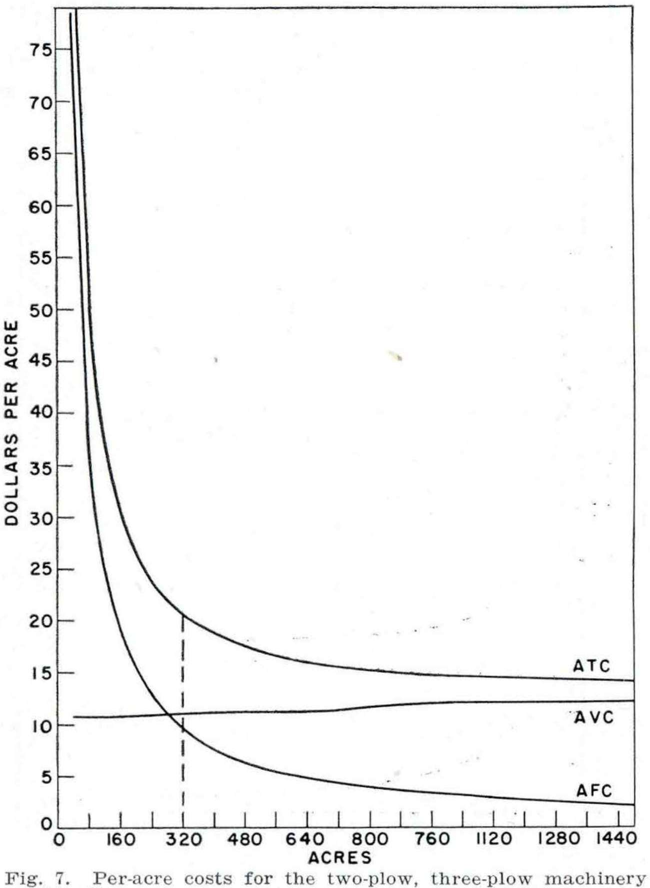

Fig. 7. Per-acre costs for the two-plow, three-plow machinery combination.

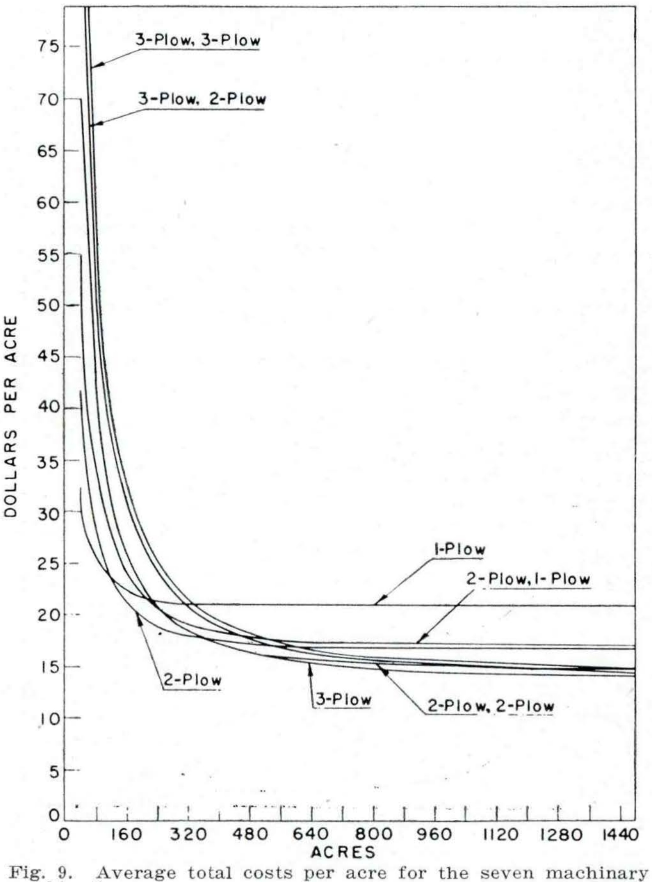

Fig. 9. Average total costs per acre for the seven machinary combinations.

a 2 two-plow combination give costs of $22.52 and $22.75, respectively. Because of the reserve power, the second unit would be preferable for the small cost differences; it allows greater flexibility for backward and untimely weather.

If we compare the per-acre costs for the seven machine combinations, with size of farm broken at 40-acre intervals to match the units by which farms are most commonly bought and sold, we have the following costs for an acreage representing the "engineering optimum" under normal weather: (1) one-plow, $25.60 at 80 acres, (2) two-plow, $23.10 at 120 acres, (3) three-plow, $22.52 at 200 acres, (4) one-plow and two-plow, $21.91 at 200 acres, (5) 2 two-plows, $20.84 at 240 acres, (6) two-plow and three-plow combination, $20.77 at 320 acres and (7) 2 three-plows, $19.38 at 400 acres.

Cost differences for the varying acreages and machine combinations are not as great as is sometimes supposed. Aside from the smallest unit, the low-cost point for "feasible" operations ranges from $23.10 for the two-plow unit to $19.38 for the 2 three-plow combination. The difference of $3.72 per acre is not as great as it might appear if we consider the fact that a large portion of the labor for the larger unit would be hired while for the smaller unit the majority would come from the operator and family; returns per acre might even be greater under the two-plow outfit when differentials due to family labor are considered.[9]

Hence we might predict that cost differentials for farms and machine combinations are not likely to be the final determinants of farm size. Cost advantages in machines do exist for larger units. However, these advantages in machine costs may be unimportant relative to cost advantages in family labor on smaller units; or, penalty and discount put on larger capital outlays because of risk and uncertainty may outweigh cost advantages for larger units. These aspects of size are discussed with more detail in later sections.

COSTS PER UNIT PRODUCED

Per-acre costs in figs. 2 to 9 never rise in the manner of the short-run curves of figs. 10 to 16 because they are based on near-linear relations; fixed costs have been calculated and to these have been added the nearly constant per-acre variable costs relating to labor, seed, fuel and the other items mentioned previously. Extension of the number of acres operated with one machine unit eventually results in lower acre yields. Normal weather fluctuations include extended periods of rain, early frosts, unseasonal snow and extreme winds; the number of days available for tillage, planting and harvesting operations are limited accordingly. This section deals with per-unit costs when weather and yield forces are considered.

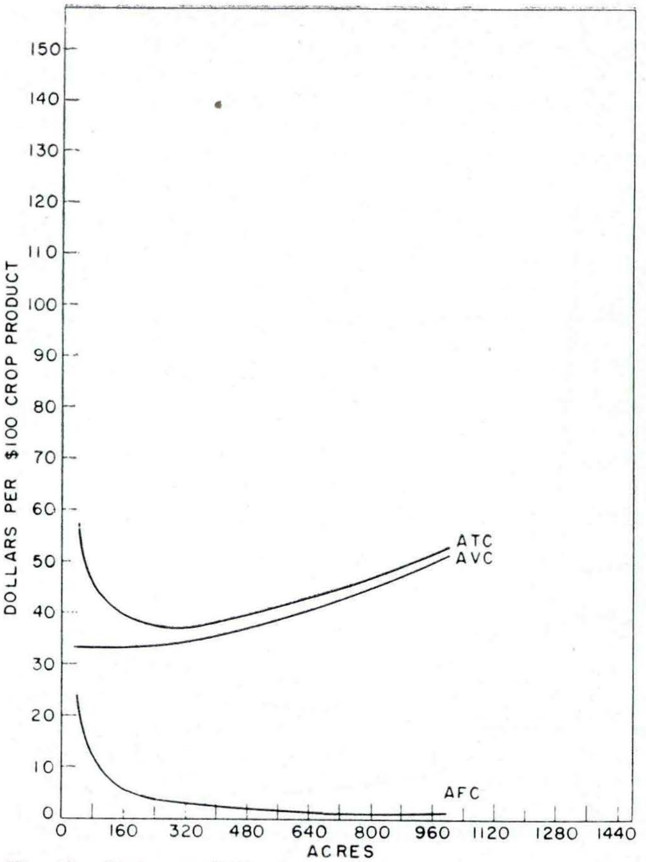

Fig. 10. Costs per $100 of crop product for the one-plow machinery combination.

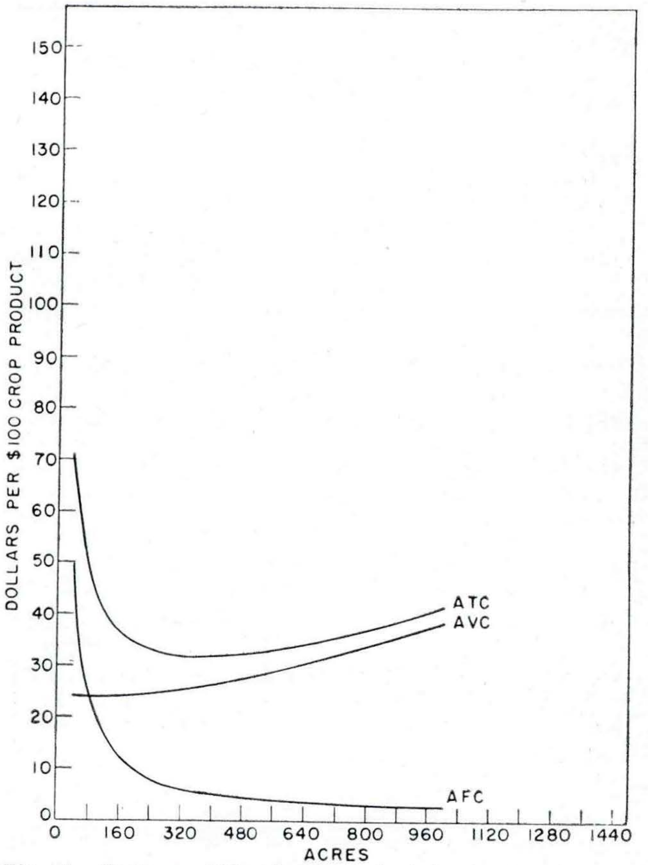

Fig. 11. Costs per $100 of crop product for the two-plow machinery combination.

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[9] All cost computations include labor figures as a cost even though it might be furnished by the family. In many instances, family labor may be considered to have a zero opportunity cost. Therefore, the cost differential between large farms using much hired labor and small farms using mainly family labor is not actually as great as the analysis would indicate.

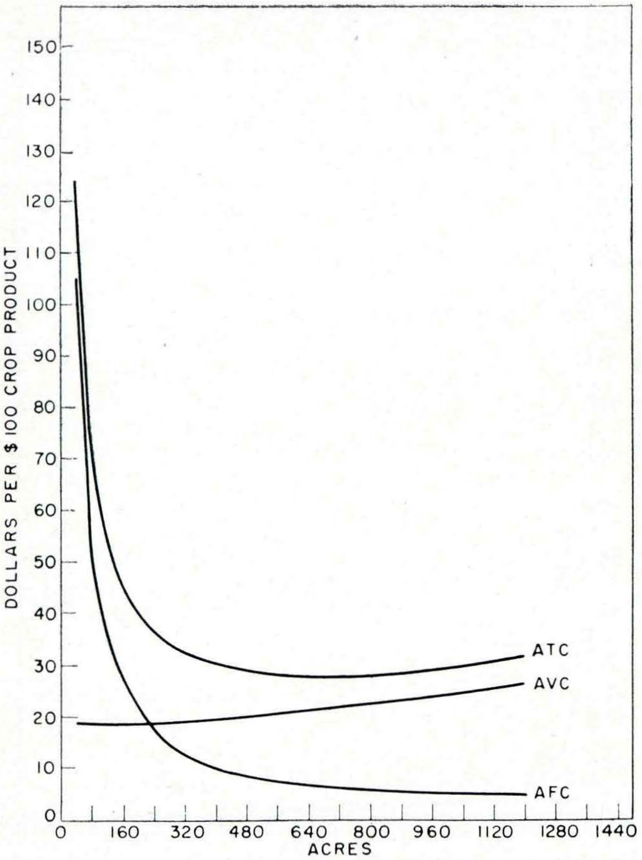

Fig. 12. Costs per $100 of crop product for the three-plow machinery combination.

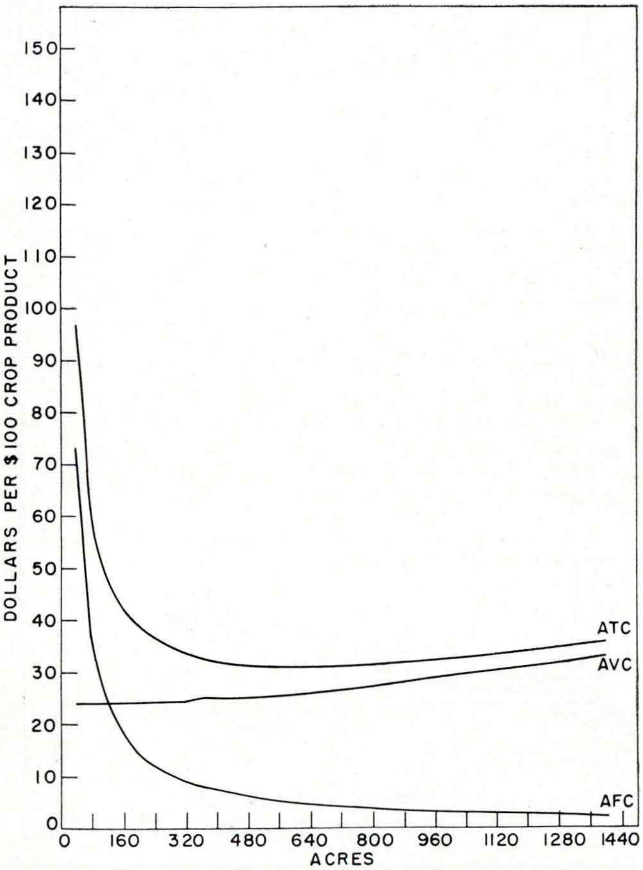

Fig. 13. Costs per $100 of crop product for the one-plow, two-plow machinery combination.

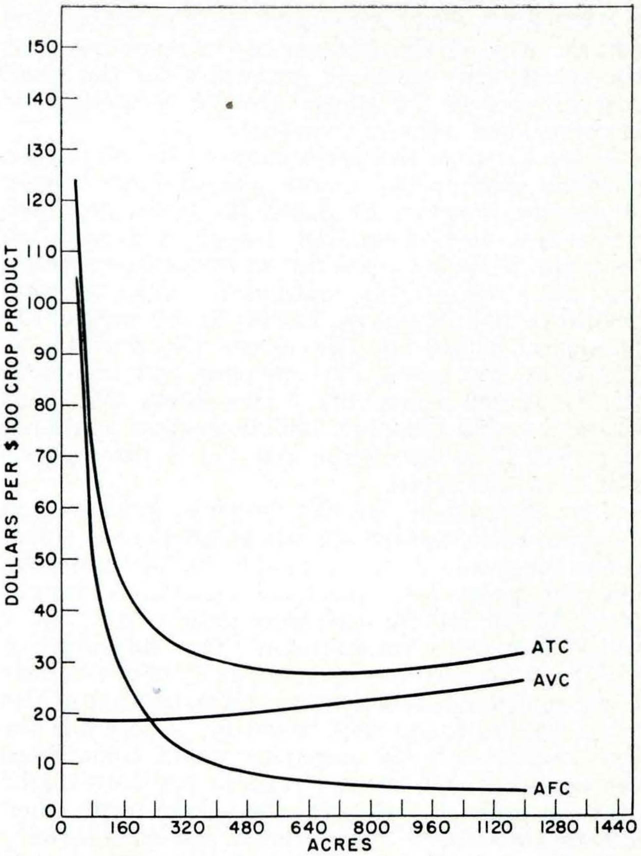

Fig. 14. Costs per $100 of crop product for the one-plow, two-plow machinery combination.

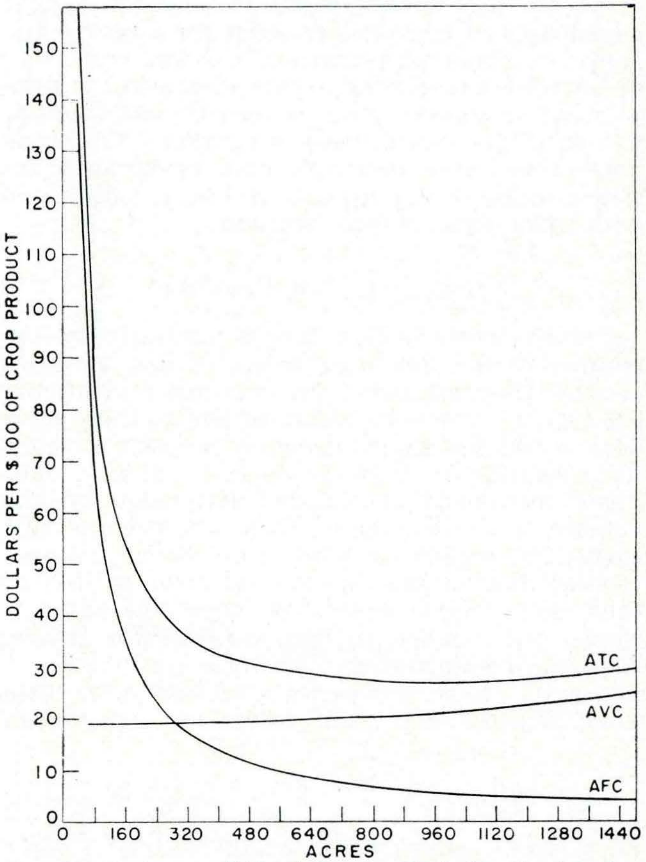

Fig. 15. Costs per $100 of crop product for the two-plow, three-plow machinery combination.

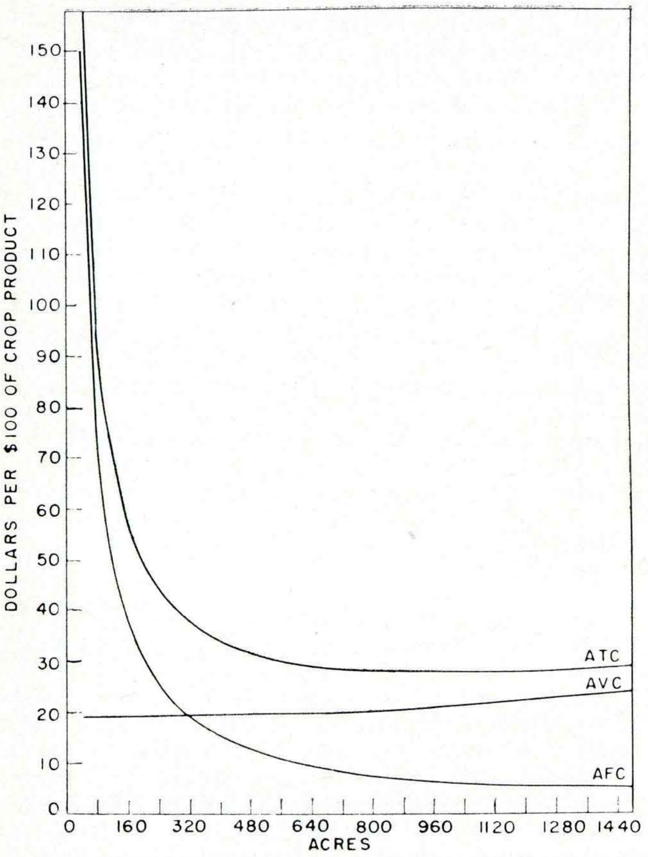

Fig. 16. Costs per $100 of crop product for the three-plow, three-plow machinery combination.

Costs are now presented on a basis of outlay per $100 of product produced.

In arriving at the expected total crop output, it was first necessary to obtain some estimate of the time available for carrying out the cropping operations during the growing season. The time available is dependent upon such factors as air and soil temperature, humidity, precipitation, soil moisture, wind velocity, frost dates and soil characteristics. Sufficient data were not available to establish the degree to which each of these factors affect the different cropping operations that must be carried out. Therefore an estimate of the time available for field operations during the cropping season was obtained from a summary of the daily work journal kept by the manager of the Iowa State College Agronomy Farm at Ames. This journal was summarized over the 19-year period, 1932 to 1952. The years 1940 and 1941 were excluded because records were not available for those years. The average number of working days available per week (see Appendix A, table A-2) was used as a basis for the budget estimates of costs per unit of output.

It was next necessary to determine the reduction in yield due to untimeliness in field operations. Not only were quantitative yields figured, but quality of crop with price differentials figured accordingly was considered.

The effect of planting date on corn and oats yields was obtained from studies carried out by the Agronomy Department of Iowa State College. Corn yields were estimated to be reduced by approximately 0.56 bushel per acre for each day that planting was delayed beyond about June 4.[10] Each day that the sowing of oats was delayed beyond April 16, the yield was estimated to be reduced by about 1 bushel per acre.[11] The quality of hay produced was determined by considering the probability of rain falling on hay that had been cut but not yet baled.[12] It was assumed that each rain falling on mown hay would reduce the quality by one U. S. hay grade. The proportion of hay output falling in each hay grade was determined by multiplying the total production by the probability of it receiving zero, one, two or three or more rains while lying in the field after being mown. The hay output in each grade was multiplied by its respective price, and the total value of the entire output was then divided by the tons of all grades of hay produced to arrive at a composite price for the hay. Time of harvesting had little effect on hay grade as long as it was harvested before maturity.[13]

As the acreage operated by a particular machine combination is expanded, timeliness considerations become more significant. The capacity of the machine combination and the time available to complete the field operations are fixed. Delay in completing the field operations will result in lower yields due to the fact that the work cannot be carried out on time. With variable costs increasing in proportion to acreage and with per-acre output declining due to untimeliness of field operations, costs per unit of output will begin to rise and the characteristic U-shaped average total cost curve will be obtained. Figures 10 to 16 show unit costs of production under the conditions outlined above. The marginal costs that correspond to these figures are given in Appendix B.

These short-run cost curves, with the machine combination representing the fixed resources in each case, now decline in early ranges due to the spreading of fixed costs over a larger acreage and output; they eventually rise due to yield reductions as more acres are operated with a fixed machine combination and operations extend into unfavorable growing or planting periods. Each cost curve has a minimum point representing the most efficient acreage under average weather conditions. These minimum cost points fall at the following acreages, in the order of the graphs presented: 280, 360, 680, 640, 800, 960 and 960. The corresponding per-acre costs are $37.54, $32.01, $27.97, $30.89, $27.33, $27.33 and $27.51.

The acreage at which these minimum points occur differs considerably from the acreage associated with "engineering optimum" previously in-

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[10] U. S. Bureau of Plant Industry, Division of Cereal Crops and Diseases. In cooperation with the Iowa Agricultural Experiment Station. Annual report of corn breeding investigations. (Unpublished research.) Ames, Iowa. 1951.

[11] Burnett, L. C. Sow oats early. Iowa Farm Science. Vol. 3, No. 9, March, 1949, p. 10.

[12] Bivens, Gordon E. Problems in evaluating the economy of improved harvesting methods. Unpublished M.S. thesis. Iowa State College Library, Ames, Iowa. 1953.

[13] Wilsie, C. P. and Hollowell, E. A. Effect of time of cutting on forage yields, seed setting and chemical composition. Iowa Agr. Exp. Sta. Res. Bul. 357. 1948.

dicated. This discrepancy is most likely due to the fact that the costs per $100 of crop product have been based on average weather conditions. The "engineering optimum" or that acreage estimated to be most feasible for each machinery combination includes a consideration of weather conditions more adverse than average. Therefore, it would be expected that the "engineering optimum" would be at a smaller acreage than the minimum costs per $100 of crop product.

The one-plow machinery combinations again result in lowest costs per $100 of crop production up to about 120 acres, where its cost curve is intersected by the curve of the two-plow combination. The unit costs of the two-plow combination are lowest relative to the other combinations from 120 to 360 acres. From 360 to 600 acres, lowest unit costs are obtained with the three-plow combination. For all machinery combinations, lowest cost per $100 of crop product is achieved by the 2 two-plow combination at acreages from 600 to 880 under average weather conditions. Lower unit costs relative to the other combinations at acreages between 880 and 1,320 are obtained with the two-plow, three-plow combination. At 1,320 acres the cost curve of this latter machinery combination is intersected by the curve of the 2 three-plow combination. Figure 18 has been included to suggest the nature of long-run or planning costs.[14] This curve is the "envelope" curve of the family of average cost curves appearing in fig. 17.

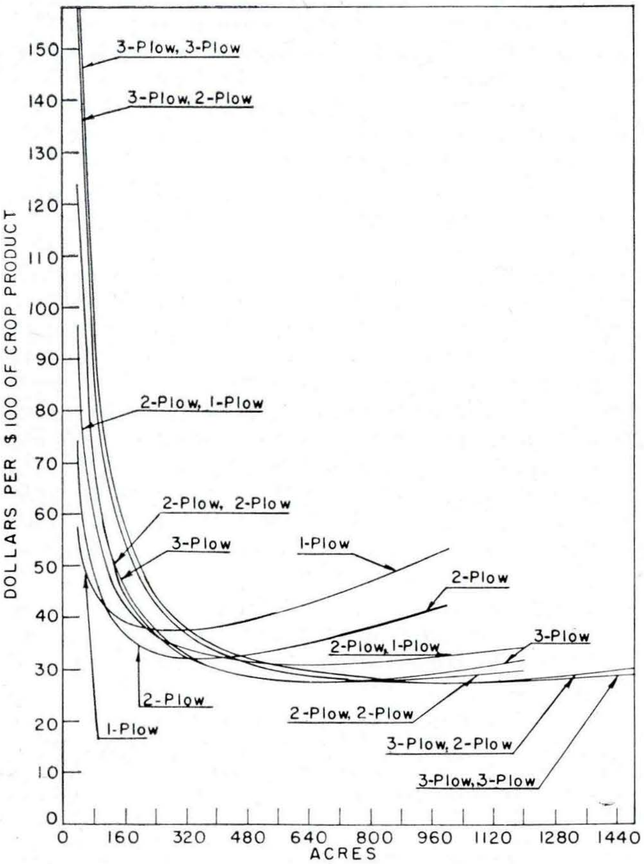

Fig. 17. Average total costs per $100 of crop product for the seven machinery combinations.

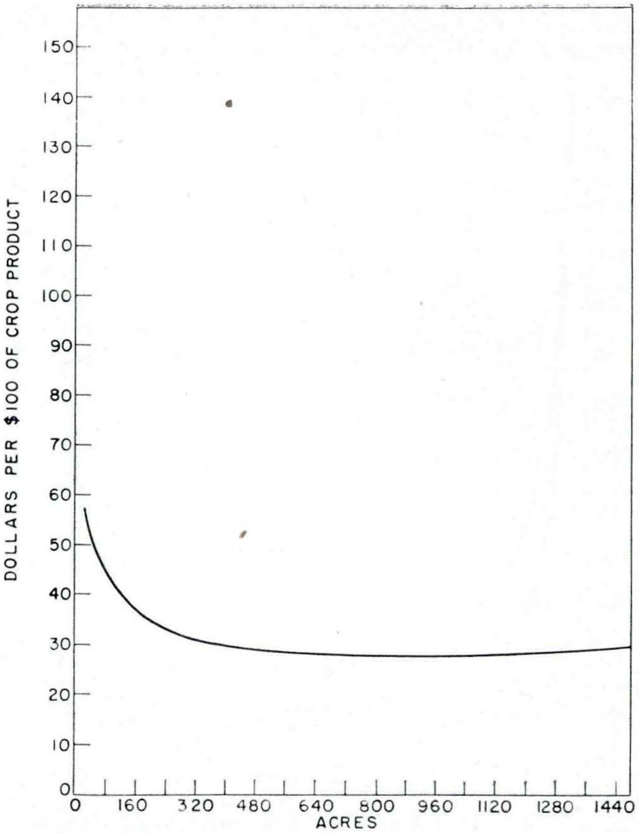

Fig. 18. Long-run average costs per $100 of crop product.

Again it is very obvious that cost differentials are not likely to be the final determining factor in farm size pattern. While costs are relatively high for small acreages operated with low-capacity equipment, the minimum costs of the higher capacity machinery combinations do not differ by very large amounts. The differences in per-unit costs are likely to be less important than other forces in determining the size of farm units. When family labor is considered, a unit with 160 crop acres likely can exist, from a cost standpoint, side by side with a 240- or 320-acre unit.

REGRESSION ESTIMATES OF SCALE RETURNS AND COST FUNCTIONS

The data of this section represent estimations of scale returns and cost structures from farm samples. Production functions are used to indicate scale returns, while cost functions are used to estimate cost structures. The cost structures involved in this section differ somewhat from those presented in the previous section. The production function estimates of scale returns are presented

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[14] Actually, however, the machine combinations are discrete and the opportunity to construct an infinite number of short-run curves does not exist under the procedures employed.

first. However, they involve the same cost structure differences as the cost data presented later. Hence, the following paragraphs are used to make certain distinctions in cost estimates.

Costs in the previous section were for different acreages operated with "distinct" or "pure" machine combinations; those presented in this section are for farms using many different machine combinations and techniques. While previous figures were estimates of short-run costs under budgeted machine situations, figures in this section are long-run estimates; they provide some notion of farm costs which extend over all acres and machine combinations found on the farms sampled. The regression estimated costs presented in this section are related to the long-run and short-run cost curves or functions presented previously in the manner illustrated by fig. 19. The short-run cost curves (SAC_1 - SAC_5) are of the nature explained earlier. LAC is the long-run cost or planning function also discussed previously.

In actuality, each farmer is faced, within a year, with a short-run cost represented by some point on the SAC curves. If all farmers operated at the point where the short-run curves are tangent to the long-run curves, a farm sample would allow regression estimates of long-run curve LAC. However, farmers operate at many points within the short-run cost structure which faces them. Some operate at the low-cost point of the short-run curve; others operate both to the right and left of it. These many cost points are found on farms because operators have limited capital and cannot attain the low-cost point of a short-run plant. Some farmers are restricted to the left of this output or acreage because of the discounts growing out of risk and uncertainty and hence the "fears" which attach to the use of more acres and a greater capital investment. Also, because they start out with a given unit and add to scale as they accumulate capital, many farmers do not move to a new short-run curve as they extend size of operations. Instead, they simply move up the short-run cost structure already attained. As a result, regression analysis provides estimates of neither short-run cost curves nor the long-run planning curve but of a curve such as REC (regression-estimated costs) in fig. 19.

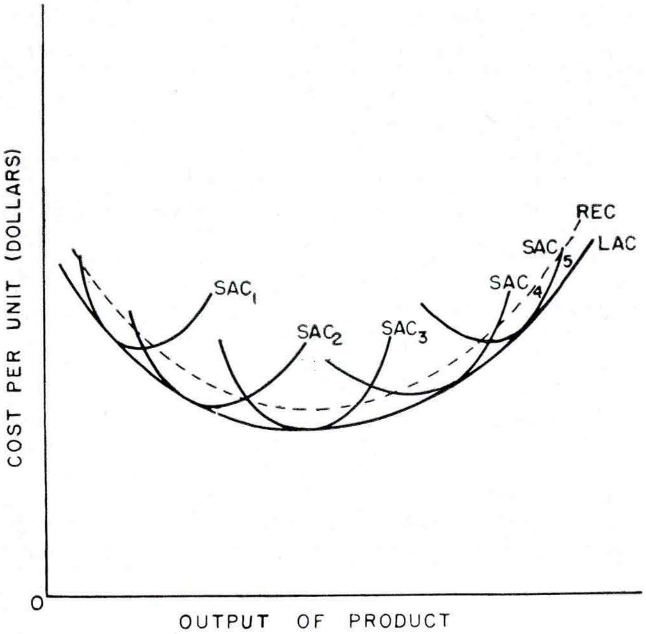

Fig. 19. Possibilities in estimating long-run cost function by regression analysis of a farm sample.

Estimates of REC are important, however. These estimates suggest the cost structure of operating farms and hence the relative advantages or disadvantages which exist under any particular price level or which may come about from any particular policy which may be applied to all farms. The cost structures presented in the previous section are most useful for individual farm planning. They also suggest the cost advantages possible as acreage is extended in the category of certain specified machine techniques. In contrast, the estimates of this section show the existing "dangers" or "strengths," from a cost standpoint, of farms with different acreages and outputs. Also, while the regression-estimated costs (REC in fig. 19) lie above the true long-run cost curve (LAC), the slopes and minimum points are likely to be similar for farms of different sizes. The regression estimates of costs cannot be used to calculate net farm incomes because they fall above the actual long-run cost curve. However, they do suggest (1) the "long-run" size which gives the lowest cost and (2) the absolute decline in costs as different sizes are attained.

Samples and Production Functions

Production functions have been derived for two different samples of farms. The first sample was taken in 1948 and includes only cash grain farms in the North Central Cash Grain area. The second sample was take in 1951 and included farms from (1) the North Central Cash Grain area and (2) the Southern Pasture area. While prices differ between the two periods in which the samples were taken, the relative advantage of farms of different sizes still exists. (Mainly, price changes have been of a nature to push the entire cost curve upward rather than to change its slope and minimum point.)

1951 SAMPLES

The 1951 samples were random samples of all farms in the North Central Cash Grain area and the Southern Pasture area. The samples represent random drawings of all farms in the areas; they are not restricted to only cash grain farms. However, only costs relating to the crop enterprise have been included in the analysis. The 1951 samples include 140 farms in the North Central Cash Grain area and 139 in the Southern Pasture area. The material from southern Iowa has been included as a check and, also, because it is expected that the general scale or size relationships are likely the same in all areas of Iowa.

1948 SAMPLE

Farms in the 1948 sample were those defined as cash grain farms. The inferences must be conditioned accordingly. This particular group of farms was selected since greatest cost advantages in Iowa apply to crop production. Cash grain farms were defined as those which have an income composed of 75 percent or more from crop sales. This sample was stratified by size measured in acres. It involved two steps: (1) An area sample was drawn and visits were made to farms within the segments. Only farms falling within the definition of "cash grain" were included. (2) A sample of large farms was selected from Iowa assessor reports. Since the number of extremely large units falling in the sample segments was small, an enumeration was first made from assessor reports of all farms over 340 acres in the area. A sample of 20 farms, stratified by size, was drawn from this list. The two samples were combined to make the analysis.

While the data from the 1948 sample are subjected to the same production function analysis, the sample itself differs considerably from those for 1951. The 1948 sample included 187 farms with the distribution indicated in table 5.

TABLE 5. DISTRIBUTION OF THE 1948 SAMPLE FARMS BY ACREAGE.

Acreage range	Number of farms
70- 99	10
100-139	17
140-179	32
180-219	22
220-259	20
260-299	11
300-339	26
340-379	11
380-419	14
420-459	8
460-499	10
500 and over	6

SCALE RETURNS FROM 1951 SAMPLES

A crop production function was derived separately from northern Iowa and southern Iowa in the 1951 samples.[15] The functions are of the form $Y = \propto X_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3}$ where X_1, X_2 and X_3 refer respectively to land inputs in acres, labor inputs measured in months and capital inputs measured in annual services and expenses.[16] Because of its logarithmic form, this equation expresses directly the production elasticities indicative of returns to scale. Each exponent (β_1, β_2 and β_3) shows the percent by which production (Y) increases for each 1-percent increase in the particular resource; the sum of the exponents indicates the percentage increase in product as all resources, with proportions held fixed, are increased by 1 percent. Under the condition $\beta_1 + \beta_2 + \beta_3 = 1.0$, constant returns to scale hold true; a simultaneous 1-percent increase of the three resources, capital, labor and land, will increase output by 1 percent. If $\beta_1 + \beta_2 + \beta_3 > 1.0$, increasing returns to scale hold true, and a 1-percent increase in all resources will increase output by more than 1 percent, the long-run cost curve will be of a declining nature and large units will have an advantage over small units. If the sum is less than 1.0, decreasing returns to scale hold true, the long-run average cost curve will be increasing, and small units will have a lower cost than large units. This function, as a single equation, does not express ranges of increasing and then decreasing returns to scale but provides the "average elasticity" over the range of observations in the sample.

The derived functions for the two areas are:

$$\text{Northern Iowa } Y = 18.75\, X_1^{0.9124} X_2^{0.0756} X_3^{0.1647}$$

$$\text{Southern Iowa } Y = 5.22\, X_1^{0.7948} X_2^{0.0875} X_3^{0.3930}$$

As the statistics of table 6 indicate, the sums of the elasticities are greater than 1.0 in each area. Increasing returns to scale, and hence declining long-run costs, hold true over the sample range. As an average over the two samples, large farms using proportionally more resources have lower costs than small farms. This type of function does not allow us to say whether or not increasing costs will eventually be encountered.[17] However, increasing returns over the entire range

TABLE 6. STATISTICS FOR CROP PRODUCTION FUNCTIONS FROM THE 1951 FARM SAMPLE.

	Northern Iowa	Southern Iowa
Value of $\hat{\beta}_1$	0.9124	0.7948
Value of $\hat{\beta}_2$	0.0756	0.0875
Value of $\hat{\beta}_3$	0.1647	0.3930
Sum of $\hat{\beta}$'s (elasticities)	1.1527	1.2753
Standard errors		
$\hat{\beta}_1$	0.0690	0.0793
$\hat{\beta}_2$	0.0486	0.0526
$\hat{\beta}_3$	0.0687	0.0803
Value of t for departure of $\Sigma\hat{\beta}_i$ from 1.0	7.85	8.48

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[15] This approach also involves difficulties. Realistically, the relationship derived can be an intra-firm function only if all the firms in the sample have the same function. However, it is the assumption that the sample farms and their resources are homogeneous enough to yield parameter estimates of intra-firm cost relationships.

[16] In classifying inputs, labor is measured in months and, as for all other resource categories, refers only to that used for crops. Land is measured in acres and includes only cropland; permanent pasture is excluded. Capital expense or service represents all annual inputs; it does not refer to capital investments. In deriving this category of inputs, seed, fertilizer, insecticides, tractor fuel, machinery repair and depreciation and all other annual capital expenses (with land and labor costs excluded) were added into a single resource category.

[17] The general type of functions employed here, $Y = \propto X_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3}$, will express total product either as increasing at a decreasing rate, at an increasing rate or at a constant rate over the entire range of acreages included in the sample. A combination of these three situations cannot be represented by this type of function as a single equation.

of sizes included in the sample is consistent with the budget analysis of a previous section. Observations in both samples fell entirely in the acreage range associated with decreasing costs in the budget analysis. Also, it should be remembered that the production function analysis deals entirely with scale returns and fixed proportions of resources, while the budget analysis deals partly with changes in the proportion of acreage to fixed machine combinations. (Although larger machines are used, a two-plow outfit does not represent twice the machine input of a one-plow outfit, etc.)

SCALE RETURNS FROM 1948 SAMPLE

Two types of production functions were derived for the 1948 sample. One of these included three categories of resources. The other type included only a single category of resource inputs. The "three-variable" production function for the 1948 sample is given below. It differs from the 1951 sample function in the sense that a somewhat different classification of resources is used. The basic function estimated from this sample is of the form $Y = \propto X_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3}$. X_1 is land input now measured in dollar value of annual services (i.e., rental value per acre), while X_2 and X_3 are respectively annual inputs of labor and capital services measured as in the previous section. The derived function is:

$$Y = 1.46\, X_1^{0.5659}\, X_2^{0.0601}\, X_3^{0.4748}.$$

The statistics in table 7 again indicate increasing returns to scale; the sum of elasticities is greater than 1.0. The sum of 1.10 suggests that each 1.0-percent increase in input of all resources will increase value of crop output by 1.10 percent; value of output is increased proportionately more than inputs. This figure again is consistent with the 1.15 figure from the 1951 sample of all farms in northern Iowa. It is consistent with the budgeted cost functions—even though the 1948 sample of cash grain farms was stratified by size in acres, all observations fell in an acreage range smaller than the optimum size determined by budgeting procedures.

"SINGLE-VARIABLE" FUNCTIONS

Two "single-variable" production functions of a least squares nature were derived from the 1948 sample. In these functions, all resource inputs were aggregated into a single "value of input" category. The first function is $Y = -0.0007X^{1.1134}$ where Y is value of crop output and X is value of aggregate inputs. The elasticity of 1.11 also is suggestive of increasing returns to scale.

The second least squares function is $X = 0.0066\, Y^{0.9852}$ where X again refers to value of inputs and Y refers to value of output.[18] While of a production-function nature, it is really a cost function.

TABLE 7. STATISTICS FOR CROP PRODUCTION FUNCTION FROM THE 1948 SAMPLE OF CASH GRAIN FARMS.

Value of $\hat{\beta}_1$	0.5659
Value of $\hat{\beta}_2$	0.0602
Value of $\hat{\beta}_3$	0.4748
Sum of $\hat{\beta}$'s (elasticities)	1.1009
Standard errors	
$\hat{\beta}_1$	0.0672
$\hat{\beta}_2$	0.0597
$\hat{\beta}_3$	0.0679
Value of t for departure of $\Sigma\,\hat{\beta}_i$ from 1.0	52.15

By using X as the dependent and Y as the independent variable, we obtain a total-cost function. A coefficient for Y of less than 1.0 suggests that while costs (X) increase with a greater value of output (Y), the increase in total costs is at a decreasing rate. Therefore, costs per unit of production decrease throughout the range of the observations, 40 to 640 acres, of the cash grain sample.[19]

COST FUNCTION FROM 1948 SAMPLE

The production functions presented above allow either one of three alternatives in cost per unit (scale returns) as size or output increases. However, they allow only one of these conditions to prevail over the entire size range; they do not allow a range of decreasing costs (returns) followed by a range of increasing costs per unit. Since this limitation is inherent in the functions, it is possible that decreasing per-unit costs may exist over most of the size range in the sample but increasing costs may be encountered in the tail-end of the "larger sizes." (The logarithmic function used above would allow only decreasing per-unit costs throughout the range of observations.) Hence, two total cost functions, one using linear and squared terms and one using linear, squared and cubic terms, were computed from the 1948 sample observations. These are given below where X again refers to total costs and Y refers to total output or volume of crop sales per farm.

$$X = 2{,}902 + 0.5808Y + 0.000003Y^2 - 0.0209\,(10^8)\,Y^3$$
$$X = 2{,}462 + 0.7084Y - 0.000007Y^2$$

The cubic term in the first equation is not significant at the 40-percent level of probability.

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[18] The corresponding average cost function (where A refers to cost per unit) is:

$$A = \frac{0.0066\, Y^{0.9852}}{Y}$$

[19] An alternative procedure of estimating the cost function by means of simultaneous equations was also employed. The estimates obtained were not entirely satisfactory. First, labor expense was an unsatisfactory variable: Its value in all computations was negative or "low positive." Yet labor is known to be an important factor in production. Second, a negative elasticity of land expense is difficult or impossible to explain. For these reasons these data have not been presented in the text. However, since the sum of elasticities is consistent with the findings presented in the text and since the procedure is of methodological importance, a brief discussion has been presented in Appendix B.

Hence, we accept the second equation as a better estimate of cost parameters for crop production on cash grain farms.[20] The regression coefficient for the linear term in the second equation is significant at the 1-percent level of probability while it is significant at the 5-percent level of probability for the squared term. These total cost equations are consistent with the production functions derived from both the 1951 and 1948 samples; all indicate declining per-unit costs as volume of output or size increases. This phenomenon is apparent in the second equation above, where \$2,462 represents the total fixed cost of capital, labor and land; fixed costs as a constant necessarily decline with greater output. The linear term, which is positive, alone would denote constant variable costs. Since the squared term is negative, however, variable costs per unit also decline as volume of crop production is increased. Declining per-unit costs also are apparent from the average cost function, which is:[21]

$$A = \frac{1}{Y}(2,462 + 0.7084Y - 0.000007Y^2)$$

Figures 20 and 21 have been constructed to show the relationship of costs to size in the farm sample. In fig. 20, costs are related to size in dollar sales of crops on cash grain farms. Curve TC is the total cost while curve AC is the average costs. In fig. 21, costs have been related to acres.

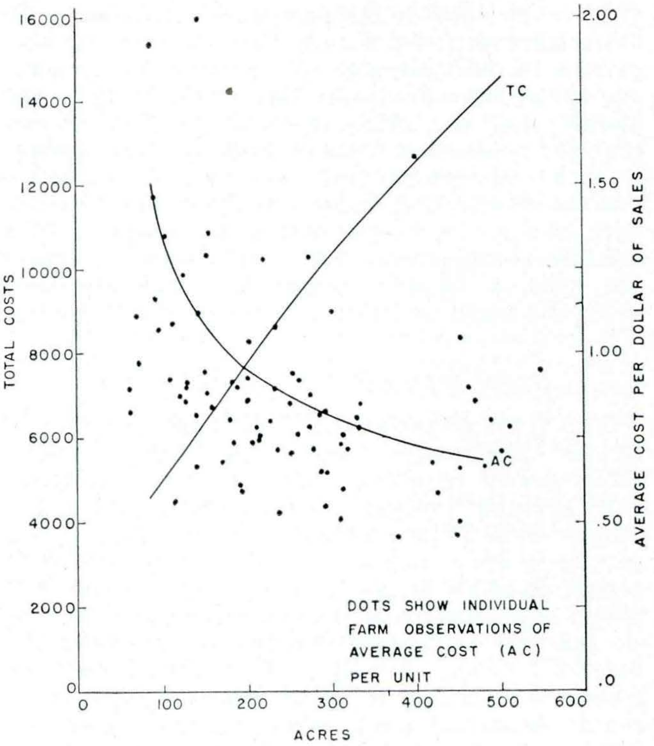

Fig. 21. Total costs and average cost per \$1 gross sales for farm sample.

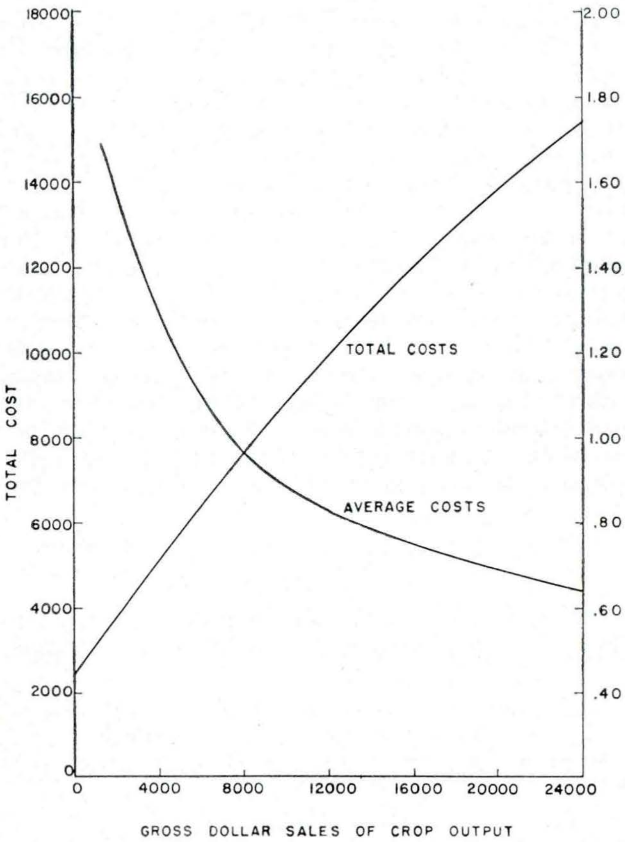

Fig. 20. Predicted total costs and average cost functions from farm sample. Costs per unit of gross sales.

DYNAMIC ASPECTS OF FARM SIZE

Considerations of risk and uncertainty were not included in the previous empirical sections. The costs derived from budgets were essentially static in nature; they did not consider changes in resource combinations which might be made to meet uncertainty. The production and cost functions derived from the sample data undoubtedly include resource and cost adjustments which are related to uncertainty. However, these "cost precautions" cannot be separated from other phases of the production or cost functions. While both of these sets of "static" data clearly indicate that costs per unit decline over a wide acreage range, it is unlikely that the cost function is alone the determinant of farm size. Risk and uncertainty considerations may restrict farms to smaller than optimum sizes (in cost terms), even where the farmer knows that per-unit costs decline with a larger acreage.[22] Thus, to obtain information on the risk consideration in farm size, the information of this section was summarized from a subsample of 115 farms in the 1948 farm survey. These data have been analyzed by farm size in acreage; they have

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[20] The multiple correlation coefficient for the first equation is 0.8416, while it is 0.8406 for the second equation.

[21] The marginal cost (MC) function is:
$MC = 0.7084 - 0.000014Y$

[22] See Heady, Earl O. Economics of agricultural production and resource use. Prentice-Hall, New York. 1952. Part III.

also been weighted by size strata to permit population inferences to be made.

FARMERS' OPINION OF THE "OPTIMUM" SIZE FOR CASH GRAIN FARMS

The cost analysis of the previous sections indicates that there are economies to scale for cash grain farms at least up to the sizes analyzed in this study. The least-cost sizes are not attained by the majority of the cash grain farmers in north central Iowa. Hence, the question arises: Do farmers have some notion of the "optimum" (in cost terms) size of cash grain farms? The 115 farmers interviewed were asked to indicate an optimum size cash grain farm for the average farmer in his area. This question assumed unlimited resources with "normal" price, technological and yield uncertainty.

Table 8 indicates the distribution of farmers' expression of optimum farm size (in cost terms). The mean size of 459 acres, as indicated in the table, is much greater than the mean acreage of cash grain farms, or all farms, in north central Iowa. When this information is adjusted for population weights, the estimate of the optimum size cash grain farm from farmers' opinions is 526 acres. This figure is 332 acres or 171 percent greater than the average size (194 acres) of cash grain farms in north central Iowa.

From the attitude data this appears to be true: Cash grain farmers know that the least-cost farm size is considerably greater than the size now operated. With this knowledge on the part of farmers, it would seem that farm size might be expected to expand rapidly in the future. However, further analysis of uncertainty attitudes explains why this is not so likely to occur.

Larger farms may result in larger incomes because of (1) lower unit costs and/or (2) a greater volume of production. Hence, farmers were asked: Why do larger farms make greater incomes?[23] The respondents answered as follows: (1) 2.6 percent said that large farms don't have greater net incomes; many smaller well-managed farms do as well or better; (2) 59.1 percent said that the greater income of large farms was due to a greater volume of production with the same or higher costs than smaller farms;[24] (3) 38.3 percent said the greater net income of large farms was due to both lower costs per unit and a greater volume of production.

TABLE 8. ESTIMATE OF THE "OPTIMUM" SIZE OF CASH GRAIN FARM ASSUMING UNLIMITED RECOURCES.

Size indicated as optimum (acres)	Distribution of respondents (no.)
120	4
160	13
200	4
240	6
320	33
480	16
640	26
800	1
960	1
1,120	2
1,280	5
1,500	1
3,000 or more	3
Mean 459.4	Total 115

Farmers currently operating large units mainly gave the third reason; medium and small farmers gave the second reason. A large number of small-scale operators also suggested that small farms were as profitable as large farms. In the three categories of answers, "3" above supposes increasing returns to scale (or decreasing costs); "2" and "1" deny that cost economies exist or at best suggest the possibility of constant returns (costs).

ATTITUDES TOWARD UNCERTAINTY IN RELATION TO FARM SIZE

To determine how risk and uncertainty might condition selection of farm size, farmers were asked to specify the farm size they would chose if they had unlimited capital resources but were faced with the normal risks and uncertainties of yields and prices. They were asked to specify a "best" size considering four equity levels, namely 100, 75, 50 and 25 percent. This best size thus is determined in terms of both their notions of scale economies and the effect of normal uncertainties on successful, continued operation of the farm (absence of bankruptcy due to unfavorable and unpredictable price or yield outcomes, etc.).

The figures in table 9 show the size of units farmers consider "best," from the standpoint of both an acceptable income and a safeguard against risk and uncertainty. These sizes are smaller than the average size predicted to have lowest unit costs. Size is discounted because of uncertainty considerations, and the discount increases with a thinning of equity. Many of the farmers preferred not to farm under low equity conditions; they felt the chance of loss to be too great and would prefer the alternatives of "not farming" or "renting with a full equity in assets other than

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[23] The actual distribution of answers to this question was as follows:

Reply	Small farmers	Medium farmers	Large farmers	Total
1. Don't make greater incomes	2	0	1	3
2. Large volume of production with same or higher costs than smaller farms	27	27	14	68
3. Lower costs per unit and greater volume of production	11	13	20	44
Total	40	40	35	115

[24] In other words, these farmers believed that large farms had attained the rising side of a U-shaped average cost curve but the greater volume and the fact that marginal return exceeded marginal cost to this point gave greater net incomes.

TABLE 9. MEAN SIZE OF FARM INDICATED "BEST" UNDER SPECIFIED EQUITY RATIOS AND WITH PRICE AND YIELD UNCERTAINTIES.

Present acreage of an operator	Number of farms	Present average size	Percent equity in farms			
			100%	75%	50%	25%
Small farms (under 219 acres)	40	137	220.5	192.8	178.5	166.3*
Medium farms (220 to 379 acres)	40	300	463.0	362.0	299.0	294.7*
Large farms (380 acres and up)	35	465	449.7	385.3*	300.6*	277.4*
All survey farms	115	285	376.0	310.6*	257.9*	242.1*
Population estimate (weighted average)		194	291.2	244.0	214.1	203.2

* These averages exclude farmers who prefer not to operate a farm under the equity conditions indicated, presumbably because of the risk of such an operation.

TABLE 10. AVERAGE SIZE OF FARM WITH DEBT THAT WOULD BE ACCEPTED IN EXCHANGE FOR A 160-ACRE DEBT-FREE FARM.*

Present size of respondents' farm		Number of farms	Equity of farm acceptable in exchange			
Range	Av.		100%	75% av.	50% av.	25% av.
Small farms (under 219 acres)	137	40	160	238.3 (20)	316.0 (30)	560.0 (37)
Medium farms (220 to 365 acres)	300	40	160	235.0 (20)	314.7 (25)	573.3 (34)
Large farms (380 acres and up)	465	35	160	229.5 (16)	325.9 (18)	585.0 (27)
All survey farms	285	115	160	233.7 (56)	319.5 (63)	576.5 (98)
Population estimate (weighted average)	194		160	237.0	316.2	564.6

* Figures in parentheses refer to the number of farmers who would *not* exchange a debt-free farm for one with the equity ratios indicated. Averages refer only to those who would change.

TABLE 11. OPTIMUM FARM SIZE UNDER CROP SHARE AND CASH LEASES WITH SPECIFIED EQUITY.

Present acreage of the operator	Crop-share lease			Cash lease			Percent difference in (av. of all classes) opt. of cash lease and crop-share lease estimates
	Percent equity			Percent equity			
	100%	50%	25%	100%	50%	25%	
Small farms (under 219 acres)	242	210	191	220* (2)	190* (4)	187* (4)	10.0
Medium farms (220 to 379 acres)	396	284* (1)	259* (1)	298* (3)	242* (5)	229* (6)	32.9
Large farms (380 and up)	439	344* (1)	316* (2)	402* (1)	292* (3)	275* (4)	9.2
All survey farms	356	276* (2)	251* (3)	303* (6)	239* (12)	208* (14)	17.5
Population estimate (weighted average)	290	235	214	249	208	202	

* These averages exclude farmers who preferred not to operate a farm under the tenure and equity conditions indicated. The number in parentheses refers to the number of such farmers.

land." Many preferred to rent land (if they had a reasonable expectation of undisturbed tenure and good buildings) to buying a farm under heavy mortgage. The averages presented hide the fact that only 59 of the farmers interviewed would change to smaller sizes if the equity ratio decreased to 25 percent. The remaining 56 would not adapt scale of operations but would cease farming.

A further question to evaluate the effects of uncertainty on farm size was stated in this way: "Suppose you had a 160-acre farm free of debt; what size of farm with 75 percent equity would you take in exchange for it?" Similar questions were asked for 50 and 25 percent equities. (Theory supposes that if one is to choose an alternative which involves more risk over one which involves less risk, income must be increased to compensate for the disutility of the greater risk.) The answers are given in table 10 by present size of farm. Only 51 out of 115 farmers would exchange a 160-acre, debt-free farm for a larger one with 75 percent equity; still fewer would exchange for one of 50 percent equity; only 17 out of 115 would exchange for a larger farm of 25 percent equity.

UNCERTAINTY AND FARM SIZE IN RELATION TO LEASE TYPE

A farmer with a given amount of capital can operate a larger unit if it is rented; he can buy equipment and supplies for a larger unit rather than investing in title to real estate. However, a cash lease itself represents a fixed payment akin to a debt and has the effect of lowering equity and increasing risk. A cash lease might also act to restrict farms to a size short of the least cost point. To test these possibilities, farmers in the sample were asked to specify the size of farm they would operate under different leasing and equity considerations. Indications were for a slightly larger unit under a crop-share lease than under a cash lease (see table 11).

PRICE UNCERTAINTY

To obtain some suggestion of how farmers view farm size in relation to price uncertainty, we asked them about the size of unit they would look upon as "best"[25] given free access to capital under either (a) the existing degree of price uncertainty or (b) with price certainty (i.e, guaranteed prices). The latter situation, like certain others of this section, is quite foreign to the experience of many farmers. Only 23 farmers (20 percent) indicated that they would select a different size of farm under the two situations. The "unreality" of the question may have colored the answer for the remainder. It is difficult for operators to visualize a situation of price certainty; production uncertainty would still remain and affect their decision of farm size. Some also stated that they would not select a larger farm in the absence of uncertainty since they (1) do not want to keep hired labor, (2) have personal biases against larger farms or (3) do not want to "bother with the management worries" of larger farms.

WEATHER AND YIELD UNCERTAINTY

A somewhat parallel question was asked on yield uncertainty. However, the question supposed price uncertainty similar to that of the past. The situation posed was not so foreign to farmer experience since the "ideal" year was used for

TABLE 12. FARMERS' ESTIMATED LEAST-COST TECHNICAL UNITS* FOR FARMS UNDER VARYING WEATHER UNCERTAINTIES.

Machinery combinations†	With normal weather risks*	With "ideal" weather conditions	Percent increase under "ideal" weather
	(acres)	(acres)	(percent)
One-man farms‡			
1. Small 1-plow tractor, 14" plow, 2-row planter and 1- or 2-row cultivator, 5′ tandem or 10′ single-disk, mower, rake and 40" combine	61.6 (80)	93.7	52
2. A 2- or 2 3-plow tractors with 2-row corn planting and tillage machinery, 2-bottom plow, 8′ tandem or 15′ single-disk, 1-row picker, 5′ combine and haying equipment	158.3 (160)	208.0	32
3. Same as No. 2 only larger size machinery for the power unit; i.e., 4-row planter, 2-row picker, etc.	176.5 (160)	226.1	28
4. A large 3 or 3-4 plow tractor, 3-bottom plow, 4-row planter, 2- or 4-row cultivator, 10′ tandem or 20′ single-disk, 2-row picker, etc.	241.4 (240)	303.7	26
Greater than one-man farms			
1. Two tractors (a 2-plow and a 1-plow) 2-bottom plow, 2-row planting and cultivating machinery, 2 suitable disks, 1-row picker, 5′ combine and haying equipment	239.8 (240)	301.7	26
2. The 2-plow tractors, two 2-bottom plows, 2- or 4-row planting and tillage machinery, 10′ tandem disks, 2-row picker, 5′ combine	333.4 (320)	418.4	25
3. Two 3-plow tractors, two 2- or 3-bottom plows, 2- or 4-row planting and tillage equipment, suitable disks, 2-row picker, etc.	464.8 (480)	579.1	25
4. Three tractors, 2- or 3-bottom plows, and full complement of the largest machinery they can handle adequately	631.0 (640)	767.8	22
5. Four tractors, 2- or 3-bottom plows, and a full complement of machinery	858.4 (800)	1,029.0	20

* Figure in parentheses is mode for particular machine combination.

† Abbreviated from schedule used.

‡ Extra help used through the busy seasons, but primarily one-man farms.

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[25] "Best" again refers to the size of the unit to be selected in terms of uncertainty and other subjective considerations, rather than in terms of costs.

comparison was 1948, a year in which moisture was ample but in which farmers had a minimum of nonoperating days. Farmers were asked to specify the "best" farm size (1) under normal weather variations and uncertainty and (2) under a situation where weather might always be like that of 1948. This situation was posed not with the thought that any person could do away with weather uncertainty; it was used to suggest the extent to which weather uncertainty restricts farms to a size less than the cost optimum. Also, the answers provide some indication of the excess machine capacity farmers feel to be necessary to meet weather uncertainty. Questioning was in terms of specific combinations of power units and machines. Data are presented in table 12 as simple averages for all farms in the sample. Significant differences did not exist between current size groups. (Figures refer to combinations for crop production only and do not include consideration of livestock.) These data suggest that farmers believe they could operate 52 percent more acres with the smallest machine combination under "ideal" weather. With the large machine combination, they believe they could operate 20 percent more acres under "ideal" weather conditions.

SUMMARY

Since 1920 there has been a trend toward farms of larger size for the state as a whole. The Northeast Dairy and the Cash Grain areas have experienced the least change in size and numbers of farms of any of the areas in the state. The greatest decrease in number of farms and hence the largest increase in farm size has been in the southern and western areas of Iowa where the average income per farm is known to be the lowest. The pattern of change in farm size in Iowa suggests that mechanization, while a factor favoring farm consolidation, has not been the only or the most important factor in bringing about farm size adjustments. Income opportunities outside of agriculture, depression, economic uncertainty and other sociological and psychological forces are also likely to have been very important in conditioning the shift in the farm size pattern.

The regression estimates of cost and production functions presented in this study indicate that decreasing costs per unit of production extend over a wide acreage on crop farms in northern Iowa, and probably in other parts of the state. The decline in costs is greatest, however, over a relatively narrow range of small farm sizes as can be seen from the budgeted cost estimates. The decline in costs per unit is relatively large up to 160 acres, due mainly to high fixed costs in crop production. Beyond 160 acres, further decline in unit costs is relatively small since unit variable costs, which are nearly constant, make up the larger proportion of total unit costs. Further acreage expansion will not reduce average fixed costs enough to produce significant cost economies. Therefore, unit costs computed on a per-acre basis are nearly constant beyond 160 acres, and variable costs approach average total costs as a mathematical limit.

When unit costs are computed on the basis of $100 of crop product and timeliness of operations is taken into consideration, the characteristic U-shaped average total cost curve is obtained. As the limit of the machine combinations capacity is approached, output is reduced due to untimeliness of field operations causing costs per unit of output to increase.

The cost estimates in this study indicate that a farm of 240 acres, one falling within most definitions of family farms, is large enough to realize the major reductions in costs. From this standpoint it is not likely that, with present production techniques, 240-acre family farms and perhaps even 160-acre family farms will be caught in a cost squeeze from larger units.

Data are included which represent farmers' subjective opinions of "best" and "least-cost" size of farms. These opinions, especially where the questions relate to hypothetical situations, are affected by the farmer's experience. However, given these limitations, they do provide the basis for certain qualitative inferences. The greatest number of farmers believe the least-cost farm is of a larger size than (1) the one they are now operating or (2) the typical unit of north central Iowa. Yet these farmers do not "step out, borrow funds and operate a larger unit" even where they estimate that returns would likely increase from doing so. The uncertainties of price and production dampen tendencies to "strike out" and endanger the equities they have built up. According to their thinking the size of unit "best" to provide an "acceptable degree" of income certainty and satisfy personal preferences is considerably smaller than the size of unit necessary to give lowest costs per unit of production.

Farmers are aware of the existence of cost economies of larger size farms. However, they tend to restrict farm size because of subjective discounting for risk and uncertainty. They believe cost economies are too small to offset the increased risk associated with the larger size unit. Many farmers have a farm of sufficient size to provide them with a "satisfactory" standard of living. They are unwilling to risk the possible chance of losing it to achieve a size of farm that is more efficient from the cost standpoint.

APPENDIX A

TABLE A-1. MARGINAL COSTS PER $100 OF CROP PRODUCT FROM THE BUDGET ANALYSIS.

Acres	Machinery combinations						
	One-plow	Two-plow	Three-plow	One-plow, Two-plow	Two-plow, Two-plow	Two-plow, Three-plow	Three-plow, Three-plow
40							
80	$ 33.44	$ 24.41	$ 18.94	$ 24.04	$ 19.86	$ 19.27	$ 19.08
120	33.66	24.41	18.94	24.04	19.86	19.27	19.08
160	33.66	24.70	18.94	24.33	19.86	19.27	19.08
200	34.06	25.82	18.94	25.21	19.86	19.27	19.08
240	34.37	26.53	19.04	25.41	20.03	19.37	19.18
280	36.24	27.60	19.16	25.87	20.12	19.50	19.31
320	38.31	29.19	20.57	26.05	20.52	19.90	19.71
360	40.96	31.13	21.53	26.44	21.18	20.17	19.98
400	44.83	33.98	21.78	26.63	21.37	20.17	19.98
440	47.57	36.00	22.05	26.73	21.46	20.26	20.07
480	50.02	37.81	22.05	26.74	21.65	20.26	20.07
520	52.63	39.73	23.13	27.72	23.54	20.31	20.07
560	55.56	41.89	24.67	28.76	24.02	20.97	20.07
600	58.94	44.38	25.17	29.30	24.02	22.35	20.79
640	62.56	48.00	26.58	30.18	24.02	22.70	21.84
680	67.48	51.80	27.79	31.47	24.42	22.72	22.07
720	72.22	55.56	29.57	32.63	25.05	22.74	22.18
760	79.01	60.70	31.24	34.83	26.10	22.94	22.56
800	86.53	66.39	32.50	36.12	27.04	23.42	23.31
840	95.38	73.10	33.70	36.85	28.23	23.90	24.02
880	106.88	81.82	34.55	38.33	28.76	24.87	24.99
920	119.66	91.50	37.68	39.26	31.35	26.08	26.21
960	138.45	105.73	50.15	40.04	32.19	26.67	27.46
1,000	164.15	125.19	61.86	41.69	36.57	27.43	28.25

TABLE A-2. WORKING DAYS AVAILABLE PER WEEK.*

Week	Days available	Week	Days available
Mar. 15-21	0.32	Aug. 2-8	4.94
22-28	1.16	9-15	5.26
29-Apr. 4	2.74	16-22	5.53
		23-29	5.24
Apr. 5-11	3.95	30-Sept. 5	5.22
12-18	4.56		
19-25	5.11	Sept. 6-12	5.50
26-May 2	4.47	13-19	5.63
		20-26	5.31
May 3-9	4.31	27-Oct. 3	5.31
10-16	5.03		
17-23	4.53	Oct. 4-10	5.22
24-30	4.97	11-17	5.47
31-June 6	4.45	18-24	5.44
		25-Nov.7	5.69
June 7-13	4.63		
14-20	4.63	Nov. 8-14	4.97
21-27	4.82	15-21	4.97
28-July 4	5.21	22-28	4.38
		29-Dec. 5	2.09
July 5-11	5.55		
12-18	5.34	Dec. 6-11	1.18
19-25	5.42	12-18	0.24
26-Aug. 1	5.21		

* Average working days available per week of the period from 1932 to 1952 exclusive of 1940 and 1941, for which records were not available.

APPENDIX B

ESTIMATES OF COST FUNCTIONS BY SIMULTANEOUS EQUATIONS

Simultaneous equations were used as an alternative estimating procedure to estimate elasticity and productivity coefficients for the 1948 sample. It was thought that this estimating system might give certain improvements over the least squares procedures of the text. First a complete model was constructed. However, since many of the variables in this model were not observable or proved to be nonsignficant, a model of the following form was used:

$$\beta_{11}y_1 + \beta_{12}y_2 + \beta_{13}y_3 + \gamma_{11}z_1 = \mu_1$$

where y_1 = crop production
y_2 = labor (costs) inputs
y_3 = operating expense (costs) inputs

z_1 = current fixed production (costs) inputs
μ_1 = unobserved random disturbances

The labor function is:

$$\beta_{22}y_2 + \gamma_{22}z_2 + \gamma_{23}z_3 = \mu_2$$

where y_2 = labor inputs
z_2 = crop acres
z_3 = total investment
μ_2 = unobserved random disturbances

The variable cost function is:

$$\beta_{33}y_3 + \beta_{31}y_1 + \gamma_{31}z_1 + \gamma_{32}z_3 = \mu_3$$

Many separate variables were considered but later were aggregated because of computational difficulties.[26] The variables used are as follows:

$y_1 = x_1$ refers to the value of crop production plus government payments. Inclusion of the latter is questionable. However, it was believed that there was no reason to separate these payments since they affect the incentive to produce crops.

$y_2 = x_2$ includes all labor measured in terms of dollars. It includes hired labor, value of labor used in custom work, and family and operator labor. Variations in the quality of labor and the length of day have been ignored, as have differences in the productivity of labor used at various times in the year.

$y_3 = x_3$ refers to cash and noncash crop expenses and can be termed "operating inputs." These inputs included seed purchases, adjusted machine hire (labor taken out), miscellaneous supplies, cost of repairs and maintenance, fertilizer and lime, gas, fuel and oil, storage and warehousing, freight, farm share of auto upkeep, interest and depreciation on equipment and machinery, and other miscellaneous items.

$z_1 = x_4$ refers to land inputs and other inputs of a current fixed cost nature. Taxes, insurance, depreciation and repairs on buildings and fences, and interest on the land and building investment were included in this variable.

$z_4 = x_5$ refers to machinery and equipment investment and is expressed in terms of the dollar value of the beginning inventory adjusted for repairs, improvements and depreciation.

$z_2 = x_7$ refers to the total number of crop acres on the farm. Unfortunately, crop acres on an inter-farm or even an intra-farm basis are a nonstandard measurement as far as the quality is concerned.

$z_6 = x_{11}$ refers to land and building investment expressed in dollar values of the beginning inventory, adjusted for repairs, improvements and depreciation. Perhaps we should call this variable real estate because we refer to land, buildings, fencing and tiling.

$z_5 = x_{10}$ refers to investment in livestock. It is expressed in terms of a dollar value of the average beginning and ending inventories, adjusted for heavy additions or withdrawals during the year.

$z_3 = x_{13}$ refers to the total capital investment on the farm, and with few exceptions it is merely the summation of the machinery, livestock, land and real estate and average working capital investment.

$y_4 = x_{14}$ refers to total costs or total inputs in current outlays and is a sum of the current labor, crop expenses and land expenses.

"JUST-IDENTIFIED" SYSTEMS

Input variables are those which the farmer (1) may "adjust" during the year, (2) may not "adjust" during the year. Therefore, the former are classified as endogenous and the latter as exogenous variables. While total investment itself may not be changed appreciably in a given production period, one component of it may be. Therefore the total capital is considered to be exogeneous and its individual components other than land are considered to be endogenous. Exogenous variables are indicated below by a double asterisk; endogenous variables by a single asterisk.

For a "just-identified" model, parameters can be estimated either by the method of moments or by the reduced form method. One method is equivalent to the other. Also, two alternative equation forms were possible: (1) an equation linear in the logarithms, or (2) an equation linear in the observed values. The first assumes constant elasticity and the latter constant marginal productivity. These assumptions are quite restricting and probably obscure the true relationship, but existing literature in simultaneous equation methods only treats linear models.

Our purpose is to estimate the parameters of the production equation in our system. Observations for the following variables, with transformations, were as follows:

$y_1{}^{*} = x_1$ = crop production (in dollars)
$y_2{}^{*} = x_2$ = labor (costs) inputs
$y_3{}^{*} = x_3$ = other variable production (costs) inputs
$z_1{}^{*} = x_4$ = fixed production (costs) input
$z_2{}^{**} = x_7$ = crop acres
$z_3{}^{**} = x_{13}$ = total investment

The variables y_1, y_2 and y_3 were considered to be endogenous, that is, determined by the system, and z_1, z_2 and z_3 to be exogenous because they were predetermined, or given, and cannot be appreciably affected by a farm in a given production period. The first production equations were obtained by using the reduced form method. The regression coefficients and the sum of the elasticities were as follows for a function linear in the logs:

Variable	Value of Coefficient
a	—1.3805
y_2*	1.1948
y_3*	0.6236
z_1	—0.2363
Sum of elasticities	1.5821

The coefficients again are the elasticities of the factors in respect to the product. Their sum indicates that a 1-percent increase in crop expense inputs alone would increase output 0.62 percent. The labor expense coefficient y_2 is extremely high; the land expense z_1 is negative (interpreted perhaps as zero). An increase of 1 percent of all the factors together would increase output 1.58 percent; increasing returns to scale would hold true even if we accepted a negative land coefficient.

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[26] They were compounded on their economic and physical and statistical relationships. Serially correlated variables were combined, and in all cases the variables combined were closely related economically.