Agricultural Development

Farm Size and Cost Function in Relation to Machinery Technology in North Central Iowa

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AGRICULTURAL AND RURAL DEVELOPMENT

FARM SIZE AND COST FUNCTIONS IN RELATION TO

MACHINERY TECHNOLOGY IN NORTH

CENTRAL IOWA

by
Yie-Lang Chen, Earl O. Heady
and Steven T. Sonka

INTRODUCTION

Agriculture has greatly contributed to and interacted with economic growth in the United States. Particular characteristics of this growth are development of advanced management systems, rapidly advancing technology which places a premium on change and furthers the mechanization process, and changes in the relative real prices of labor and capital. Collectively, these forces have led to development of larger and more highly capitalized farming systems. Both machine technology and the decline in the real cost of capital relative to labor encourage the substitution of capital technology for farm manpower. Under intensive capital technology, fixed costs ordinarily are larger and per unit costs of production are lower for larger farms than for smaller ones. Lower per unit costs result from expansion of farm size and greater specialization so that machine capacity can be more fully utilized.

Other forces also have encouraged larger and fewer farms as farm efficiency increased and new developments in technology occurred. Farmers used more nonfarm inputs and transferred more product handling functions to off-farm businesses. As efficiency improved further, profit margins narrowed and the individual farmer could only expand to produce more output so as to attain income levels deemed consistent with the standards of the rest of society. In addition, public programs enacted to provide income to the farming sector, ranging from direct payments for nonproduction to farm credit, appear to have been geared more to larger units than to smaller ones (1, p. vii-viii).

How far will these forces carry the farm industry? Are the economies associated with large farms great enough to merit sacrifices in other directions? These questions are vitally important to a nation now using only about 5 percent of its labor and nonland capital for farm production and at the same time faced with major diseconomies in large population centers. Still, the number of farms, the farm work force, and the entire population of rural communities continue to decline. To analyze this and related problems a basic question to be answered concerns the nature of returns to scale and the economies of farm size.

This subject is one which is of interest to scientists, farmers and the general citizenry. Farm operators are interested in the nature of returns to scale from the standpoint of profits; the nonfarm population is interested in farm size not only from the standpoint of efficiency of food production but also from the standpoint of political and sociological goals. At the farm level, the operator must compare the utility from (possible) added profits with the disutility from (possibly) taking greater risks or exerting greater energies in the management function. At the national level, society may choose between larger farms as a means of attaining economies in food production and

smaller farms as a means of attaining sociological and political objectives and in giving greater impetus to rural communities. The extent to which one goal should be extended at the expense of another, either at the farm or national level, depends in large part on the nature of returns to scale in farming. If scale or size economies are great, other societal goals may be extended only at a very great sacrifice. If scale economies are small or nonexistent, smaller farms can be used with less sacrifice in attaining a more nearly equal distribution of farm wealth, political stability within agricultural, and similar goals (9, p. 349).

Cost economies and diseconomies of farm size can best be examined by estimating the per-unit costs associated with farms of different sizes. By cost economies or cost diseconomies we refer to phenomena which cause unit costs to decrease or increase as size of the plant and output are expanded (9, p. 361).

Specific Problem

Farmers, legislators, scientists and agribusinessmen frequently have different objectives and therefore have different concepts of the optimum farm size. The optimum farm size is not likely to be the same when the primary objective is rural community benefit as when it is maximization of farmer income or minimization of consumer food costs. Even for the same objective, the optimum size will quite likely change over time. The adequacy of any particular size or scale of enterprise decreases over time because of changes in resources, technology, prices, and the environment.

Farmers have less than perfect knowledge, their expectations are not always correct, and there are time lags and discontinuities in the size of the adjustment they make. Thus, farm level decision-making takes place in an environmental of uncertainty. For example, farmers may be quite uncertain as to the effect shifting from conventional 40"-row machinery combinations to recently introduced 30"-row machinery combinations may have on per-unit production costs and on farm income. Farmers are also uncertain as to what farm size and machinery combination can be used to realize the major cost economies available under current machinery technology. Of course, great uncertainty often surrounds commodity prices, trends in input prices and the technology they represent. These uncertainties affect capital use of farmers and hence farm size.

This report is designed to provide information on the effect of alternative farm sizes and recent machinery technology on unit production costs for cash-crop farming. It also indicates the resource combinations which can be used to attain the major cost economies available in north central Iowa.

The study is one in a series made periodically to determine the extent to which new technology has changed the size of farms which result in minimum costs or which exploit the major cost advantages of declining fixed machinery costs. We have made such studies at intervals in time as sufficient new machine technologies have come into existence (12, 13, 16, 25). We do not make this study as a consideration in new concepts. We make it at periodic intervals for the reasons mentioned above.

Previous Research

This section of the report presents a brief discussion of the theoretical basis for the assumed presence of economies and/or dis-economies of scale in agricultural production. It also refers to several previous quantitative studies which have analyzed this question. This section, although a disgression from the main thrust of the report, does indicate the philiosophical basis from which the study was generated.

The traditional view of the long-run cost situation for American farming operations is presented in Figure 1 below. For this illustration, the vertical axis is cost of production per unit of output and the horizontal axis is farm size, in acres. In some instances, of course, it is more proper to use other measures of farm size such as volume of output or number of breeding stock. The section of the graph from points A to B represents a decline in per unit costs as farm size expands. These cost reductions result from the possibility of more fully utilizing the farmer's fixed productive assets by operating more acres. For most farming situations, it has traditionally been assumed that point B can be reached relatively quickly.

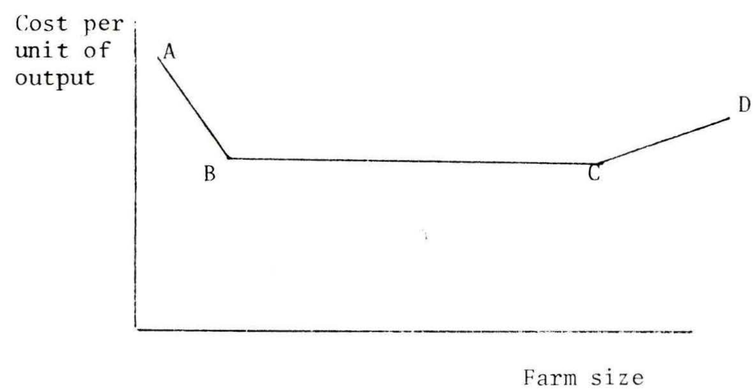

Figure 1. Hypothetical view of long-run costs for the traditional farm firm.

The segment of Figure 1 from point B to point C represents a region of constant, or very slightly declining, costs. This segment is usually assumed to hold for a very wide range of farm sizes. Madden analyzed fifteen studies of scale economies in grain, dairy, and livestock production in 1967. He concluded that, "in most of the farming operations examined, a modern and fully mechanized one-man or two-man operation can produce efficiently and profitably, achieving all or nearly all of the economies of size" (24). Castle, Becker, and Smith present a long-run cost curve for wheat production in the Columbia Basin of Oregon which indicates very nearly constant costs for wheat acreages of from 1000 to 2800 acres (3). A study by Frisby and Bockhop in the early 1960s indicates a wide range for constant per acre returns for corn production in Iowa (8). That study details optimal machinery systems ranging from 285 to 1,325 acres for a corn production area consistent with the area described in this study.

Typically, studies analyzing economies of scale are concerned with factors at the firm level. A report by Sonka and Heady is an exception to this normal pattern and examines the effect of different farming structures for a large number of agricultural regions (35). The study also supports the theoretical cost structure of Figure 1. In addition, the report hypothesizes, and provides a quantitative illustration of the trade-off between rural community welfare and rising per farm net income as farm-size expands.

The third segment of Figure 1, from point C to point D, represents a region of increasing per unit costs. This section of the graph corresponds

to a farming situation where farm-size expansion has proceeded too far. Diseconomies of scale for this situation are usually attributable to limitations of the management input.

Given the theoretical structure of Figure 1, an obvious question relates to the continued existence of farming operations which are smaller than a size corresponding to point B in Figure 1. Castle, Becker, and Smith provide five possible justifications for the existence of these smaller farming units (3): (a) lack of knowledge regarding potential cost reductions from size expansion, (b) conservative nature of the farmer or limited capital reserves, (c) lack of farmer profit motivation, (d) conflict between size expansion and other family goals, at the particular point of the life cycle of the farm firm, and (e) greater return to labor in alternative employment, especially for part-time farmers.

Typically (as in this report), studies of economies of scale have not considered the 'giant' farming enterprise. Usually these types of operations are few in number, so that data for them is difficult to obtain. Also their small number (in the past) suggests that production economies for them may not be great. Recently, however, more of these giant operations have come into existence and have, in some enterprises, become the norm rather than the exception.

Indeed, the study by Madden indicated that units much larger than one-or-two-man operations are needed to exhaust scale economies for commercial beef feeding in the Western states (24). The rationale for the very large operations is often related to other factors than production economies, however. Krause and Kyle hypothesize a number of incentives for these 'super-sized' operations (23). They include market discounts for volume buying of inputs and premiums for large-scale merchandising of output. Also the possibility of hiring management specialists for particular tasks increases as the size of operation reaches very large levels. Of course, a factor with intense public interest is the establishment of large-scale farming enterprises by nonfarm conglomerates. This issue is especially interesting if the farming enterprise is organized more to provide an income tax shelter than to earn a profit from agricultural production.

An examination of large-scale corn production units is provided by Krause and Kyle (23). They compared corn production units of 500, 1000, 2000, and 5000 acres, allowing market advantages to the larger units both in input procurement and output marketing. Increased costs for the larger units are reflected in higher wage rates labor and management. Using these assumptions, they estimate a $7.30 per acre advantage for the 5000 acre unit as compared to a 500 acre operation. Put on a per unit of output basis, this saving would probably be of the magnitude of 5 percent or less, however.

Objectives of this Study

The major purposes of this report are (a) to determine the per unit cost relationship associated with various farm-size and machinery combinations and (b) to specify and compare the resource combinations required to attain the major cost economies available with current machinery technology in north central Iowa. To accomplish these objectives cost functions have been budgeted for the study area for both 30"-row and 40"-row machinery combinations based on several cropping systems and price levels. From this budgeting procedure cost curves are derived which describe the cost relationships associated with farm size in the short- and long-run.

The specific objectives of this report are: (1) to determine the nature and extent of cost economies and diseconomies associated with farm-size and various selected machinery combinations, (2) to compare budgeting results on minimum average costs and minimum average cost acreage for various selected machinery combinations with several cropping systems and price levels, and (3) to compre residual returns to labor and land for farms based on different cropping systems and price levels. As mentioned previously, this is another study of farm cost economies made periodically (12, 13, 16, 25) to ascertain whether (and the extent to which) the scale of farm operations necessary to exploit the main cost advantages of accumulated or new machine technologies has changed.

Although we are concerned in this report with the relationships between farm-size and cost economies or diseconomies, we also must recognize that size of farm is affected by uncertainty and capital availability. Managerial ability, risk aversion, and capital rationing are other important factors in determining prevailing farm sizes.

The cost analysis is based on specific prices for farm resources, inputs, and crops. These prices were relevant for the time the study was initiated (1972) and for comparison of output levels consistent with minimum acre or unit costs. The prices are not, however, representative of the recent period of high exports and high land, labor, and grain prices. The costs computed and used in this study are for comparisons of cost or scale economies of farm-size in acreage--and not for measurement or indication of price levels which should exist if current grain producing costs were to be covered or attained by market prices or government support prices. Recent per unit costs, if inflated land values and high prices for other inputs are included, are considerably higher than the cost functions derived in this study for comparisons among farm machinery sets and farm size.

THE STUDY AREA AND FARM SITUATION

To examine potential economies of scale at the firm level, a particular soil and cropping system must be chosen in isolating the effect of differing sizes of machinery. This section of the report presents a description of the study area and farm situation selected for this analysis.

Soil Association Area

The cost curves developed apply to the Clarion-Nicollet-Webster soil association area in north central Iowa. This soil association, Figure 2, occupies all or parts of 29 counties in Iowa. Its topography is generally level to gently sloping, although some gently to strongly sloping areas are also present. Most land in this soil association has a good corn suitability rating (CSR) and the average corn yield in this area was 105 bushels per acre for the period 1967-1972. This yield compares with the state average yield of 97 bushels for the same period.

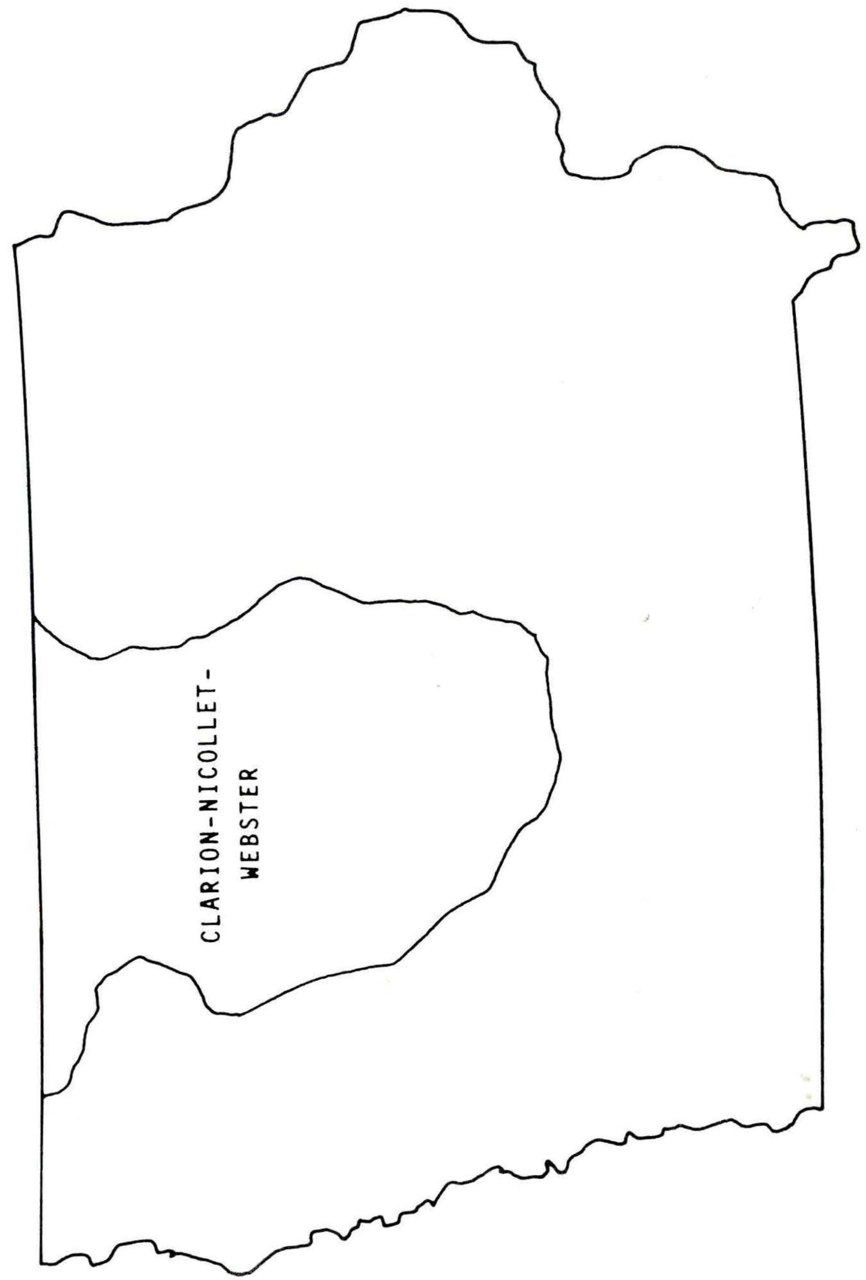

Figure 2. Soil association area of Iowa considered in this report.

Within the soil association area, there is a large number of soil mixtures each producing a unique set of land restrictions to be used in the budgeting model. But because of the limitations of time and expenditures, only one soil mixture is specified for the analysis. The soil mixture chosen, however, was selected to represent the typical soil mixture in this soil association.

The Humboldt farm

In Iowa, soils can be grouped into three different classes in terms of their CSR. Soils with CSR of less than 70 are considered below average, soils with a CSR between 70 and 80 are average, and those with a CSR between 80 and 90 are above average. From the sample soil survey conducted by the Soil Conservation Service and the Iowa Agricultural Experiment Station, we obtained detailed information about soil mixtures in the study area (38). A judgement selection of one specific unit of land was made to define the soil-type mixtures to be used. The selected section and its location is: section 25 in township 92 north and range 27 west of Humboldt county. The area is 35.5 percent Nicollete loam, 50.9 percent Webster silty clay loam, and 13.6 percent Clarion loam. The CSR for this area is 81.6.

Having selected the specific soil mixture, the next step is derivation of land restrictions. The multiplicity, size, shape and location of the soil survey mapping units prohibit considering them as fields or operational units. Consequently, these mapping units are aggregated

into the following general categories: (1) cropland, (2) permanent pasture and (3) waste land (homestead, roads, etc.). A representative quarter section of land so organized is given in Appendix Table A-I.

Specification of the Cropping System

Corn, soybeans, oats, and hay are the major crops of north central Iowa. From 1961 to 1970, the area maintained 36 percent of the cropland in corn. Soybeans increased from 21.7 percent to 31.9 percent, oats decreased from 8.6 percent to 2.9 percent, and hay decreased from 6.9 percent to 2.8 percent (17, 18).

Only two cropping systems are considered in this study. One, called the current cropping system, involves a mixture of corn, soybeans, oats, and hay production and corresponds to the crop mix grown in the area. These percentages are corn, 49.8; soybeans, 42.9; oats, 3.5; and hay, 3.8 (18). The continuous corn cropping system assumes that nothing but corn is produced. This assumption is based on the fact that some farms in the central Corn Belt are becoming specialized in corn production alone. Also, on most other farms in the Corn Belt where soybeans and other crops are raised, corn is the dominant crop (33).

A recent technological development, narrow-row culture, has increased the choices open to producers. The advantages of narrower row spacings over wider (40")-row spacings include better use of radiation of light energy, more efficient use of water, and shading of weeds to reduce competition for moisture and nutrients. For this study, 30"-row spacings are specific to illustrate the cost relationships of narrower-row spacings.

Available data show that for planning purposes, a farmer can expect a 5 percent increase in corn yields and a 10 percent increase in soybean yields by shifting from 40" to 30" spacing (26). The per acre yields for each rotation with both row spacings are presented in Table 1. Achieving the yield estimates presented requires a high level of management and use of 'most-known' technology. This high-level management assumes all necessary inputs or operations are near the optimum level. It is believed that the yields presented could be surpassed readily in any year, but only a small percentage of farms could be expected to achieve yields as much as 10 percent higher than those shown over a 5-year period (7).

Table 1. Composition of crops in rotations and resulting yields per acre (no untimeliness losses assumed).[a]

	Corn	Oats	Soybeans	Hay
Current cropping system				
Acres per 100 acres of cropland	49.8	3.5	42.9	3.8
Yields per acre				
40" row	110.6 bu	88.4 bu	42.2 bu	4.57 tons
30" row	116.1	88.4 bu	46.8 bu	4.57 tons
Continuous corn				
Yields per acre				
40" row	110.6 bu			
30" row	116.1 bu			

[a]Sources: (7, 39). The yields require a high level of management and use of most known technology.

BUDGETING PROCEDURES

This section of the report is concerned with the budgeting procedures used to estimate cost functions for the different machinery combinations and farm sizes examined in this study. Descriptions included in this section are: (1) assumptions underlying the budgeting procedure, (2) selected machinery combinations, (3) costs of inputs and prices of outputs, (4) timeliness of operation and (5) derivation of cost functions and cost curves.

Budgeting Procedure Assumptions

Several simplifying assumptions are necessary to allow development of the various cost functions. These assumptions are: (1) In the continuous corn cropping system, machinery combinations differ slightly from those in the current cropping system. (2) The farm operator pays current market prices for all inputs not produced on the farm and all crops are sold for cash at specified price levels. (3) Land and labor are unlimited in supply (at market prices) and farm size can be expanded to achieve economies without management limitations. (4) The farmer owns the machinery and custom work or machine rental are not used.

Selected Machinery Combinations

The five-machinery combinations, with the total investment for new machines for 30 inch and 40 inch rows, used as a basis of deriving per acre costs are:

1. 4-row	30" ($ 49,990) 40" ($ 50,369)
2. 6-row	30" ($ 66,039) 40" ($ 67,346)
3. 8-row	30" ($ 79,237) 40" ($ 78,883)[1]
4. 4-row,4-row	30" ($ 93,275) 40" ($ 94,033)
5. 4-row,6-row	30" ($109,171) 40" ($110,857)

The first three sets of machinery combinations are 1-man, 1-tractor combinations but the last two sets are 2-man, 2-tractor combinations. The purchase price of machines included in each set of machinery combination is presented in Tables A-2 through A-6. These prices estimate the total cost of the machines listed and were derived from the National Farm Tractor and Implement Blue Book (28) and local farm machinery dealers in central Iowa. These investment estimates, as well as the other input prices used here, relate to 1972 prices unadjusted for inflation since that time.

Cost of Inputs and Price of Outputs

Total cost is divided into two components, fixed cost and variable cost. Total fixed costs are those which do not vary with the amount of use and include certain machinery depreciation, interest on investment, insurance, taxes, and housing. The types of depreciation included as a fixed cost relate to a decline in machinery value resulting from obsolesence, rust, and corrosion. From an accounting point of view, depreciation is the

[1]Because 8-40" corn heads are not available, the 8-40" machinery combination includes a 6-40" corn head. The result of this substitution is that the 8-40" combination is slightly less expensive than the 8-30" combinatio

annual recovery of a prepaid cost over the useful life of the machine. The most common methods of calculating depreciation for tax purposes are the straight-line, declining-balance, and sum-of-digits methods. The Farmer's Income Tax Guide, published yearly by the Internal Revenue Service, explains these methods (20).

The straight-line method is used in this study to compute average depreciation costs. The formula for this method is:

$$D = \frac{P-S}{N} \quad (1)$$

where: D = average depreciation costs, P = purchase price, S = salvage value, and N = number of years in use. The number of years of use estimated by the Agricultural Engineers Yearbook 1963 (in 15) is given in Appendix Table A-7. The salvage value is assumed to be 10 percent of the purchase price.

Interest on investment is the annual interest charge on the unrecovered cost of machinery. This factor is included as an operational cost because money used to buy a machine cannot be used for other productive enterprises. The interest rate used is 8 percent on the average machinery investment (32). Average investment is determined as follows:

$$A = S + \frac{P-S}{2} = \frac{P+S}{2} \quad (2)$$

where: A = average investment and P and S are defined as before.

Liability insurance coverage is included because tractors and other machinery may be involved in accidents resulting in liability claims. There also may be losses as a result of fire or high winds. Insurance is estimated as 0.25 percent of the purchase price of machines (15). Personal property taxes are estimated as 1 percent of purchase price (10). Housing costs are also estimated as 1 percent of purchase price (33).

The annual total fixed costs of the five selected machinery combinations used in the current cropping system are presented in Appendix Table A-8. The annual fixed machinery costs are $7,072, $9,404, and $10,942, for 4-40", 6-40", and 8-40" machinery combinations, respectively. The annual fixed machinery costs for 30" rows are slightly less than those of 40" rows, as shown in Table A-8.

Total variable costs are those which vary with the amount of use; including machine repair, fuel and oil, seed, insecticide and fertilizer, land rent, and labor. Cost of repairs is an important factor in determining the point of replacement for a machine. Estimated annual repair costs per acre for corn are $6.51, $6.20, and $6.61 for the 4-40", 6-40", and 8-40" machinery combinations, respectively. Per acre repair costs estimated for soybeans are slightly less than those estimated for corn. Since 30"-row and 40"-row combinations have different effective capacities, the repair costs estimated for them also are different. Usually, the 30"-row machinery combinations have higher repair costs than 40"-row machinery combinations.

The amount of fuel used per hour depends on the size of the tractor, the type of fuel it is using, and the job it is doing (2). The price of diesel fuel is assumed to be $0.186 per gallon.

Estimated seed, insecticide, and fertilizer costs per acre are given in Table A-9. The fertilizer used is consistent with the efficient fertilizer use recommended for this area (37). The amount of fertilizer used differs among crops as shown in Table A-10 in the Appendix. To reflect the greater intensity of narrow-row cultivation the cost per acre for seed, insecticide, and fertilizer for the 30"-row spacing is set 5 percent higher than for the

40"-row spacing. Land rents per acre, interest on the purchase price of land, and property taxes are given in Table A-11.

Variable labor costs include the labor required for maintenance and repair, in addition to actual field operations. The variable maintenance requirements for labor are set at 30 percent of the labor required for field operations (20). In calculating labor costs, wage rates of $2.00 per hour for both operator and regular hired labor are assumed.[1] Labor costs for 40"-row machinery combinations are slightly lower than those for 30"-row machinery combinations. Variable costs for the 30"-and 40"-row combinations are presented in Tables A-14, A-15, and A-16.

The per unit cost curves developed in this study measure costs per dollar value of crop product. Hence at least one set of prices is needed to determine total value of output. Two sets of prices are compared in this study, however, to indicate the effect of changes in output price on costs per dollar of output. The two price levels chosen are averages (a) for the years 1971-73 and (b) for the single year 1973, as reported in Prices of Iowa Farm Products 1930-1973 (31). Average prices for the 1971-73 period are lower than the 1973 prices. In the period 1971-73, the price of corn, for example, averaged $1.38 per bushel while in 1973 the corn price was $1.81 per bushel. The prices used in estimating the cost functions are presented in Table A-12 of the Appendix.

Timeliness of Operation

Many field tasks must be accomplished within a limited period of time if "excessive" production losses are to be avoided. Therefore, adequate machine capacity is needed to prevent "excessive" yield losses. Yield

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[1] Per hour wage rates for farm labor averaged $1.84 in the United States in 1972 (36). This wage rate would not include any charge for management, however.

losses from delays in machine operations differ both for various machine operations on a given crop and for the same machine operations on different crops. A farmer attempting to avoid yield losses from delays in various machine operations generally gains most by owning those machines for which timely operations prevent greatest losses (11). In this report, the following operations are assumed to cause losses in yields due to untimely operations: (1) corn planting, (2) corn cultivation, (3) corn harvesting, (4) soybean planting, (5) soybean cultivation, and (6) soybean harvesting. Since oats and hay are very small proportions of the current cropping system, they are excluded from the calculation of yield losses.

Yield losses from untimely operations relate to the number of hours available for field work each day, the number of hours available in the optimal periods for specific field operations, the estimated average crop losses per acre from untimely field operations, and the machinery capacities per hour for various field operations. The estimated average number of hours available for field work by weeks in north central Iowa was obtained from McKee (25) and adjusted on the basis of climatologic data (34) (see Table A-13). The estimated average number of hours available in the no-loss periods for specific field operations are presented in Table 2. It is assumed that these field operations must be performed during optimum, or no-loss, time periods to achieve the yields presented in Table 1. The estimated average crop losses per acre from untimely field operations in north central Iowa are given in Table 3.

Table 2. Estimated average number of hours available by no-loss periods for specific crop field operations.[a]

Crop field operations	Period	Hours available
Corn planting	May 2-10	45.9
Soybean planting	May 10-17	45.5
Corn cultivation		
First	June 14-20	45.2
Second	July 1-6	41.1
Soybean cultivation	June 21-27	41.4
Corn harvesting	Oct. 22-27	43.6
Soybean harvesting	Oct. 3-7	37.5

[a]See Table A-13.

Table 3. Estimated average crop losses per acre from untimely field operations in north central Iowa.

Crop field operations	Date losses begin	Losses per acre per day late
Corn planting[a]	May 11	First 10 days 0.8 bu. Next 10 days 1.0 bu.
Soybean planting[b]	May 18	0.9 bu.
Oats planting[c]	April 12	1.0 bu.
Corn cultivation[d]		
First	June 21	0.5 bu.
Second	July 7	0.25
Soybean cultivation[e]	June 27	0.75 bu.
Oats harvest[e]	July 21	1.3%
Soybean harvest[e]	Oct. 6	1.3%
Corn harvest[e]	Oct. 26	0.6%

[a]Source: From (5).

[b]Source: From (12).

[c]Source: From (16).

[d]Source: From (22).

[e]Source: From (26).

The effective field capacity of a machine is a function of the rated width of the machine, the percentage of rated width actually utilized, speed of travel, and the amount of field time lost during the operation (21). The effective capacity of a machine may be expressed as follows:

$$C = \frac{5280 \times S \times W \times E_f}{43{,}560 \times 100} = \frac{S\ W\ E_f}{825} \qquad (3)$$

where: C = effective field capacity, in acres per hour, S = speed of travel, in miles per hour, W = rated width of implement, in feet, E_f = field efficiency, in percent, and 43,560 = number of square feet in an acre.

Derivation of Cost Functions and Cost Curves

In the budgeting procedure, data from agronomists, agricultural engineers, economists, and others were used to estimate input-output relationships and prices. Based on these empirical data, total cost functions were estimated from which unit cost curves were derived (13). Equations 4-8 are used to illustrate the process of estimating the cost functions.

$$C_i = b_i + a_i\ X \qquad (4)$$

$$T_i = a_i + b_i/X \qquad (5)$$

$$L_i = f_i\ (X) \qquad (6)$$

$$TR_i = (P*Y*X - L_i)/X \qquad (7)$$

$$TC_i = T_i/TR_i \qquad (8)$$

where: i = a specific machinery combination, X = number of acres, C_i = total cost of producing X acres with the ith combination, b_i = fixed costs for the ith combination, a_i = variable costs for the ith combination, T_i = average total cost for the ith combination, L_i = untimeliness loss for farming X acres with the ith machinery combination, f_i = unspecified functional form

which relates X to a dollar value of untimeliness loss for the ith operation, TR_i = total revenue per acre for the ith operation, P = output prices, Y = yield with no untimeliness losses, and TC_i = dollar cost per dollar of crop product (land rent not included).

The cost functions and cost curves presented in the next chapter do not include a land rent in the calculation of total costs. In the following chapter, however, budgeting results are presented with land rent included in total costs.

Short-run and long-run cost curves

The relationship between proportionality of factor combinations, unit costs of production, and the optimum size of firm, either in a minimum cost or maximum profit sense, is best explored through concepts of long-run and short-run cost curves. Short-run refers to a cost structure and time period in which some factors are fixed in quantity and form. The term long-run refers to the cost possibilities which face a producing unit over a period of time long enough that no factors need be considered fixed (10, p. 364).

From the estimated cost functions, short-run cost curves can be derived to indicate the relationship between average total cost and farm size[1] with the current machinery technology. For single season planning short-run cost curves can be used to demonstrate the minimum average cost for each machinery combination and the crop acreages necessary to attain that minimum

[1]In this report, farm size and crop-acres are used interchangeably. Since we assumed all crop-acres are harvested, crop-acres actually mean harvested crop-acres.

unit cost. Long-run cost curves indicate the farm size and machinery combinations necessary to attain the major cost economies available when multi-season planning decisions are made.

In addition to farm size and machinery combinations, other factors such as price levels and row width also can affect the unit cost and profitability of production. In this analysis, therefore, we also consider the effects of these factors. Table 4 outlines the combinations of cropping systems, row width, and price levels for which cost functions are detailed in this report.

Table 4. Combinations of cropping systems, row width, and price levels for which cost functions are developed.

No.	Combinations
1	Current cropping systems, 40" row, 1971-73 prices
2	Current cropping system, 30" row, 1971-73 prices
3	Continuous corn cropping system, 40" row, 1971-73 prices
4	Continuous corn cropping system, 30" row, 1971-73 prices
5	Current cropping system, 40" row, 1973 prices
6	Current cropping system, 30" row, 1973 prices

BUDGETING RESULTS

This section presents the results for the budgeting analysis, i.e., the cost structures for the various farm sizes and conditions. The cost functions estimated under the specific situations are presented first. Then the short-run and long-run cost curves derived from these functions are detailed. Cost functions are estimated for each of the five selected machinery combinations for acreages ranging from 160 to 1280 acres.

Because of length consideration, only two of the six combinations in Table 4 are discussed in this section. A later section of the report, however, will compare the six combinations. In this section detailed analysis of cost curves are presented for combinations 1 and 2 of Table 4. Similar detail for the other four combinations is available in (4).

The cost functions and cost curves presented in this section do not include land costs. Omission of a land charge from the total costs does not greatly change the curvatures and relative positions of these cost curves. Although land costs are not considered in the derivations in this section, the term total cost will be used.

Cost Structures for 40" Rows

Short-run total costs have two components, total fixed cost and total variable cost. The greatest cost advantage for larger acreages arises as the proportions of resources are changed and total fixed costs are spread over a greater output. For any given set of machinery combinations, an increase in the acreage operated causes per acre cost to decline (assuming no loss due to untimely operations). Because a major portion of total cost is fixed, total cost per acre declines as more acres are operated even if the variable cost of fertilizer, seed, tractor fuel and labor are constant.

Short-run average total cost per acre

Average per acre costs for selected 40"-row machinery combinations, based on the current cropping system and no crop loss penalties, are presented in Table 5 and Figure 3.[1] Since per-acre variable costs are different

[1]The remainder of this section refers only to 40"-row machinery combinations based on the current cropping system and 1971-73 average prices. To save space, therefore, that entire phrase may not always be used.

Table 5. Average total cost per acre for selected 40"-row machinery combinations based on the current cropping system and no crop loss penalties.

	Machinery combination				
	4-40"	6-40"	8-40"	4-40" 4-40"	4-40" 6-40"
Total fixed cost	$ 7,072.00	$ 9,404.00	$10,942.00	$13,177.00	$15,492.00
	Per-acre variable cost				
for corn	$54.97	$51.83	$50.62	$54.97	$53.39
for soybeans	38.44	36.37	35.74	38.44	37.41
for oats	23.30	22.85	22.46	23.30	23.07
for hay	51.84	51.84	51.84	51.84	51.84
combined variable cost	46.65	44.19	43.28	46.65	45.41
crop-acres	Average total cost per acre				
160	$90.85	$102.96	$111.66	$129.00	$142.23
320	68.75	73.57	77.47	87.82	93.82
480	61.38	63.78	66.07	74.10	77.68
640	57.70	58.88	60.37	67.23	69.61
800	55.49	55.94	56.95	63.12	64.77
960	54.01	53.98	54.67	60.37	61.54
1120	52.96	52.59	53.04	58.41	59.24

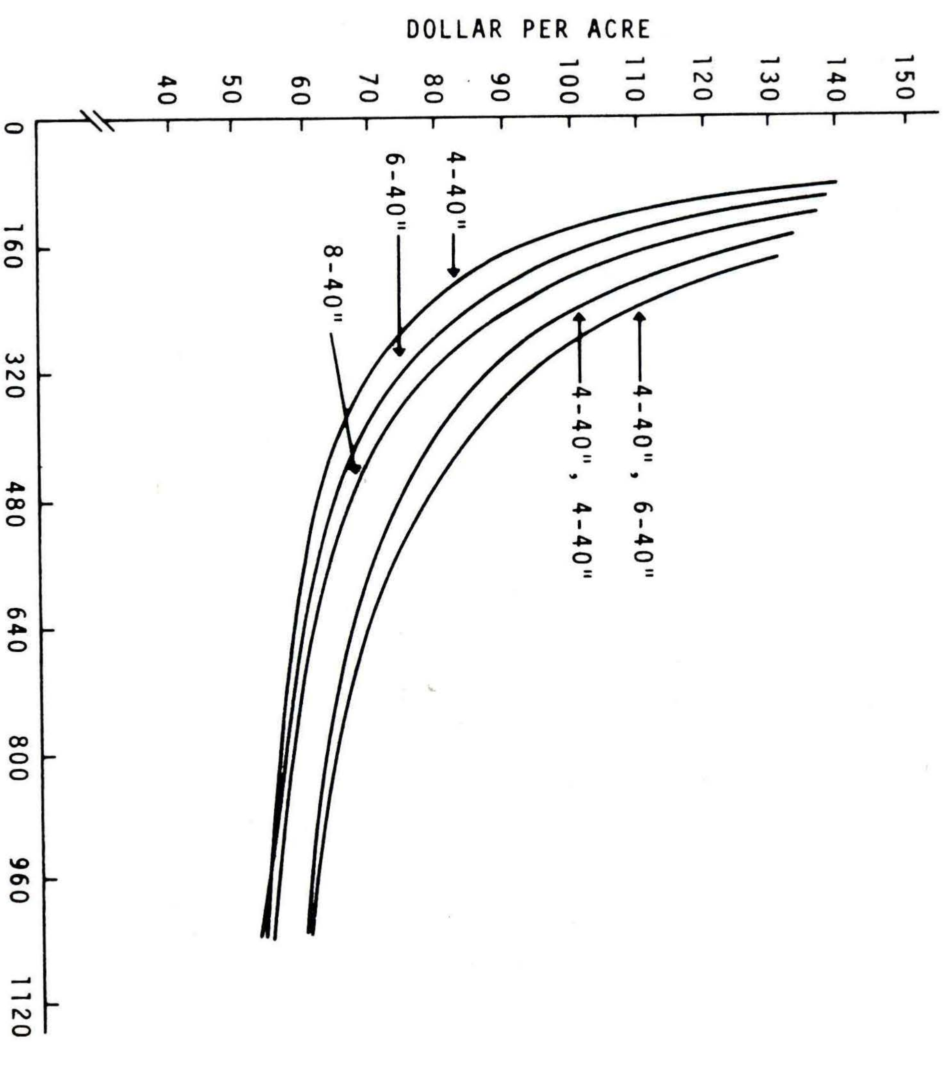

Figure 3. Average total cost per acre for selected 40"-row machinery combinations based on the current cropping system and no crop loss penalties

for corn, soybeans, oats and hay, a combined variable cost per acre was calculated according to the percentage of each crop's acreage specified in the current cropping system. The larger the machinery capacity, the lower the per acre variable cost. Per acre variable costs are $46.65, $44.19, and $43.28, for the 4-40", 6-40", and 8-40" combinations, respectively (Table 5). Larger machinery capacity results in lower labor requirements but higher fixed costs. Labor costs per acre are $9.46, $6.90, and $5.40 for 4-row, 6-row, and 8-row machinery combinations, respectively (Table A-15).

Figure 3 indicates that average total cost per acre declines sharply as crop acres increase. For the 4-40" machinery combination, average total cost per acre decreases from $90.85 at 160 acres to $61.38 at 480 acres. This characteristic of declining expense per acre also holds true for all other machinery combinations examined.

An important point dealing with the cost advantages of farms of different size is that the average total cost curves tend to "flatten out." For example, after farm size for the 6-40" machinery combination attains 640 acres, cost per acre declines only slightly as size is increased to 1,120 acres. The per acre cost curves flatten out when the main advantages of spreading fixed costs have been attained. The curves become nearly flat when most costs are of a variable nature and total costs per acre cannot be lowered by a great percentage as acreage is expanded further. For each machinery combination with the current cropping system, a farm with 640 acres has a great cost advantage over one with 320 acres, but gains relatively little if it expands to 1,120 acres (even without untimeliness losses).

Among all 40"-row machinery combinations, Figure 3 indicates that the 4-40" machinery combination is, cost-wise, most efficient for less than 880 acres. Other machinery combinations have a higher total average cost per acre. However, other important factors such as physical output per acre, losses due to untimeliness of field operations and the prices of farm product are not considered in the derivation of Figure 3. When these factors are considered, the cost curves which describe the per unit cost and farm size for all selected machinery combinations provide more practical information for making machinery decisions.

Cost and revenue per acre when untimeliness losses are introduced

Figure 3 relates cost per acre to the number of crop-acres when land acreage is varied for each machinery combination. In this formulation, the machinery combination is fixed and the amount of land, labor, tractor fuel, and seed is variable. Per acre costs decline as long as more acres are operated with one set of machinery because variable costs are constant and machinery costs per acre decline with more acres. However, an infinite number of acres cannot be operated with one size of machinery without lowering yields. As more acres are farmed; planting, cultivating, and harvesting time for corn and soybeans stretches over a longer period. Even though variable costs per acre are constant as more acres are operated, a decline in per acre yields will cause variable costs per unit of product to increase. Total cost per unit will then increase as soon as the increase in variable cost is greater than the decline in fixed cost, even though the total cost per acre may still be declining as more acres are operated.

Output and total revenue are ignored in the construction of Figure 3, thus implicitly assuming that output and total revenue per acre are constant. However for any given set of machinery, output and total revenue per acre are not constant when the losses because of untimeliness of field operations are introduced. For example, average revenue declines sharply after farm size reaches 640 acres with the 6-40" combination (Figure 4). Hence in order to examine the cost economies of farm size and machinery combinations, total cost, total revenue, and acreage must be considered in one figure. In the rest of this section, the cost curves will be presented with the ratio of average total cost to average total revenue on the vertical axis and crop acreage on the horizontal axis.

Short-run average total cost per dollar of crop product

The cost functions (without land costs) estimated for the five selected machinery combinations considered are:

$$TC_{4\text{-}40''} = 46.7(185.9 - 0.0793X)^{-1} + 7{,}072.0(185.9X - 0.0793X^2)^{-1} \quad (11)$$

$$TC_{6\text{-}40''} = 44.2(167.9 - 0.0271X)^{-1} + 9{,}404.0(167.9X - 0.0271X^2)^{-1} \quad (12)$$

$$TC_{8\text{-}40''} = 43.3(178.0 - 0.0439X)^{-1} + 10{,}942.0(178.0X - 0.0439X^2)^{-1} \quad (13)$$

$$TC_{4\text{-}40'',4\text{-}40''} = 46.7(167.8 - 0.0182X)^{-1} + 13{,}177.0(167.8X - 0.0182X^2)^{-1} \quad (14)$$

$$TC_{4\text{-}40'',6\text{-}40''} = 45.4(164.5 - 0.0114X)^{-1} + 15{,}492.0(164.5X - 0.0114X^2)^{-1} \quad (15)$$

The average costs of producing $1 of crop product for the 40" machinery combinations, the current cropping system, and 1971-73 prices are presented in Table 6 and Figure 5. For 40"-row spacing, yields per acre are 110.6, 88.4, and 42.2 bushels for corn, oats, and soybeans, respectively and 4.57

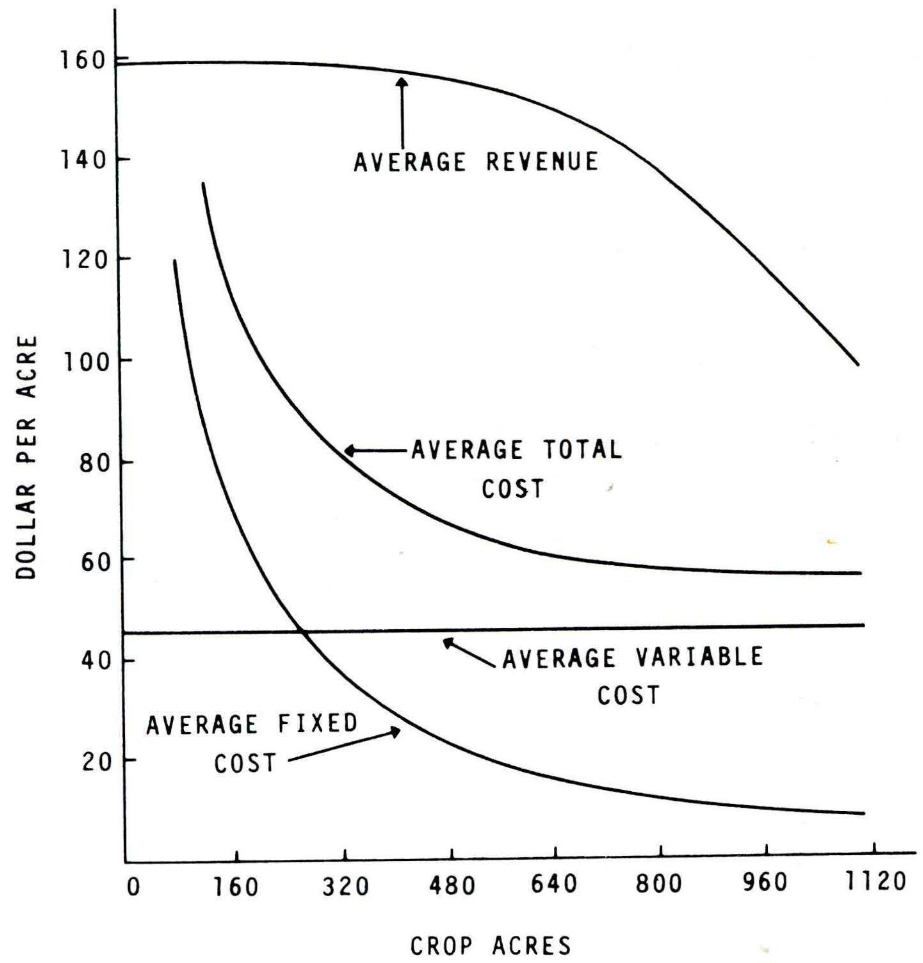

Figure 4. Average costs and revenue per acre for the 6-40" machinery combination based on the current cropping system.

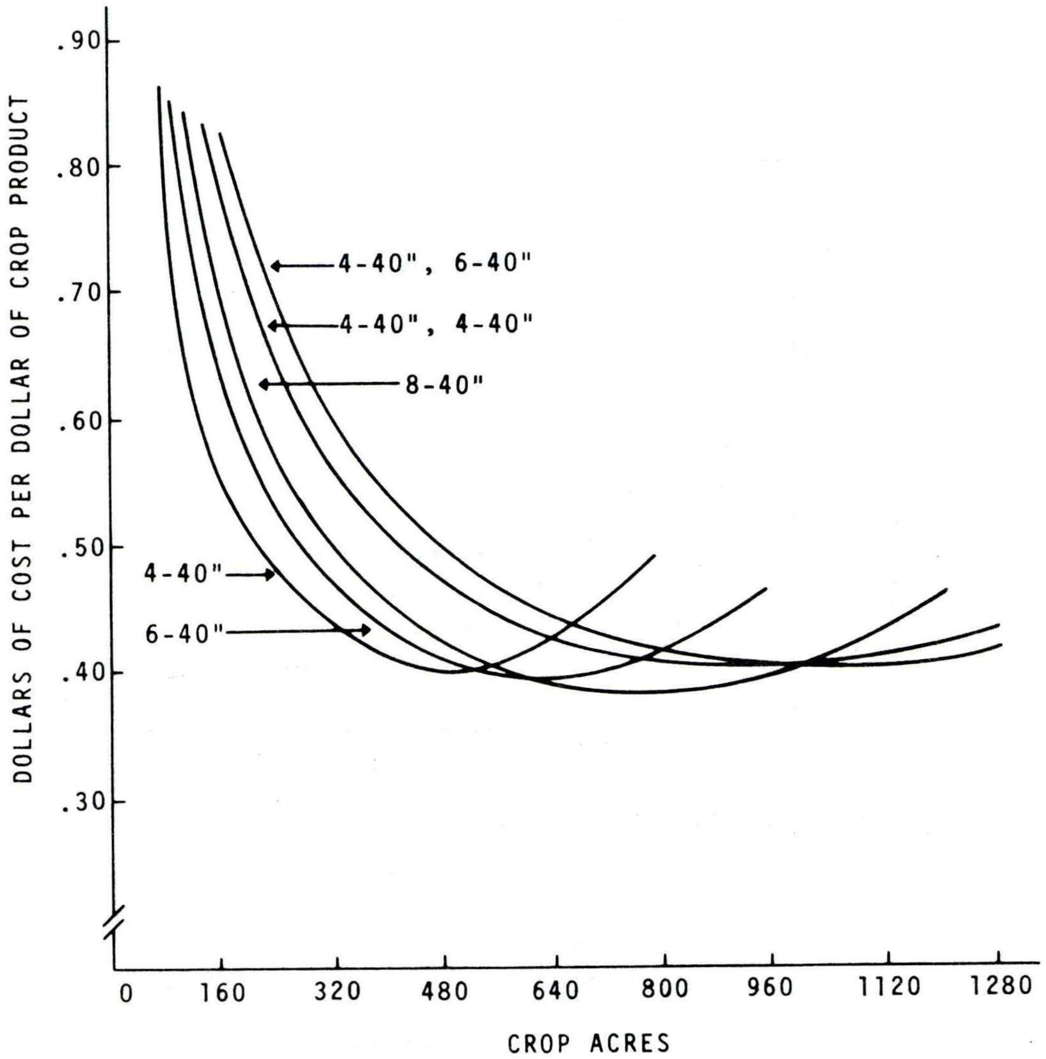

Figure 5. Average costs of producing $1 worth of crop product for selected 40"-row machinery combinations based on the current cropping system and 1971-73 prices.

Table 6. Average costs of producing $1 worth of crop product for selected 40" -row machinery combinations, the current cropping system, and 1971-73 prices

Crop acres	Machinery combination				
	4-40"	6-40"	8-40"	4-40" 4-40"	4-40" 6-40"
80	$ .849	$ 1.017	$ 1.132	$ 1.329	$ 1.503
160	.571	.647	.702	.811	.894
320	.435	.464	.488	.552	.590
480	.401	.407	.421	.466	.489
640	.435	.393	.390	.426	.439
800	.510	.417	.382	.402	.411
960	--	.471	.395	.396	.397
1120	--	--	.435	.407	.398
1280	--	--	--	.427	.409

Table 7. Untimeliness losses in dollars per acre for selected 40"-row machinery combinations with the current cropping system and 1971-73 prices

Crop acres	Machinery combination				
	4-40"	6-40"	8-40"	4-40" 4-40"	4-40" 6-40"
160	$0.0	$0.0	$0.0	$0.0	$0.0
320	1.1	0.7	0.5	0.0	0.0
480	6.4	2.6	2.3	0.2	0.1
640	26.5	9.4	4.5	1.1	0.8
800	50.5	25.2	10.4	2.2	1.8
960	--	44.6	20.8	6.9	4.2
1120	--	--	--	16.1	10.1
1280	--	--	--	25.9	18.7

tons for hay (Table 1). Under 1971-73 prices, prices per bushel are $1.38, $0.77, and $4.23 for corn, oats, and soybeans, respectively, and $22.70 per ton for hay. Thus, with no losses because of untimeliness, total revenue per acre is $159.10 for the current cropping system. However, untimeliness losses occur when field operations are performed in suboptimal time periods. Untimeliness losses for the selected 40"-row machinery combinations are presented in Table 7.

The average cost curves in Figure 5 are U-shaped, passing through stages of decreasing, constant and increasing cost. After the minimum cost acreage has been attained, the losses from untimeliness more than offset the decline in average fixed costs causing the average cost curves to turn upward.

For given machinery combinations, Figure 5 indicates that average costs vary with crop acres. For the 4-40" machinery combination, for example, average costs are $0.40 and $0.57 per dollar of output when farm size is 480 and 160 acres, respectively. With the 4-40" machinery combination, a farm size of 480 acres is the most efficient resource combination, since the average cost with the 4-40" machinery combination is at a minimum with 480 crop acres. When acreage expands beyond 480 acres, however, the average cost curve for the 4-40" combination turns upward because of the increasing untimeliness losses. Even though 480 acres is most efficient, Table 7 indicates that the untimeliness loss for the 4-40" machinery combination is $6.40 per acre at 480 acres. This result implies that a farmer should expand his farm size beyond the point where no untimeliness losses occur for the complement of machinery. For example, no untimeliness losses are estimated for the

4-40" combination at the 160 acre size. But per acre fixed costs for this machinery complement at 160 acres are almost $30 higher than at 480 acres. Therefore, the $6.40 untimeliness loss at 480 acres is more than offset by the reduction in average fixed cost attained by operating more acres, thus increasing profit.

Table 8 indicates that the 4-40" machinery combination is, costwise, most efficient for a farm of less than 480 acres. The higher average variable cost of the 4-40" machinery combination is more than offset by its lower average fixed cost for less than 480 acres. Beyond 480 acres, however, average costs for the 4-40" combination increase sharply as its advantage in decreasing fixed costs is canceled by rapidly increasing untimeliness losses.

Table 8. Cost per dollar of crop product for selected 40"-row machinery combinations with the current cropping system and 1971-73 prices

Machinery combination	Range in acreage with lowest average total costs	Minimum average cost acreage	Minimum average cost
4-40"	0-500	480	$.40
6-40"	500-580	640	.39
8-40"	580-990	800	.38
4-40",4-40"	none	960	.40
4-40",6-40"	990-1280	960	.40

The 6-40" machinery combination has a larger field capacity than the 4-40" machinery combination and is estimated to be the most efficient machinery combination between 500 and 580 acres. The 6-40" combination attains its minimum average cost, \$0.39, at 640 crop acres, 160 acres larger than for the 4-40" machinery combination and 64 acres greater than the upper acreage for which this machinery combination had the lowest per unit cost.

When crop acres vary between 580 and 990, the 8-40" machinery combination has the lowest average total costs among all machinery combinations. This combination requires 800 crop acres to achieve its minimum average cost of \$0.38.

The 4-40", 4-40" machinery combination contains the identical machines as does the 4-40" combination. The difference between these two alternatives is that the former contains twice as many of the major field machines as contained in the latter. Table 8 indicates that the 4-40", 4-40" machinery combination does not give the lowest per unit cost for any of the acreages considered. Although the 4-40", 4-40" combination attains a minimum average cost of \$0.40 at 960 crop acres, the 8-40" combination is slightly more efficient at this acreage.

The 4-40", 6-40" combination combines the major field machines contained in the 4-40" and 6-40" combinations. This machinery complement has the largest machinery capacity of the five combinations considered. When crop acreage is greater than 990 acres, the 4-40", 6-40" combination results in the lowest average total cost. The minimum average cost for this combination, \$0.40, is attained at 1,100 crop acres.

Although the average cost curves for all five machinery combinations are U-shaped (as shown in Figure 5), the curve is wider (the shape is

"flatter") for machinery combinations with larger capacities. This "flatness" arises because untimeliness losses increase at a slower rate when machinery capacities are larger. Thus, the average cost curve for the 4-40" combination turns upward more rapidly than for the 8-40" combination after their respective minimum average costs are attained. Since in the short run machinery combinations are fixed, this is one advantage of a larger machinery combination over a smaller one.

Costs and returns by scale of operations

The cost and net income advantages for the alternative 40"-row machinery combinations, at each combination's minimum average cost acreage, are presented in Table 9. The minimum average cost is \$0.40 for the 4-40" and \$0.39 for the 6-40" combinations at 480 and 640 acres, respectively. Total revenue per acre after untimeliness losses for the 4-40" and 6-40" combinations is \$152.70 and \$149.70, respectively, at these acreages. Thus at 640 acres, the 6-40" combination has a \$2.70 cost advantage per acre over the 4-40" combination, a rather small advantage. This statement also applies for the 8-40" combination at 800 acres. But the total cost advantage for the 6-40" combination at 640 acres is \$1,728 over the 4-40" combination.[1] Similarly, the 8-40" combination at 800 crop acres has a \$3,664 cost advantage over the 4-40" combination.

Net farm income can increase with scale of operation in two ways: (1) from lower per acre costs as productive factors are combined more economically and fixed costs are spread over a greater output, and (2) from

[1]This concept of cost advantage assumes that the only justification for farm-size expansion would be gain the \$2.70 cost differential between the 4 and 6 row systems.

Table 9. Cost and net income advantages for alternative 40"-row machinery combinations over the 4-40" combination at each combination's minimum average cost acreage (based on the current cropping system and 1971-73 prices)

	Machinery combination				
	4-40"	6-40"	8-40"	4-40" 4-40"	4-40" 6-40"
Minimum average cost	$ .40	$ .39	$ .38	$ .40	$ .40
Minimum-average-cost acreage	480	640	800	960	1100
Total revenue per acre after untimeliness losses	$ 152.7	$ 149.7	$ 148.7	$ 152.2	$ 149.0
Cost advantage per acre over the 4-40" combination	---	$ 2.70	$ 4.58	$ 0.0	$ 0.0
Total cost advantage over the 4-40" combination	---	$ 1,738.0	$ 3,664.0	$ 0.0	$ 0.0
Net farm income[a]	$43,977.6	$58,432.0	$73,280.0	$87,649.0	$98,340.0
Total increase in net farm income over the 4-40" combination	---	$14,454.4	$29,302.4	$43,670.4	$54,362.4
Increase in net farm income over the 4-40" combination due to greater volume alone	---	$12,726.4	$25,638.4	$43,670.4	$54,362.4

[a]Land rent is included in the net farm income.

greater volume alone, even if costs remain constant. This last phenomena holds true even if output were pushed beyond the minimum cost situation, as long as the addition to cost is less than the addition to income (9, p. 172).

Although the first of these reasons can contribute to farm-size expansion, the data of Table 9 illustrate that the second factor far outweighs the first in terms of net income gains to the farmer. As can be seen in Table 9, each machinery combination has a greater net income than that of the immediately smaller machinery combination. In every case, the increase in net income due to volume alone is much greater than that due to lower costs alone.

These data suggest several important relationships. The first is that income can be increased somewhat on the small unit through cooperative use of machinery and equipment or through custom operations. Such practices tend to spread certain fixed costs over a greater output and divide the total among several farms. Also, the development of smaller machines and power units which could cut down on overhead costs represent another possibility for increasing income on the small unit. Much more, however, can be added to the farmer's income by increasing his scale of operation. Although the two go hand in hand within a certain range of farm size, lower per unit costs may not be as important as greater volume in explaining further expansion of farming operations.

Long-run average total cost per dollar of crop product

With a given machinery combination, scale economies can be realized, in the short-run, by moving forward or backward along a particular cost curve in Figure 5 until minimum average cost is attained. In the long-run, however, all inputs, including the machinery combination, are variable. Thus, one advantage of larger acreages is that, in the long-run, the farmer is able to shift to a machinery combination with a larger power unit and more effective field capacity.

The long-run average cost curve, or envelope curve, for 40"-row machinery combinations is presented in Figure 6.[1] It provides estimates of the cost economies that can be achieved when both crop acreages and machinery combinations are considered variable. Figure 6 indicates that the acreage of minimum long-run average cost is approximately 800 crop acres. Thus, when all resource inputs are variable (with the resource prices assumed), a farm of 800 acres with the 8-40" machinery combination could survive at the lowest product prices.

Although minimum cost is attained with 800 acres, between 460 and 1,180 acres, long-run average cost varies by only 5 percent from that minimum cost. For this acreage range, therefore, average costs are essentially constant. Hence, the 4-40"; 6-40"; 8-40"; 4-40"; 4-40"; 4-40"; and 6-40" machinery combinations are almost equally efficient at their minimum cost acreages and could be utilized to achieve the major share of the cost economies currently available.

Cost Structures for 30" Rows

Short-run average total cost per dollar of crop products

In the previous section, all cost relationships were developed for 40"-row machinery combinations. In recent years, however, 30"-row machinery

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[1]The long-run average cost curve is determined by choosing the least-cost machinery combination for all the farm-sizes of Figure 4.

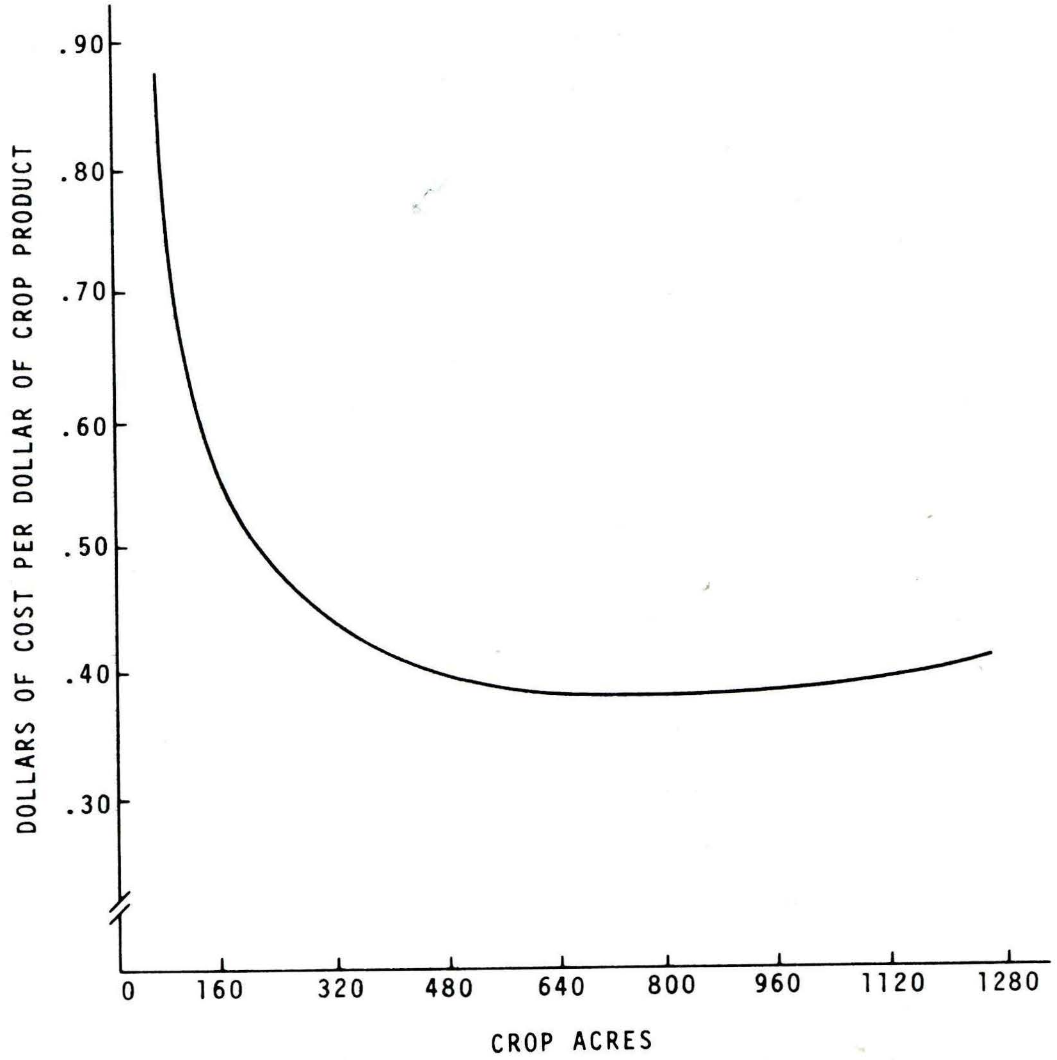

Figure 6. Long-run average cost curve for selected 40"-row machinery combinations based on the current cropping system and 1971-73 prices.

combinations have become more popular. The justification for an increased usage of the 30"-row spacing is the possibility of higher per acre yields for corn and soybeans. Because of this shift, we also examine the cost relationships for 30"-row machinery combinations.[1]

The total purchase cost of the 30" machinery complements considered ranges from $49,990 for the 4-30" combination to $109,171 for the 4-30", 6-30" combination. The total purchase cost is approximately $1,000 less for 30"-row than 40"-row for all machinery combinations, except for the 8-row combination. In the 8-40" combination, the 6-40" corn head is substituted for the 8-40" corn head because the latter does not exist in the current market. However, the 8-30" corn head does appear in the 8-30" machinery combination but the price of the 8-30" corn head is about $1,700 higher than the 6-40" corn head. Thus, the purchase cost for the 8-30" combination is $79,237, $354 higher than for the 8-40" combination (see Tables A-2--A-6).

Although the 30"-row combinations have slightly smaller total fixed costs than the 40"-row combinations, per acre variable costs are higher because greater variable costs (seed, insecticide, fertilizer and labor) are incurred. Therefore, average total costs per acre are higher for the 30" combinations than for the 40" combinations. For example, average total costs per acre are $71.20, $75.60, and $78.80 for the 4-30", 6-30", and 8-30" combinations, respectively at a farm size of 320 crop acres (Table 10). With the same farm size, average per acre costs are $68.75, $73.57, and $77.47 for the 4-40", 6-40" and 8-40" machinery combinations, respectively.

[1]As in the previous section, we will not repeat the phrase; current croppi system, 30"-row machinery combinations and 1971-73 prices at all times. This section deals only with that situation, however.

Table **10**. Average total costs per acre for selected 30"-row machinery combinations based on the current cropping system and no crop loss penalties

	Machinery combination				
	4-30"	6-30"	8-30"	4-30" 4-30"	4-30" 6-30"
Total fixed cost	$ 6,899.00	$ 9,216.00	$10,578.00	$13,070.00	$15,247.00
	Per-acre variable cost				
for corn	$ 59.26	$ 55.61	$ 54.20	$ 59.26	$ 57.43
for soybeans	40.40	38.06	37.28	40.40	39.23
for oats	23.30	22.85	22.46	23.30	23.07
for hay	51.84	51.84	51.84	51.84	51.84
combined variable cost	49.65	46.80	45.75	49.65	48.19
Crop-acres	Average total costs per acre				
160	$ 92.76	$ 104.40	$ 111.86	$ 131.33	$ 143.48
320	71.20	75.60	78.80	90.49	95.83
480	64.02	66.00	67.78	76.87	79.95
640	60.42	61.20	62.27	70.07	72.01
800	58.27	58.32	58.97	65.98	67.24
960	56.83	56.40	56.76	63.26	64.07
1120	55.80	55.02	55.19	61.31	61.80

With no crop losses and 30"-rows, yields are estimated to be 116.1, 88.4, and 46.8 bushels for corn, oats, and soybeans, respectively, and 4.57 tons for hay. Using 1971-73 prices, total revenue per acre is estimated to be $171 when no crop losses occur. However, after farm size is expanded beyond the optimal capacity of each machinery combination, untimeliness losses will occur. Per acre untimeliness losses for the selected 30" machinery combinations are presented in Table 11.

Table 11. Untimeliness losses in dollars per acre for selected 30"-row machinery combinations with the current cropping system and 1971-73 prices

Crop acres	Machinery combination				
	4-30"	6-30"	8-30"	4-30" 4-30"	4-30" 6-30"
160	$ 0.0	$ 0.0	$ 0.0	$ 0.0	$ 0.0
320	3.1	0.8	0.5	0.0	0.0
480	27.5	4.9	2.1	0.4	0.2
640	52.6	21.3	6.9	3.0	1.0
800	76.6	40.7	13.0	10.5	3.3
960	--	66.0	37.2	21.9	7.5
1120	--	--	59.7	36.9	20.0
1280	--	--	--	--	--

The cost functions estimated for selected 30"-row machinery combinations are:

$$TC_{4-30''} = 49.7(217.5 - 0.1546X)^{-1} + 6,899.0(217.5X - 0.1546X^2)^{-1} \qquad (16)$$

$$TC_{6-30''} = 46.8(192.7 - 0.0640X)^{-1} + 9,216.0(192.7X - 0.0640X^2)^{-1} \qquad (17)$$

$$TC_{8-30''} = 45.8(203.4 - 0.0727X)^{-1} + 10,578,0(203.4X - 0.0727X^2)^{-1} \qquad (18)$$

Figure 7 presents estimates of the average cost of producing $1 worth of crop product for selected 30"-row machinery combinations. The average cost curves of Figure 7 indicate that the 4-30" machinery combination is the most efficient combination when the crop acreage is less than 380. With a size between 380 and 500 acres, however, the 6-30" machinery combination achieves lowest average total costs. And when acreage expands from 500 to 880 acres, the 8-30" machinery combination has the cost advantage over the other combinations. Beyond 880 crop acres, the 4-30", 6-30" combination results in the greatest cost economies. As estimated for the 4-40", 4-40" combination, the 4-30", 4-30" combination never has the lowest average total cost.

The acreage at which the minimum average cost (Table 12) is attained varies for the different machinery combinations. These least-cost acreages are 320, 480, and 800 acres for the 4-30", 6-30", and 8-30" combinations, respectively. Although minimum average cost for the 4-30", 6-30" combination

Table 12. Cost per dollar of crop product for selected 30"-row machinery combinations with current cropping system and 1971-73 prices

Machinery combination	Range in acreage with lowest average total costs	Minimum average cost acreage	Minimum average cost
4-30"	0-380	320	$0.42
6-30"	380-500	480	0.40
8-30"	500-800	800	0.37
4-30",4-30"	none	800	0.41
4-30",6-30"	800-1120	960	0.39

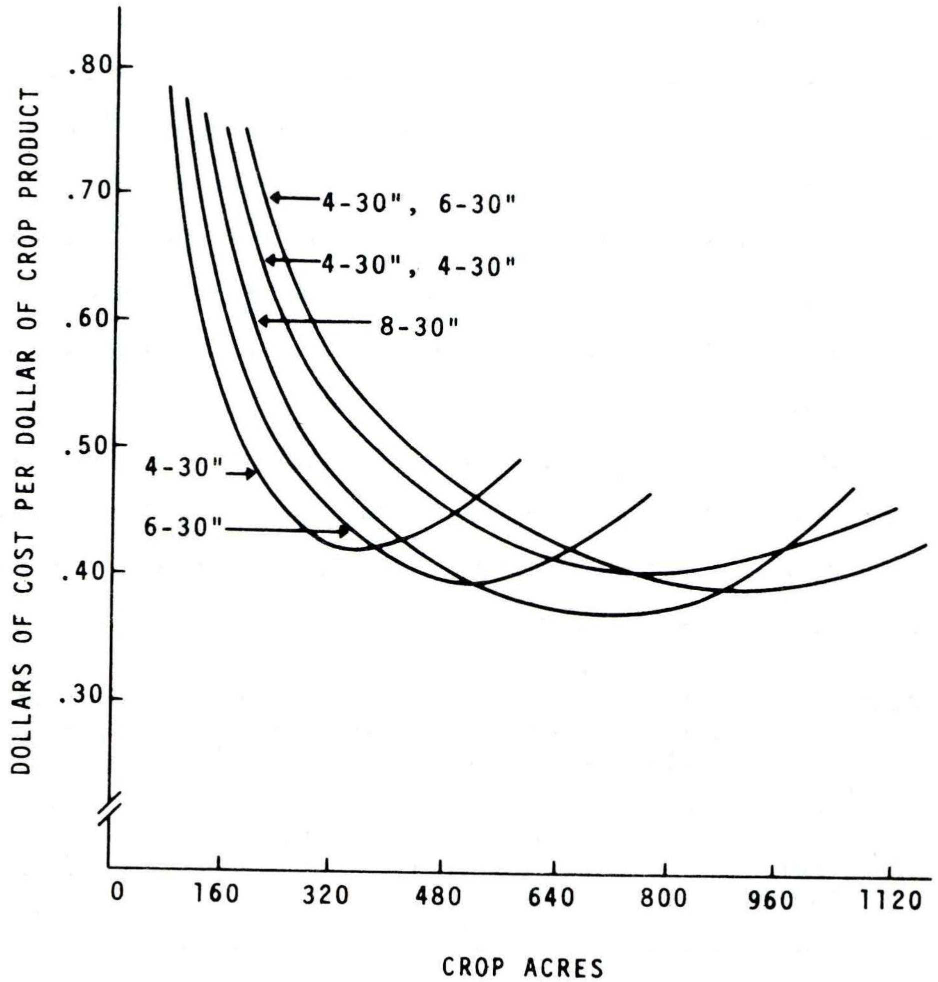

Figure 7. Average costs of producing $1 worth of crop product for selected 30"-row machinery combinations based on the current cropping system and 1971-73 prices.

($0.39) is similar to that of the 6-30" combination ($0.40), the crop acres which are required to attain these minimum average costs are 480 acres for the 6-30" combination as compared to 960 acres for the 4-30", 6-30" combination. We conclude, therefore, that in terms of pure cost economies of farm size and machinery combinations alone, the 6-30" combination at 480 crop acres can compete efficiently with the 4-30", 6-30" combination at 960 crop acres. Of course, in terms of net farm income, the larger system is much more profitable because of its greater volume. With the current cropping system and 1971-73 prices, Table 12 also indicates that the 8-30" machinery combination at 800 crop acres has the lowest minimum average cost of all the 30"-row machinery combinations considered.

Long-run average total cost per dollar of crop product

The long-run average cost curve for the selected 30" machinery combinations is presented in Figure 8. It indicates that the acreage of minimum average cost for 30"-row combinations is approximately 800 crop acres. Between 440 and 1,020 acres, however, unit cost varies by less than 5 percent from that minimum cost and can be considered approximately constant throughout this range. With 30"-row machinery combinations, the major share of the cost economies can be achieved with three combinations of land and machinery: (a) the 6-30" combination with 440-500 acres of cropland, (b) the 8-30" combination with 500-880 acres of cropland and (c) the 4-30", 6-30" combination with 880-1,020 acres of cropland.

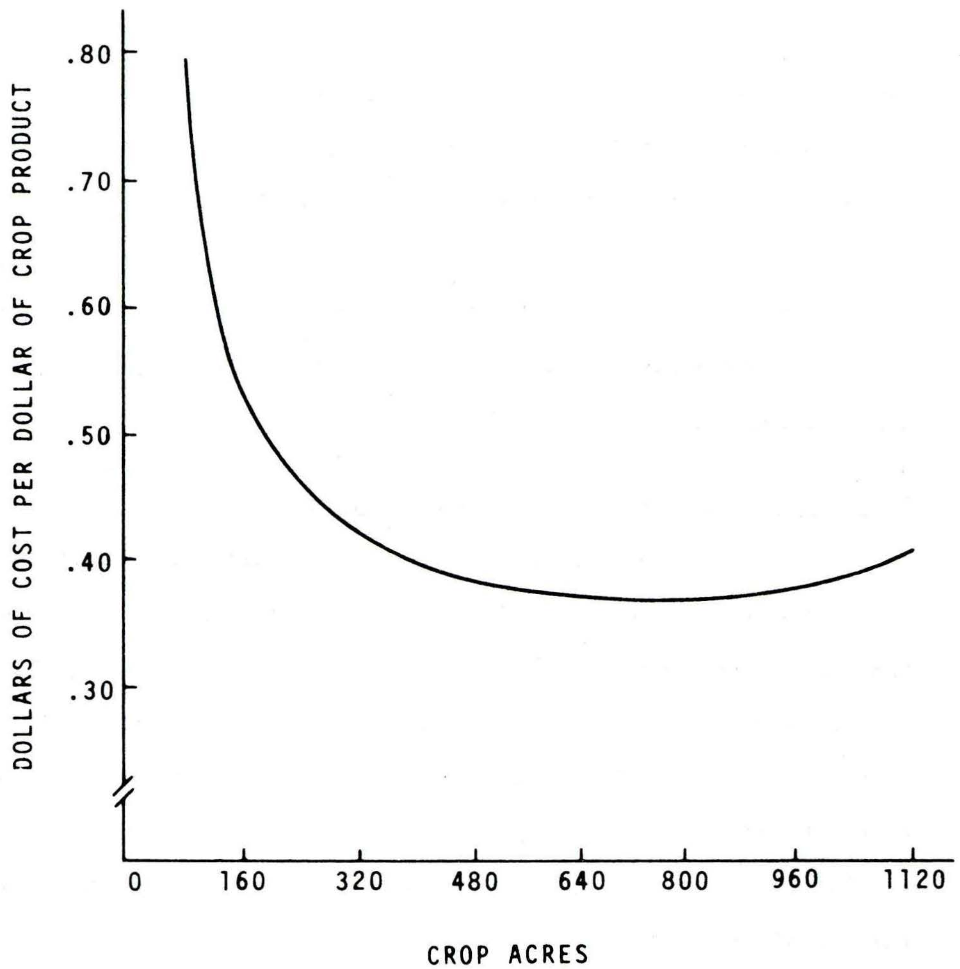

Figure 8. Long-run average cost curve for selected 30"-row machinery combinations based on the current cropping system and 1971-73 prices.

COMPARISON OF RESULTS

The position and shape of both the short-run and long-run cost curves presented in the previous section are estimated for a specific cropping system, price level and machinery combination. In this section, budgeting results under different specifications are presented and compared. When land rent is included in the total cost, the cost curves are also affected. Therefore, effects of land rent on the cost curves are also examined in this section.

Factors Affecting the Cost Function

The major budgeting results for the different situations considered are presented in Tables 13 and 14. Table 13 presents comparisons of minimum per unit cost for selected machinery combinations with two cropping systems

Table 13. Comparisons of minimum per unit cost (per $1 of output) for selected machinery combinations for two cropping systems and two price levels.

Machinery combination	Minimum cost acreage		Minimum average cost		
			current cropping system		continuous corn
	current cropping system	contin-uous corn	1971-73 prices	1973 prices	1971-73 prices
4-40"	480	480	$0.40	$0.29	$0.49
6-40"	640	480	0.39	0.28	0.47
8-40"	800	640	0.38	0.27	0.46
4-40",4-40"	960	800	0.40	0.28	0.49
4-40",6-40"	960	960	0.40	0.28	0.48
4-30"	320	320	$0.42	$0.30	$0.53
6-30"	480	480	0.40	0.28	0.49
8-30"	800	480	0.37	0.37	0.48
4-30",4-30"	800	640	0.41	0.27	0.53
4-30",6-30"	960	800	0.39	0.28	0.51

and two price levels. In the short-run, machinery investment is fixed and there is a specific crop acreage required to attain the minimum average cost for that particular combinations. Table 13 provides the short-run minimum-cost acreages for all selected machinery combinations.

Table 14 presents the selected machinery combinations and crop acreages necessary to achieve unit costs within 5 and 10 percent of the minimum unit cost for two cropping systems and two price levels. Thus, Table 14 provides long-run comparisons for various factors which affect the efficiency of resource combinations.

Cropping system

The cost curves for selected machinery combinations have been derived for both the current and the continuous corn cropping systems. Table 13 indicates that changing from the current cropping system to the continuous corn affects the cost curves in two ways. First, the minimum average cost is increased by 8 to 12 cents per dollar output for each machinery combination (using 1971-73 prices). Secondly, the crop acreage necessary to attain minimum unit costs is reduced for some of the combinations. For example, the acreage associated with minimum cost declines from 640 acres to 480 acres for the 6-40" combination and from 800 acres to 480 acres for the 8-30" combination. In contrast, the acreage for the 4-40" combination remains at 480 acres and that for the 4-30" combination remains at 320 acres when the cropping system is changed to continuous corn.

Long-run average costs for both 40"-row and 30"-row machinery combinations are also affected by changes in the cropping system. Table 14 indicates

Table 14. Selected machinery combinations and crop acreage necessary to achieve unit cost within 5 and 10 percent of minimum unit cost based on two cropping systems and two price levels

5 percent						10 percent	
current cropping system				continuous corn		current cropping system	
1971-73 prices		1973 prices		1971-73 prices		1971-73 prices	
Machinery combination	Range in crop acreage	Machinery combination	Range in crop acreage	Machinery combination	Range in crop acreage	Machinery combination	Range in crop acreage
4-40" 6-40" 8-40" 4-40",6-40"	460- 1180	4-40" 6-40" 8-40" 4-40",6-40"	430- 1160	4-40" 6-40" 8-40" 4-40",6-40"	360- 1080	4-40" 6-40" 8-40" 4-40",6-40"	380- 1320
6-30" 8-30" 4-30",6-30"	440- 1020	6-30" 8-30" 4-30",6-30"	420- 1080	6-30" 8-30" 4-30",6-30"	340- 900	4-30" 6-30" 8-30" 4-30",6-30"	360- 1140

that the crop acreage necessary to achieve unit costs within 5 percent of minimum unit cost is reduced from the range of 460-1,180 acres to a range of 360-1,080 acres for the 40"-row combinations. Similarly the range of nearly constant minimum costs is reduced from 460-1,020 acres to a range of 340-900 acres for 30" row combinations.

The machinery combinations required to attain constant unit costs remain the same when the cropping system is changed. For 40"-row combinations, four sets of combinations (4-40", 6-40", 8-40" and 4-40", 6-40") can be used to achieve major cost economies. For 30"-row combinations, only three sets of combinations (6-30", 8-30", and 4-30", 6-30") can be used to realize the main benefits of cost advantages.

Comparison between the current and the continuous cropping systems with respect to land and management returns, at the prices used are included in Table 15. For each machinery combination, fixed costs for the continuous cropping system are less than for the current system because machines specific to the hay, oats, and soybeans enterprises are not required

Table 15. Estimates of returns to land and management for the continuous and current cropping systems.

Machinery combination	Current cropping system: Minimum cost acreage	Current cropping system: Returns to land and management ($/ac.)	Continuous cropping system: Minimum cost acreage	Continuous cropping system: Returns to land and management ($/ac.)
4-40"	480	91.32	480	68.95
6-40"	640	90.82	480	75.57
8-40"	800	91.75	640	74.90
4-40",4-40"	960	91.82	800	72.75
4-40",6-40"	960	93.36	960	72.26

for the former. Variable costs, however, are higher under the continuous cropping system because commodities other than corn in the current system have lower per acre variable outlays than does corn. Table 15 shows reduced per acre returns to land and management for the continuous system as compared to the current cropping system. These reductions range from $15 to $22 per acre for the five machinery combinations. With the current cropping system, major pieces of equipment, such as tractors, tillage equipment, and combines (except for the platform head), can be used for greater periods of time over the different crops without extremely large untimeliness losses. These results, plus the opportunity to spread price risk over two crops, help explain why soybeans is a popular crop and are planted on about a third of the acreage in the area (17, 18).

Output price changes

Two price levels, 1971-73 prices and 1973 prices, have been used in the construction of the cost curves for the selected machinery combinations.[1] However, the same input prices are used for both price levels. Compared to 1971-73 prices, the data of Table 13 indicate that the minimum average cost per $1 of output is 10-12 cents lower with 1973 prices for both 40" and 30"-row combinations (with the current cropping system). This change in price level causes the short-run cost curves to move vertically downward and thus changes the position of the cost curves but the shape of the

[1] The output prices used in this study for the 1971-73 average are: $1.38 per bushel for corn, $4.23 per bushel for soybeans, $0.77 per bushel for oats, and $2.70 per ton for hay, and for the 1973 average are: $1.81 per bushel for corn, $6.49 per bushel for soybeans, $0.94 per bushel for oats, and $25.80 per ton for hay (31,20).

curves remains unchanged. Hence, the change in price level does not affect the crop acreage required to attain the short-run minimum cost for each selected machinery combination.

For the long-run cost curve, however, the crop acreage necessary to achieve unit cost within 5 percent of minimum cost is slightly reduced when the level is changed from 1971-73 to 1973 prices. The long-run cost curve moves vertically downward and thus a wider range of crop acres can attain available cost economies. For example, the crop acreage is reduced from 460 acres to 430 acres for the 40"-row combinations and reduced from 440 acres to 420 acres for the 30"-row combinations. Since the crop acreage required to achieve the main cost benefits is reduced only by 20-30 acres, the machinery combinations used to attain the major cost economies of size remain unaltered when the price level is changed. Table 14 indicates that the same four sets of 40"-row combinations and the same three sets of 30"-row combinations are required to achieve the cost advantages for both the 1971-73 prices and the 1973 prices.

40"-row vs. 30"-row machinery combinations

Since field capacities differ for 40"-row and 30"-row combinations, untimeliness losses vary between them. Furthermore, total revenue per acre for the 40"-row and 30"-row combinations also varies because of differing yield potentials for the two systems. The budgeting results of the long-run analysis (summarized in Table 14) indicate that the crop acreage required to attain unit costs within 5 percent of minimum cost, and thus realize the major cost economies is 20 acres less for 30"-row

combinations than for 40"-row combinations based on the current cropping system and 1973 prices.

Another, and possibly more interesting, way to compare the 30"- and 40"-row combinations is by comparing their effect on profitability of production. As noted previously, total revenue per acre is estimated to be higher for the narrow-row combinations than for the traditional 40"-row situation. Therefore, simply comparing the cost per unit of output does not detail the entire differential between the two situations.

To provide this more complete analysis, Table 16 presents the estimated per acre return for various acreages and machinery combinations for both the 30"-row and 40"-row specifications. These net returns are based on 1971-73 average output prices and the current cropping systems. Also, charges for land and management have yet to be deducted from the return estimates, therefore, these estimates indicate returns to land and management for each situation.

For the 40"-row combinations, the greatest per acre return occurs at 960 acres with the largest machine combination, the 4-40", 6-40" package.

Table 16. Estimates of returns to land and management for the 30"- and 40"-row combinations.

Acreage	40"-Row Machinery combination	Returns to land and management ($/acre)	Acreage	30"-Row Machinery combination	Returns to land and management ($/acre)
320	4-40"	89.25	320	4-30"	96.70
480	4-40"	91.32	480	6-30"	100.10
640	6-40"	90.82	640	8-30"	101.83
800	8-40"	91.75	800	8-30"	99.03
960	4-40",4-40"	91.82	800	4-30",4-30"	94.52
960	4-40",6-40"	93.36	960	4-30",6-30"	99.43

For the entire range of acreages presented, however, per acre returns only fluctuate by slightly over \$4.00, a result consistent with the per unit cost results discussed previously. The 30"-row combinations display a slightly different return pattern with greatest per acre returns occurring at 640 acres and the 8-30" machinery complement, But, similarly to the 40"-row combinations, per acre returns vary only by about \$7 throughout the range of situations considered.

Land rent

Land rent was not including total cost estimates presented in previous sections. In this section, however, land rent consisting of property taxes and an interest charge on the price of land is included in the estimates of total cost. The land rent used is \$62.50 per acre (Table A-11).

The cost functions estimated for the selected 40"-row machinery combinations, based on the current cropping system and 1971-73 prices, with a charge for land rent included are:

$$TC_{4\text{-}40''} = 109.2(185.9 - 0.0793X)^{-1} + 7{,}072.0(185.9X - 0.0793X^2)^{-1} \quad (21)$$

$$TC_{6\text{-}40''} = 106.7(167.9 - 0.0271X)^{-1} + 9{,}404.0(167.9X - 0.0271X^2)^{-1} \quad (22)$$

$$TC_{8\text{-}40''} = 105.8(178.0 - 0.0439X)^{-1} + 10{,}942.0(178.0X - 0.0439X^2)^{-1} \quad (23)$$

$$TC_{4\text{-}40'',4\text{-}40''} = 109.2(167.8 - 0.0182X)^{-1} + 13{,}177.0(167.8X - 0.0182X^2)^{-1} \quad (24)$$

$$TC_{4\text{-}40'',6\text{-}40''} = 107.9(164.5 - 0.0114X)^{-1} + 15{,}492.0(164.5X - 0.0114X^2)^{-1} \quad (25)$$

The comparisons of minimum per unit costs for the selected machinery combinations, with and without a charge for land rent in the total costs, are presented in Table 17. The minimum average cost for each combination increases

in Table 17. The minimum average cost for each combination increases substantially when land rent is included. Land rents higher than those who (e.g. rents at 1975 levels) would push unit costs even higher. Table 17 also indicates that the crop acreage necessary to attain the minimum cost acreage is reduced for some combinations.

Table 17. Comparisons of minimum per unit costs for the selected machinery combinations based on the current cropping system and 1971-73 prices with and without a charge for land rent in the total costs.

Machinery combination	Minimum cost acreage for: Total cost with land rent	Total cost without land rent	Minimum average cost with land rent	without land rent
4-40"	480	480	\$0.81	\$0.40
6-40"	480	640	0.80	0.39
8-40"	640	800	0.79	0.38
4-40",4-40"	800	960	0.80	0.40
4-40",6-40"	960	960	0.80	0.40
4-30"	320	320	\$0.80	\$0.42
6-30"	480	480	0.77	0.40
8-30"	640	800	0.76	0.37
4-30",4-30"	640	800	0.79	0.41
4-30",6-30"	800	960	0.77	0.39

This can be explained as follows: As farm size expands, untimeliness losses cause land cost per dollar value of crop product to increase and thus help to compensate for the decrease in average fixed cost. This causes the average cost curve for a machinery combination to turn upward at a lower crop acreage when land rent is included in the total cost.

The long-run cost curve also is affected by land rent. Table 18 presents the selected machinery combinations and crop acreage necessary to achieve unit costs within 5 and 10 percent of minimum unit cost, based on

Table 18. Selected machinery combinations and crop acreage necessary to achieve unit costs within 5 and 10 percent of minimum unit cost based on two cropping systems and two price levels with a charge for land rent in the total cost.

5 percent				10 percent	
current cropping system 1971-73 prices		continuous corn 1971-73 prices		current cropping system 1971-73 prices	
Machinery combination	Range in crop acreage	Machinery combination	Range in crop acreage	Machinery combination	Range in crop acreage
4-40"	340-1230	4-40"	260-1100	4-40"	260-1360
6-40"		6-40"		6-40"	
8-40"		8-40"		8-40"	
4-40",4-40"		4-40",6-40"		4-40",4-40"	
4-40",6-40"				4-40",6-40"	
4-30"	300-1080	6-30"	270-820	4-30"	225-1180
6-30"		8-30"		6-30"	
8-30"		4-30",6-30"		8-30"	
4-30",6-30"				4-30",6-30"	

two cropping systems and two price levels with a charge for land rent in the total cost. The crop acreage necessary to achieve major cost economies shifts from a range of 460-1,180 acres without land rent to a range of 340-1,230 acres for the 40"-row combinations based on the current cropping system and 1971-73 prices (Tables 14 and 18) when land rent is included in the total cost. Similar shifts occur for the other situations described in Table 18. Another effect of including a land rent in total costs is that machinery combinations required to attain major cost economies change slightly. With land rent included, five sets of 40"-row combinations and four sets of 30"-row combinations are required to attain the major cost economies, as shown in Table 18.

SUMMARY

This report was designed (1) to determine per unit cost relationships for various machinery combinations and farm situations in north central Iowa and (2) to determine the effect of these situations on profitability of crop production. Throughout the last four decades, American agriculture has been changing rapidly to larger and fewer farms, a smaller work force, greater capital inputs and growing commercialization. This report is concerned with the present nature and extent of "economies of scale" and their effect upon the ongoing trend toward fewer and larger farms. Cost functions are estimated for the Clarion-Nicollet-Webster soil association of north central Iowa, through a budgeting process for farms of different crop acreages with various selected machinery combinations. The selected machinery combinations include five sets of more recent 30"-row machinery combinations as well as five sets of traditional 40"-row combinations. Both short-run and long-run cost curves are derived as a function of crop acres to illustrate the nature and extent of cost economies of farm size. The range of crop acreage considered varies from 160 to 1,280 crop acres. Two cropping systems, the current cropping system and a continuous corn cropping system, are considered. In addition, two output price levels, 1971-73 average prices and 1973 average prices, are used to compare the effect of shifts in output price on farm size and profitability.

Revenue and yield reductions from untimely field operations are estimated for different crop acreages and particular machinery combinations based on a specific farm situation. Untimeliness loss is the only factor considered in this report which can result in rising average costs and thus limit farm size expansion. A high level of management, efficient fertilizer use, average weather, a fixed set of field operations for each crop, and effective utilization of each machinery combination were assumed in budgeting each cost function.

The study results indicate that a slight reduction in average total cost per dollar of crop product can be obtained by utilizing larger machinery combinations on larger crop acreages for the 1-man, 1-tractor machinery combinations. If crop acreage expands further and 2-man, 2-tractor machinery combinations are utilized, average costs per dollar of crop production rise slightly. For example, based on 1971-73 prices, if farm size expands from 480 crop acres and a 4-40" machinery combination to 800 crop acres and a 8-40" machinery combination, the average total cost per dollar of crop

product (with land costs excluded) declines only from $0.40 to $0.38. But as farm size expands further to 960 crop acres and a 4-40", 6-40" machinery combination, average cost returns to $0.40. Similarly, an expansion of farm size from 320 crop acres and the 4-30" machinery combination to 800 crop acres operated with the 8-30" machinery combination reduces the average total cost from $0.42 to $0.37. But again, as farm size expands to 960 crop acres and the 4-30", 6-30" machinery combination average total cost per dollar value of output rises to $0.39. (The figures cited above do not include land rent in total costs.)

The short-run cost curves suggest that large machinery combinations such as the 8-40" combination and the 4-40", 6-40" combination result in very high total average costs on small crop acreages. But fixed machinery costs can be significantly reduced by utilizing smaller machinery combinations on these small farms. Hence, for fewer crop acres, the 4-40" or 4-30" machinery combinations have the lowest average total cost. However, excessive crop losses due to untimeliness occur for the 4-40" or 4-30" combinations when crop acreage expands past 640 or 800 crop acres. Because of these untimeliness losses, much higher average costs result for smaller machinery combinations when crop acreage is expanded beyond 640 crop acres.

For practical purposes, it was assumed that resource combinations achieving a unit cost within 5 percent of minimum cost have attained most of the available cost economies of farm size. For 40"-row combinations, 4, 6, 8, or a 4 and 6 row combination and 460-1,180 crop acres can attain the major cost economies available with the current cropping system and

1971-73 prices. Similarly, for 30"-row machinery combinations, 6, 8, or a 4 and 6 row combination and 440-1,020 crop acres attain most of the cost economies available.

Cost functions are considerably different when calculated with and without land rents. For example, minimum average cost doubles after land rent is included for the 4-40" machinery combination based on the current cropping system and 1971-73 prices. In addition, the minimum acreage required to attain the major cost economies is reduced from a range of 440-460 crop acres to a range of 330-340 crop acres when land rent is considered.

A second variable considered in this study was output price. Output prices of the 1971-73 period and those of 1973 alone were compared. Although the higher prices of 1973 did not substantially affect the scale economy factors, these increased prices have a tremendous effect on profitability of production. The estimated return to land and management averaged $61 per acre higher for the five machinery combinations with the increased output price levels of 1973. These increases in residual returns, which averaged about 67 percent, can be translated into larger increases in land values--if the higher output prices are assumed to continue for a long period of time.

Recently narrower row widths than the traditional 40" system have become more popular for corn and soybean production. Therefore, profitability of production for the 40" system was compared with that of a 30"-row system. As regards economies of scale, the 30" system generally

favorered slightly smaller acreages than the 40" system for the machinery combinations considered. Additionally, net returns to land and management were higher for a specific machinery combination equipped with 30" as opposed to 40"-row machinery.

A major policy implication of the analysis is described by the net income data of Table 9. In this table, the incentives for expansion (a) reducing unit costs and (b) increasing volume of output, are quantitatively compared. These comparisons indicate that the advantage for farm-size expansion relates dominately to the latter and only slightly, if at all, to the former. This result means that society, under currently available technologies, is unlikely to benefit greatly through lowered food costs, from further farm-size expansion. Hence, the major part of these benefits will be internalized in the farming sector.

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APPENDIX

Table A-1. Soil composition per 160 acres for the farm situation studied.

New units and proposed land use	Soil components of new units	Acres	Percent of total
Cropland		142.3	89.0
	55-2-0	44.7	
	95-1-0	16.6	
	138-3-1	17.1	
	107-1-0	63.9	
Pasture		13.7	8.5
	6-0-0	2.3	
	90-0-0	8.0	
	95-1-0	3.4	
Waste		4.0	2.5

Table A-2. Purchase price of the machines included in the 4-row combination[a].

Machines	Average retail price	
Tractor, 4 plow, diesel	$10,356	
Plow, 4-16"	1,380	
Stalk chopper, 12-ft rotary	1,705	
Tandem disk, 12'	1,265	
Harrow, 20'	345	
Endgate seeder	172	
Planter, 4-40" (4-30")	1,980	(1,980)
Rotary hoe, 4-row	770	
Cultivator, 4-40" (4-30")	1,295	(1,150)
Combine, S.P.	17,103	
Platform, 14'	1,385	
Corn head, 4-40" (4-30")	5,949	(5,715)
Mower, 7'	825	
Side delivery rake	810	
Baler	3,025	
Wagon, 200-bu.	880	
Elevator, 48'	1,124	
Total purchase cost	50,369	(49,990)

[a]Sources: (28) and local farm machinery dealers in Central Iowa.

Table A-3. Purchase price for the machines included in the 6-row combination[a].

Machines	Average retail price	
Tractor, 6 plow, diesel	$14,254	
Plow, 6-16"	1,968	
Stalk chopper, 18-ft rotary	2,705	
Tandem disk, 18'	2,485	
Harrow 30'	403	
Endgate seeder	172	
Planter, 6-40" (6-30")	3,082	(2,970)
Rotary hoe, 6-row	1,100	
Cultivator, 6-40" (6-30")	2,017	(1,426)
Combine, S.P.	22,191	
Platform, 16'	1,541	
Corn head, 6-40" (6-30")	8,324	(7,720)
Mower, 7'	825	
Side delivery rake	810	
Baler	3,025	
Wagon, 300-bu.	1,320	
Elevator	1,124	
Total purchase cost	67,346	(66,039)

[a]Sources: (28) and local farm machinery dealers in Central Iowa.

Table A-4. Purchase price of the machines included in the 8-row combination[a].

Machines	Average retail price	
Tractor, 8-plow, diesel	$18,532	
Plow, 7-16"	2,415	
Stalk chopper, 18-ft rotary	2,705	
Tandem disk, 24'	3,250	
Harrow 30'	430	
Endgate seeder	172	
Planter, 8-40" (8-30")	3,838	(3,640)
Potary hoe, 8-row	1,320	
Cultivator, 8-40" (8-30")	3,148	(1,988)
Combine, S.P.	25,992	
Platform, 18'	1,680	
Corn head, 6-40" (8-30")	8,324	(10,036)
Mower, 7'	825	
Side delivery rake	810	
Baler	3,025	
Wagon, 300-bu.	1,320	
Elevator	1,124	
Total purchase cost	78,883	(79,237)

[a]Sources: (28) and local farm machinery dealers in Central Iowa.

Table A-5. Purchase price of the machines included in the 4-row,4-row combination[a]

Machines	Average retail price
Tractor, 4 plow, diesel	$10,356
Tractor, 4 plow, diesel	10,356
Stalk chopper, 12-ft rotary	1,705
Stalk chopper, 12-ft rotary	1,705
Plow, 4-16"	1,380
Plow, 4-16"	1,380
Tandem disk 12'	1,265
Tandem disk 12'	1,265
Harrow 30'	403
Endgate seeder	150
Planter, 4-40" (4-30")	1,980 (1,980)
Planter, 4-40" (4-30")	1,980 (1,980)
Rotary hoe, 4-row	770
Rotary hoe, 4-row	770
Cultivator, 4-40" (4-30")	1,295 (1,150)
Cultivator, 4-40" (4-30")	1,295 (1,150)
Combine, S.P.	17,103
Combine, S.P.	17,103
Platform, 14'	1,385
Platform, 14'	1,385
Corn head, 4-40" (4-30")	5,949 (5,715)
Corn head, 4-40" (4-30")	5,949 (5,715)
Mower, 7'	825
Side delivery rake	810
Baler	3,025
Wagon, 300-bu	1,320
Elevator	1,124
Total purchase cost	94,033 (93,275)

[a]Sources: (28) and local farm machinery dealers in Central Iowa.

Table A-6. Purchase price of machines included in the 4-row,6-row combination[a]

Machines	Average retail price
Tractor, 4 plow, diesel	$10,356
Tractor, 6 plow, diesel	14,254
Plow, 4-16"	1,380
Plow, 6-16"	1,968
Stalk chopper, 12-ft rotary	1,705
Stalk chopper, 18-ft rotary	2,705
Tandem disk, 12'	1,265
Tandem disk, 18'	2,485
Harrow 20'	345
Harrow 30'	403
Endgate seeder	150
Planter, 4-40" (4-30")	1,980 (1,980)
Planter, 6-40" (6-30")	3,082 (2,970)
Rotary hoe, 4-row	770
Rotary hoe, 6-row	1,100
Cultivator, 4-40" (4-30")	1,295 (1,150)
Cultivator, 6-40" (6-30")	2,017 (1,426)
Combine, S.P.	17,103
Combine, S.P.	22,191
Platform, 14'	1,385
Platform, 16'	1,541
Corn head, 4-40" (4-30")	5,949 (5,715)
Corn head, 6-40" (6-30")	8,324 (7,720)
Mower, 7'	825
Side delivery rake	810
Baler	3,025
Wagon, 300-bu	1,320
Elevator	1,124
Total purchase cost	110,857 (109,171)

[a]Sources: (28) and local farm machinery dealers in Central Iowa.

Table A-7. Life of farm machines, repair cost in percentage of purchase price[a]

Machine	Years until obsolete	Repair cost, average per hour in % of purchase price
Cultivator	12	.060
Disk harrow	15	.065
Plow, moldboard	15	.070
Spike-tooth harrow	20	.040
Spring-tooth harrow	20	.060
Row-crop planter	15	.070
Combine, S.P.	10	.027
Corn head	10	.032
Hay baler	10	.031
Mower	12	.120
Rake, side-delivery	12	.070
Tractor, wheel	15	.012
Wagon	15	.018

[a]Source: (15).

Table A-8. Annual total fixed machinery costs of five selected machinery combinations used in current cropping systems[a]

Machinery combination	Depreciation	Interest	Tax, housing and insurance	Total
4-row	3,998 (3,966)	1,940 (1,921)	1,134 (1,012)	7,072 (6,899)
6-row	5,295 (5,190)	2,595 (2,541)	1,514 (1,485)	9,404 (9,216)
8-row	6,129 (5,747)	3,038 (3,049)	1,775 (1,782)	10,942 (10,578)
4-row, 4-row	7,443 (7,379)	3,619 (3,592)	2,115 (2,099)	13,177 (13,070)
4-row, 6-row	8,726 (8,590)	4,269 (4,204)	2,497 (2,453)	15,492 (15,247)

[a]Figures shown in the parentheses are for 30"-row combinations. Other figures are for 40"-row combinations.

Table A-9. Estimated seed and chemical costs per acre for selected crops[a].

	Corn	Soybeans	Oats	Hay
Seed	$8.00	7.00	3.50	7.25
Fertilizer and lime	19.25	8.50	5.50	7.50
Herbicides and insecticides	9.00	6.60	1.10	.60
Total	36.25	22.10	10.10	15.25

[a]Source: (14).

Table A-10. Fertilizer used on selected soils[a].

Soil type	Corn			Soybeans		Oats			Hay	
	N	P	K	P	K	N	P	K	P	K
Clarion	190	44	50	22	17	60	35	42	18	50
Nicollet	190	44	50	22	17	60	35	42	18	50
Webster	200	44	83	22	33	60	35	75	18	83

[a]Source: (39).

Table A-11. Estimated land rent per acre.

	Humboldt farm
Land price[a]	$625.00
Interest charge[b]	50.00
Tax charge[c]	12.50
Land rent	62.50

[a]Source: (27).

[b]Interest rate of 8 percent.

[c]Source: (19). Assessed value is 27 percent of the land price and the tax rate is 73.8 mills per dollar.

Table A-12. Prices used in budgeting cost functions[a]

	Unit	1971-73 prices ($)	1973 prices ($)
Corn	bu.	1.38	1.81
Soybeans	bu.	4.23	6.49
Oats	bu.	.77	.94
Hay	ton	22.70	25.80
Fertilizer, N	lb.	.09	
Fertilizer, P_2O_5	lb.	.08	
Fertilizer, K_2O	lb.	.05	
Limestone	ton	5.00	
Seed corn	bu.	23.50	
Seed oats	bu.	1.80	
Soybean seed	bu.	5.20	
Alfalfa seed	cwt.	.61	
Diesel fuel	ga.	.19	

[a]Sources: (31, 20).

Table A-13. Estimated average number of hours available for field work by weeks in north central Iowa[a]

Week		Hours per day	Hours per week
March	22-28	1.5	3.4
	29-April 4	3.5	14.6
April	5-11	5.1	32.7
	12-18	5.9	44.9
	19-25	6.6	51.1
	26-May 2	5.8	44.7
May	3- 9	5.6	43.1
	10-16	6.5	50.3
	17-23	6.5	45.3
	24-30	7.1	49.7
	31-June 6	6.4	44.5
June	7-13	6.6	46.3
	14-20	6.6	46.3
	21-27	6.9	48.2
	28-July 4	7.5	52.1
July	5-11	7.9	55.5
	12-18	7.6	53.4
	19-25	7.8	54.2
	26-Aug. 1	7.5	52.1
Aug.	2- 8	7.0	49.4
	9-15	7.5	52.6
	16-22	7.9	55.3
	23-29	7.5	52.4
	30-Sept. 5	7.5	52.2
Sept.	6-12	7.9	55.0
	13-19	8.0	56.3
	20-26	7.6	53.1
	27-Oct. 3	7.6	53.1
Oct.	4-10	7.5	52.2
	11-17	7.8	54.7
	18-24	7.8	54.4
	25-31	8.1	56.9

[a]Basic data obtained from McKee (25) and adjusted on the basis of climatologic data (34).

Table A-13 (Continued)

Week		Hours per day	Hours per week
Nov.	1- 7	8.1	52.9
	8-14	6.4	44.7
	15-21	6.4	44.7
	22-28	5.6	38.8
	29-Dec. 5	2.7	10.9
Dec.	6-12	0.4	2.4

Table A-14. Variable costs per acre for selected 30"-row machinery combinations in producing corn and soybeans

Machinery combination	Machine repair	Fuel and oil	Seed, insecticide & fertilizer	Land rent	Labor	Total
corn						
4-30"	$7.25	$3.13	$38.06	$ 62.50	$10.82	$121.76
6-30"	6.88	2.81	38.06	62.50	7.86	118.11
8-30"	6.87	2.63	38.06	62.50	6.64	116.70
4-30",4-30"	7.25	3.13	38.06	62.50	10.82	121.76
4-30",6-30"	7.06	2.97	38.06	62.50	9.34	119.93
soybeans						
4-30"	$6.11	$2.24	$23.21	$ 62.50	$8.84	$102.90
6-30"	6.07	2.14	23.21	62.50	6.64	100.56
8-30"	6.23	2.04	23.21	62.50	5.80	99.78
4-30",4-30"	6.11	2.24	23.21	62.50	8.84	102.90
4-30",6-30"	6.09	2.19	23.21	62.50	7.74	101.73

Table A-15. Variable costs per acre for selected 40"-row machinery combinations in producing corn and soybeans

Machinery combination	Machine repair	Fuel and oil	Seed, insecticide & fertilizer	Land rent	Labor	Total
			corn			
4-40"	$6.51	$2.75	$36.25	$ 62.50	$9.46	$117.47
6-40"	6.20	2.48	36.25	62.50	6.90	114.33
8-40"	6.61	2.36	36.25	62.50	5.40	113.12
4-40",4-40"	6.51	2.75	36.25	62.50	9.46	117.47
4-40",6-40"	6.35	2.61	36.25	62.50	8.18	115.89
			soybeans			
4-40"	$5.99	$2.09	$22.10	$ 62.50	$8.26	$100.94
6-40"	6.01	2.00	22.10	62.50	6.26	98.87
8-40"	6.20	1.92	22.10	62.50	5.52	98.24
4-40",4-40"	5.99	2.09	22.10	62.50	8.26	100.94
4-40",6-40"	6.00	2.05	22.10	62.50	7.26	99.91

Table A-16. Variable costs per acre for selected machinery combinations in producing oats and hay

Machinery combination	Machine repair	Fuel and oil	Seed, insecticide & fertilizer	Land rent	Labor	Total
			oats			
4-row	$3.14	$2.08	$10.10	$ 62.50	$7.98	$ 85.80
6-row	3.43	2.04	10.10	62.50	7.28	85.35
8-row	3.43	1.99	10.10	62.50	6.94	84.96
4-row,4-row	3.14	2.08	10.10	62.50	7.98	85.80
4-row,6-row	3.28	2.06	10.10	62.50	7.63	85.57
			hay[a]			
all combinations	$9.94	$5.35	$15.25	$ 62.50	$21.30	$114.34

[a]Source: (20).

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