Farm Machinery Costs in Relation to Machinery and Farm Size

CARD Report 80

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FARM MACHINERY COSTS IN RELATION

TO MACHINERY AND FARM SIZE

by

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PREFACE

This study examined farm machinery costs in relation to machinery and farm size in central Iowa. The objectives of the study were: (a) to calculate costs for individual machines for constant and varying economic conditions; (b) to determine machinery combination costs, value of yield losses, and combined costs for two different restrictions on the number of suitable field days.

Total costs per hour were calculated for utility model gasoline and diesel tractors, standard, and 4-wheel-drive (4WD) tractors. Costs per acre were calculated for different sizes of moldboard plows, disk harrows, rotary hoes, row-crop cultivators, planters, combined with corn heads, gravity-flow wagons, and trailer-type sprayers.

Total machinery costs are affected by changes in economic conditions. The following economic conditions were varied: (a) interest rates, (b) fuel prices, (c) wage rates, (d) length of ownership period, and (e) marginal income tax rates. The economic conditions or variables were varied individually with the noneconomic variables held constant to determine their effect on total machinery costs.

Machinery combination cost curves were derived for both narrow row and wide row equipment. Narrow row machinery combinations consisted of 6-, 8-, and 12-30 inch row planting and tillage equipment and 3-, 4-, and 6-30 inch harvesting equipment. Wide row machinery combinations consisted of 4-, 6-, and 8-38 inch row planting and tillage equipment and 2-, 3-, and 4-38 inch row harvesting equipment. The combined costs included the total costs for each of these combinations plus the value of yield losses. These combined costs were calculated for the average number of suitable field days and the average minus one standard deviation number of field days. The one standard deviation was used to obtain a range in the number of suitable field days. The standard deviation was used because the underlying distribution for the suitable field day data was unknown.

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INTRODUCTION

The structure of U.S. agriculture changed dramatically over the years 1950 to 1975. The number of farms declined from 5,647,800 in 1950 to 2,818,580 in 1975 [14, 25]. At the same time, average farm size increased from 213 acres to 385 acres. In conjunction with this decline in farm numbers, there also has been a sharp decline in the total number of workers on farms (both family and hired workers), from 9,926,000 in 1950 to 4,392,000 in 1974, or less than half the number in 1950 [23, 24].

In the period 1960 to 1974, farms with annual sales of $20,000 and more increased in number, while those with less than $20,000 in sales declined sharply [21]. The percentage distribution of farms by sales classes changed markedly during this period. The percentage with $40,000 and more in annual sales increased from 2.9 percent of all farms in 1960 to 16.6 percent in 1974. Farms with less than $2,500 in sales declined from 1,849,000 farms to 707,000 farms, or from 46.6 percent to 25.0 percent of the total. Therefore, there has been a significant shift in the size of farms in terms of sales during this 14-year period. Farms in the United States are continually increasing in size (both acres and sales) and also are becoming more capital intensive.

Similar changes in farm structure have occurred in Iowa, with the number of farms in Iowa declining from 206,000 in 1950 to 137,000 in

1975. Farm size increased from 169 acres to 250 during this period [14, 25]. The number of farm workers in Iowa declined from 346,000 in 1950 to 203,000 in 1974 [23, 24].

The increase in farm size and the decline in the number of farm workers created a greater demand for farm machinery as well as larger farm machinery in both Iowa and the United States. Therefore, it is important to determine the costs associated with owning and operating various sizes of farm machinery.

OBJECTIVES

This study examines farm machinery costs in relation to machinery and farm size. The major objectives of the study are: (a) to derive the total (fixed and variable) costs for a number of machines of various sizes on a per hour or per acre basis for a given set of economic or financial conditions; (b) to derive the total (fixed and variable) costs for selected machines of different sizes on a per hour or per acre basis under varying economic conditions; and (c) to derive the total machine costs per acre for machinery combinations of various sizes with restrictions placed on the number of days suitable for field work in continuous corn production. The value of yield losses from untimely field operations is added to total machine costs to obtain the combined costs per acre for machines of different sizes.

The economic conditions (assumptions) for the first objective are: (a) a single rate of interest, (b) no inflation on repairs, housing, property taxes, and insurance, (c) a single wage rate, (d) constant diesel fuel and gasoline prices, and (e) a 7-year ownership period for all machines. The costs are calculated per hour for tractors and per acre for all other machinery.

Under the second objective, interest rates, wage rates, diesel fuel prices, and length of ownership are varied individually to determine the effect that the particular variable has on the total machinery costs. Two marginal income tax rates also are used to determine the effect of tax savings from tax deductions on machinery costs. Three sizes of tractors are used to determine not only the effect that a change in an economic variable has on machinery costs but also the effects that these changes have on different sizes of machines and investment levels. In addition, three sizes of plows are used to further illustrate the effects of changes in interest rates, fuel prices, and wage rates on machinery costs.

Economic conditions for the third objective are the same as those for the first objective. Only one tillage-planting-harvesting sequence is examined for each machine size in continuous corn production. Restrictions are placed on the number of days suitable for field work in central Iowa for each climatic week. A particular climatic week always falls at the same days of the month each year because the first week of the climatic year is considered to be March 1-7. Although central Iowa is one of nine regions in Iowa in which suitable field day data is collected, central Iowa was chosen because of its central location in the state and the fact that it is part of the cash crop area of Iowa. The central region of Iowa encompasses the following counties; Boone, Dallas, Grundy, Hamilton, Hardin, Jasper, Marshall, Polk, Poweshiek, Story, Tama, and Webster.

Yield losses represent the loss in potential yields because of untimely planting and harvesting of the corn crop. The harvesting timeliness losses are preharvest losses and do not include mechanical harvesting losses. The amount of loss will vary with the lateness of the

planting and harvesting operations and the value of these losses will depend upon the price of corn. Crop losses due to machinery breakdowns are not considered in this study. These losses are difficult to estimate because they are dependent upon machinery reliability, the number of available days for field work, and the particular time the breakdowns occur in the planting and harvesting seasons. The total costs for each machine are summed to determine the total machinery costs for a particular machinery combination. These costs are used to derive the short-run average total cost curves for each machinery combination. The economies of size for different machinery combinations can be determined from these curves.

METHOD OF ANALYSIS

Machinery costs are composed of fixed (or ownership) costs and variable (or operating) costs. The fixed costs include: depreciation, interest on investment, sales and property taxes, insurance, and housing. The variable costs are: repairs and maintenance, fuel, engine oil and filters, and labor. In addition to these costs, tax deductions for interest paid on debt, investment credit, and depreciation are calculated to determine after tax costs. The value of the yield losses from untimely operations also should be considered when analyzing machinery costs. A larger machine will have higher fixed costs than a smaller machine, but the reduction in yield losses may offset the higher fixed costs.

Depreciation

In this study depreciation is calculated by using the farm machinery value equations in the Agricultural Engineers Yearbook [1]:

(a) group 1 implements Percent = $64(0.885)^n$

(b) group 2 implements Percent = $60(0.885)^n$

(c) group 3 implements Percent = $56(0.885)^n$

(d) tractors Percent = $68(0.920)^n$

The equations express the remaining on-farm value of a machine for end of year n as a percentage of the initial list price of the machine. Remaining on-farm values are computed by multiplying the percentage times

the list price of the machine. Thus, the difference between the list price and the remaining farm value is the amount of depreciation.

The ownership period of a machine is assumed to be seven years. This period was chosen to represent a "normal" or useful life of a machine. Also, a machine with a useful life of at least seven years is eligible for the full investment credit. Under the first and third objectives, it is assumed that all machinery is kept for seven years. In the second objective, whereby economic conditions are varied, 4 and 10-year ownership periods also are considered. The 4-year ownership period represents the farm operator who wants a reliable machine and is willing to bear the increased ownership costs to obtain this extra reliability. In addition, the farmer who does much custom work may want to keep his machinery only four years. The 10-year ownership period represents the farm operator who keeps his machinery for an extended period of time. Thus, we can determine the effect that length of ownership has on machinery costs--particularly the ownership costs.

Interest on Investment

The capital recovery method is used to determine depreciation and interest on investment. This method combines the repayment of depreciation and the return on the investment during the life of the investment into a series of equal annual payments at compound interest [12]. There are many techniques for computing the annual equivalent cost of initial price and salvage. It is important, however, to distinguish those which are mathematically exact and those which are approximations [19].

The exact technique used in this study is found in Smith [19, pp. 47, 94]:

$$AEC = B(a/p)^i_n - V(a/f)^i_n$$

where AEC = annual equivalent cost

B = initial cost or price of the machine

V = salvage value at the end of the n-th year

i = interest rate

n = number of years

$a/p = i(1+i)^n / ((1+i)^n-1)$ a uniform series worth of a present sum or capital recovery factor

$a/f = i/((1+i)^n-1)$ a uniform series worth of a future sum or sinking fund factor.

The annual equivalent cost equals the annual equivalent of the initial cost less the annual equivalent of the salvage value.

For objectives one and three, where economic conditions are held constant, the interest rate is assumed to be 9 percent. This interest rate reflects the current levels of interest on farm machinery loans in Iowa. Interest rates of 6, 12, and 15 percent are also examined to determine whether or not interest rate levels significantly affect machinery costs. Possibly, at the higher interest rates labor may substitute for machinery on farms. As interest rates change, the values of the capital recovery factor and the sinking fund factor also will change.

Sales and Property Taxes

An annual tax rate of 1 percent of the remaining value of the machine is used to represent both sales and property taxes. The annual tax is discounted and is then summed to find the present value. The present value figure is multiplied by the capital recovery factor to find the annual equivalent cost of sales and property taxes.

Insurance

Insurance premiums vary depending upon the type of coverage and the insurance company. However, a rate of $5.00 per $1,000 of machinery value is common and is applied to the remaining value of machinery [5]. The annual equivalent cost of insurance is calculated in the same manner as the annual equivalent cost of sales and property taxes.

Housing

Housing can significantly increase the useful life and "trade-in" value of farm machinery, particularly if the machine has many moving parts. In this study, annual housing costs are 1 percent of the list price or original cost of the machine [5]. This 1 percent includes part of the cost of tools and a farm shop. The housing cost is expressed as a percentage of the original cost. Because the housing cost is the same each year, the annual equivalent cost of housing is the annual cost.

Repairs and Maintenance

Repairs and maintenance costs are estimated from a series of equations [6]. Repair costs include all parts and labor, whether the repairs are made in a "shop" or on the farm. The general form of the total repair cost equations is:

$$TAR = ILP \times RC1 \times RC2 \times L^{RC3}$$

where TAR = total accumulated repair costs estimated at "L"

L = percentage of wear out life of the machine when accumulated repair costs are estimated

ILP = initial list price of machine

RC1 = a constant that expresses the ratio of TAR to ILP at L = 100 percent [7].

RC2 and RC3 are constants that determine the shape of the accumulated repair cost curve for any specific machine. The value of the expression $RC2 \times L^{RC3}$ for all equations will equal one when L equals 100 percent. The equations were derived from data collected in a survey of farm machinery costs in 1966 in Illinois and Indiana [7]. These equations assume that there is no inflation on parts and labor.

Parts and labor do inflate in price over the life of the machine. However, machinery repair costs are not inflated for any of the objectives. Total accumulated repair costs are not calculated beyond the useful mechanical life of a machine because the estimates are not very reliable. The cost of repairs and maintenance are calculated for each year. These costs are discounted and then summed to find the present value of repairs and maintenance costs. This figure is multiplied by the appropriate capital recovery factor to determine the annual equivalent cost of repairs and maintenance.

Fuel

Fuel costs are estimated by two methods. The first is based upon the PTO (power-take-off) horsepower of tractors. This method determines the average fuel usage of tractors in gallons per hour. The average fuel consumption for gasoline, diesel, and LP gas tractors can be determined from these formulas [18]:

(a) PTO hp x 0.06 (for gasoline tractors)

(b) PTO hp x 0.044 (for diesel tractors)

(c) PTO hp x 0.072 (for LP gas tractors).

The fuel consumption formulas are derived from Nebraska Tractor Test Data. This procedure is used to determine the fuel consumption for tractors when the particular machine operation is not specified.

The second method is used to determine the fuel consumption for specific field operations. For this method, the fuel consumption per acre for a specific operation is assumed to be independent of the size of the machine or tractor [2, 3]. Fuel consumed for travel to and from fields is not included in the fuel consumption figures because it is difficult to estimate.

The prices for gasoline and diesel fuel are $0.370 and $0.345 per gallon, respectively. These prices are averages for several points in Iowa in May of 1975. The 4 cents federal and 7 cents state taxes have been subtracted from the gasoline price. Fuel prices have risen sharply since the fall of 1973. To determine the effect of fuel prices on machinery costs, several different fuel prices are used in this study. The November 1972 diesel fuel price of $0.186 per gallon [16] is used to compare the effect that this price has on machinery costs with the current price. Diesel fuel prices of $0.50, $0.75, and $1.00 per gallon are used to determine the effect of higher fuel prices on machinery costs.

Engine Oil and Filters

Engine oil and filter costs are estimated at 15 percent of the fuel costs. This method of estimating lubricant costs is that used in the Agricultural Engineers Yearbook [1]. Transmission oil and filters and other lubricants such as grease are included with the repairs and maintenance costs.

Labor

Different machine sizes require different quantities of labor to accomplish the same task. Thus, it is necessary to consider the differences in labor costs for different sizes of machines in an analysis of machinery costs. Because of the time required to prepare and service machinery, both at the farmstead and in the field, and the travel time to and from the field, actual man-hours of labor needed will usually exceed the actual field time by 10 to 25 percent [6, 9, 12]. Hence, the labor cost per hour of field time will range from 110 to 125 percent of the hourly wage rate.

For the third objective, restrictions are placed on the number of man-hours of field time available per suitable field day. Hours of family labor are limited to one operator and a 15-year-old son on a part-time basis. Hired labor is limited to one hired employee on a

full-time basis. Thus, labor consists of one hired employee plus family labor.

For the first and third objectives, where economic conditions are held constant, the wage rate is $4.00 per hour. For the second objective, wage rates are varied to determine the effect of different wage rates on machinery costs. Wage rates of $3.00, $5.00, and $6.00 per hour are analyzed and compared with the $4.00 rate. The effect of different wage rates can be compared with the effects of different interest rates and fuel prices on machinery costs.

Tax Deductions

Tax deductions are calculated for certain fixed costs. The tax deduction per hour or per acre declines as the number of hours or acres increases. Hence, the tax deductions will have a much greater impact on the ownership costs of machines that are used a small number of hours per year than those that are used extensively throughout the year.

Tax deductions are calculated for interest paid on debt, investment credit, and depreciation. In this study the machine is financed 60 percent through debt capital and 40 percent through equity capital. The interest rate for debt capital is the same as it is for interest on investment. The debt is paid off in four equal principal payments plus annual interest. The interest paid each year is tax deductible.

In 1975 the investment credit was raised to 10 percent. Since only new machinery is purchased, the basis for investment credit is the initial list price. Machinery kept for 7 to 10 years is eligible for the full

10 percent investment credit. For machinery kept four years, only one-third of the investment is eligible for investment credit [26].

Three methods can be used to determine machinery depreciation for tax purposes. The most common method used by farmers is the straight-line method. The other two are the declining-balance and sum of the year-digits methods. The straight-line method is used in this report to calculate machinery depreciation for tax purposes. An additional first-year depreciation allowance can be taken on new or used machinery that has a useful life of 6 years or more when purchased. The first-year additional depreciation is subtracted off before calculating the annual depreciation [26].

The initial list price of the machine becomes the adjusted basis for depreciation. The salvage value of the machine is the remaining farm value at the end of 4, 7, or 10 years. If salvage value is less than 10 percent of the adjusted basis of the machine, it is ignored when computing depreciation because salvage value can be reduced up to 10 percent of the adjusted basis of the machine. The total amount of depreciation deducted, however, cannot exceed the adjusted basis of the machine less salvage less the 10 percent salvage reduction [26].

Marginal income tax rates of 29 percent (22 percent federal and 7 percent state) and 39 percent (32 percent federal and 7 percent state) are used to determine the effects of two different tax rates on machinery costs for machinery owned 4, 7, and 10 years. The 29 percent marginal tax rate applied to farmers filing a tax return with a taxable income of $8,000 to $12,000 [15, 27]. In 1972 the realized net farm income

per farm in Iowa was $10,181 [22]. The 39 percent tax rate would be the marginal tax rate for farmers filing a tax return with a taxable income of $20,000 to $24,000. The realized net farm income per farm in Iowa was $22,238 in 1973 [22]. The annual equivalent value of tax savings is calculated using the straight-line method of depreciation. The annual equivalent value is then subtracted from the total cost figure. The resulting total cost figure is the after tax costs of farm machinery. This difference in the total cost of machinery represents the savings in taxes due to tax deductions.

Cost Adjustments for Yield Losses from Untimely Field Operations

To determine the value of yield losses from untimely field operations, the number of days suitable for field work and the yield losses from delayed field operations are determined. The value of these yield losses are then added to machinery costs to get the combined per acre costs of operating a particular machinery combination for specific acreages.

<u>Days suitable for field work</u>

The days suitable for field work recorded by the Iowa Crop and Livestock Reporting Service for the central region of Iowa are used in this study [13]. The weekly data cover the years 1958 to 1974 and are reported from the beginning of April to the end of November. For 1974, however, no data are available for the harvest season. The Iowa Crop and Livestock Reporting Service data are recorded by calendar week. These weekly data are converted to climatic weeks, so that each week falls on the same days of the month for every year. The first climatic week occurs on March 1-7 and the fifty-second climatic week occurs on February 21-27. In this study the recorded (calendar) week data are allocated to the closest climatic week. For example, if the recorded data for the calendar week April 14-20 is 4.9 suitable days, all 4.9 days would be allocated to climatic week, April 12-18. This procedure is repeated for each of the 17 years. In 3 of the 17 years, the recorded and climatic weeks correspond exactly. For many climatic weeks there are 17 years of data. However, a number of the climatic weeks at the beginning and the end of the reporting period have fewer years of data because of the variability in the starting dates for spring field work and the completion dates for fall harvesting.

The average number of days suitable for field work during each climatic week is calculated only for the number of years that the data are recorded. The standard deviation[1] is calculated for each climatic week as a measure of the dispersion of the data from the mean (average). For climatic weeks with 8 or more years of data, the standard deviations range from a low of 0.5 days for the 26th week to a high of 2.3 days for the 6th week. For each climatic week, one standard deviation is subtracted off the average to obtain a range in the number of suitable field days. Since the underlying distribution of the original data is unknown, a probability cannot be assigned to the latter set of suitable

[1] The standard deviation is the square root of the variance. The variance, in turn, is the sum of the square of the deviations of the individual observations from the mean divided by the number of observations (years) minus one. The observations in this case are the number of suitable field days for a particular climatic week.

field days. This range in suitable field days will affect the number of acres that can be farmed and the level of yield losses that are incurred for each machinery size combination.

The average number of days suitable for field work represents an average weather year. The average minus one standard deviation data set would represent an unfavorable weather year. These two sets of data define the number of days suitable for field work for the third objective.

In this study the period suitable for field work begins March 29 and ends December 5. In some years, however, field work could begin before and continue after these dates. The latter situation is more likely to occur, because days suitable for field work are not reported after the corn harvesting is 92-94 percent completed.[2]

The total amount of labor available per day consists of the operator and a 15-year-old son on a part-time basis and one employee on a full-time basis. The total hours of labor per week are determined by multiplying the total hours of labor available per day times the number of suitable field days in the week. The total man-hours of labor available per week are calculated for the average and the average minus one standard deviation categories. Total tractor hours available per week for each tractor are determined by multiplying the number of tractor hours per suitable field day (11.0) times the number of days suitable for field work in the week. Combine hours per week are calculated on the

[2] Duane M. Skow, Iowa Crop and Livestock Reporting Service, personal communication.

basis of 10 hours available per suitable field day. Tractor and combine hours per week are calculated for both categories of suitable field days.

From these weekly hours, the number of hours available for field work is determined by periods of the year. The number of hours available for field work are calculated for a preplanting period in the spring, five planting periods, three harvesting periods, and one post-harvesting period in the fall. The number of hours in these periods, particularly the planting and harvesting periods, determines the number of acres of corn that can be grown and the yield losses that are incurred for the different machinery combinations.

Timeliness and crop yields

Crops planted, cultivated, and harvested during certain periods will have yields which are higher than those planted, cultivated, and harvested in other periods. Hence, timeliness becomes an important consideration in machinery selection. To assign a value to timeliness, we need to determine the yield losses from untimely field operations. For corn, the major yield losses arise from delays in planting and harvesting.

This study assumes there are no losses in yields for corn planted during climatic weeks 9 and 10 (April 26 to May 2 and May 3 to May 9). If corn is planted during climatic weeks 11, 12, 13, and 14, corn yields are reduced by 3, 8, 15, and 25 percent, respectively, from those in the two previous weeks [4]. Losses due to delayed harvesting are more difficult to determine [4, 8, 17]. Delays in harvesting result in

increased lodging and ear loss. Assumed yield losses from delayed harvesting are zero for the first harvesting period. (September 27 to October 17), 2 percent for the second period (October 18 to November 7), and 5 percent for the third period (November 8 to November 28) [4]. Harvested yields for the no loss planting periods (climatic weeks 9 and 10) are 130, 127, and 124 bushels per acre, respectively, for the three harvesting periods. The losses for each harvesting period are subtracted from the yields for each of the subsequent planting periods (climatic weeks 11, 12, 13 and 14) to determine the harvested yields.

Only corn planted in the first two periods is harvested in the first harvesting period. Harvesting in the first period is limited to the climatic week October 11-17 because the moisture levels of the grain are 25 to 27 percent at the beginning of the harvest period. In the second harvesting period the moisture content of the grain ranges from 20 percent for the earliest planted corn to 23 percent for the latest planted corn.

The value of the yield losses (both planting and harvesting) is calculated for corn priced at $2.00 per bushel. The value of the per acre loss is considered a cost and therefore added to machinery costs to obtain the combined costs per hour. It is estimated that $2.00 per bushel is needed to cover corn production costs in 1975 [20]. The value of these losses is estimated for each 25 acre increment in corn acreage. If the 25 acre increment is completed within the planting period, then the losses are calculated on the basis of losses for that planting period.

If the 25 acre increment straddles two periods, the losses are calculated on the basis of the planting period in which the 25 acre increment is completed. Planting is the last operation in a sequence of operations carried out during the planting period. Similarly, if the 25 acre increment is completed within the harvesting period, losses are determined on the basis of losses for that harvesting period. If the 25 acre increment involves two periods, the harvesting losses are prorated on the basis of the number of hours falling in the preceding and succeeding harvesting periods. The accounting program simultaneously determines the planting and harvesting losses for each 25 acre increment.

These loss values are added to the total costs for the particular machinery combination to obtain the combined costs per acre. Separate loss values are calculated over a series of acreages for each machinery size combination for each of the two suitable field day categories, with corn priced at $2.00 per bushel.

Machinery combinations

The narrow-row machinery combinations are 6, 8, and 12 row planting and tillage equipment and 3, 4, and 6 row harvesting equipment. The wide-row machinery combinations are 4, 6, and 8 row planting and tillage equipment and 2, 3, and 4 row harvesting equipment. Narrow rows are 30 inches wide and wide rows are 38 inches wide. Each machinery combination has the appropriate tractor sizes and other nonrow type equipment (Table A.1). The anhydrous ammonia applicator is rented at a cost of $0.65 per acre from the local fertilizer supplier. The tractor, fuel,

and labor costs are additional. Dry fertilizer is applied by the fertilizer supplier at a cost of $1.25 per acre, materials not included [10].

A difficult problem in determining implement costs is the handling of tractor costs. Tractor costs per hour vary inversely with the number of hours of annual use. One approach is to assume that a tractor is used a specified number of hours per year. Thus, tractor costs for a particular tractor and implement combination are constant per hour or per acre. Alternatively, tractor costs could be specified in 50-or 100-hour increments, but the allocation of these hours among the various implements becomes a difficult problem. Consequently, the approach used in this study is to assume that all tractors are used 600 hours per year when calculating tractor and implement combination costs.

For machines with base units and attachments, such as a combine with a separator (base) unit and a corn head, the total cost for the machine includes both the base unit and attachment costs. The cost of hauling grain from the field to on-farm storage is calculated per acre. The capacity of the hauling system in terms of acres per hour is dependent upon the combine harvesting capacity.

Only one sequence of tillage, planting, and harvesting operations is used in this study. Although there are a number of alternative tillage systems, the "conventional" tillage system involving the moldboard plow is still the most widespread tillage system used in corn production for central Iowa. For continuous corn production, the sequence is: spread P and K in fall, disk stalks fall and spring, plow fall and spring, disk, apply anhydrous ammonia, spray on herbicides, disk, plant and apply starter fertilizer and insecticide, rotary hoe twice, cultivate once, combine, and haul grain to farm storage. Sixty percent of the disking of stalks and plowing is assumed to be done in the fall and 40 percent in the spring. Fall versus spring plowing is not assumed to alter corn yields. Land preparation immediately preceding planting, or planting, does not begin before the 8th climatic week (April 19-25). Rotary hoeing is assumed to begin the week of May 10-16. The second rotary hoeing is assumed to begin sometime during the week of May 17-23. Cultivating begins during the week of May 31 to June 6. Disking of stalks and fall plowing do not start until the second harvesting period (October 18 to November 7). The spraying of herbicides is a separate field operation using a trailer-type sprayer.

The accounting program adds together the cost for each operation to find the total costs for a particular machinery size combination for each 25 acre increment. The process is repeated for a particular machinery combination for each restriction on the number of suitable field days. The acreage limit of each machinery combination is dependent upon these restrictions on suitable field days. The cost for drying and storage of grain are not included in the total machinery combination costs. These costs are largely independent of machinery and farm size.

RESULTS AND DISCUSSION

Farm Machinery Costs Under Constant Economic Conditions

Under the first objective, the total (variable and fixed) costs for each machine are calculated for a given set of economic conditions or assumptions. The assumptions are: (a) 9 percent rate of interest, (b) 1.5 percent of remaining value for property taxes and insurance, (c) 1 percent of list price for housing, (d) $0.370 per gallon for gasoline and $0.345 per gallon for diesel fuel, (e) 15 percent of fuel costs for engine oil and filters, and (f) $4.00 per hour for labor. All machinery is owned for seven years and there is no inflation in repair costs over the ownership period.

Tractors

The variable and fixed costs per hour for utility model gas and diesel tractors are presented in Fulton [11]. The different variable costs for tractors are constant per hour except for repair costs, which increase with the hours of annual use. The annual equivalent fixed cost (depreciation, interest on investment, property taxes, insurance, and housing) for all tractors is 17.66 percent of the list price of the tractor. The annual fixed cost is not affected by the hours of annual use. Thus, per hour fixed costs decline as the hours of use increase. The total cost per hour declines continuously as the annual use increases from 50 to 1,500 hours. The decrease in fixed costs per hour more than offsets the increase in repair costs. Initially, the diesel tractors have higher total costs than the gasoline tractors because of higher fixed costs. At the higher levels of annual use, however, diesel tractors have lower total costs because the lower fuel costs eventually compensate for the higher fixed costs.

Figures 1 and 2 illustrate the decline in total cost per hour for utility model gasoline and diesel tractors as the hours of annual use increase. The horizontal axes in these figures are in 100-hour units. For example, 4.00 represents 400 hours. By 600 hours of annual use, most of the decline in total cost has occurred. Also, by this level, total cost per hour for diesel tractors is less than the cost for an equivalent size gasoline tractor.

The fixed costs for the 80 to 180 power-take-off tractors are considerably higher than for the utility tractors because of the greater investment. The total costs per hour for these tractors are given in Figure 3. Although there are large declines in total costs by 600 hours of annual use, costs decline considerably beyond this level of use, especially for the 180 horsepower four-wheel-drive (4WD) tractor. The cost curves for the 150 horsepower (hp) two-wheel-drive tractor and the 150 horsepower 4WD tractor intersect at approximately 1,500 hours. The two curves intersect because the assumed lower repair costs per hour of the 4WD tractor eventually offset the higher fixed costs.

Tillage equipment

Moldboard plows range in size from 3-16" to 8-16" bottom plows. The soil is a Clarion-Webster loam and plowing depth is 7 inches. The

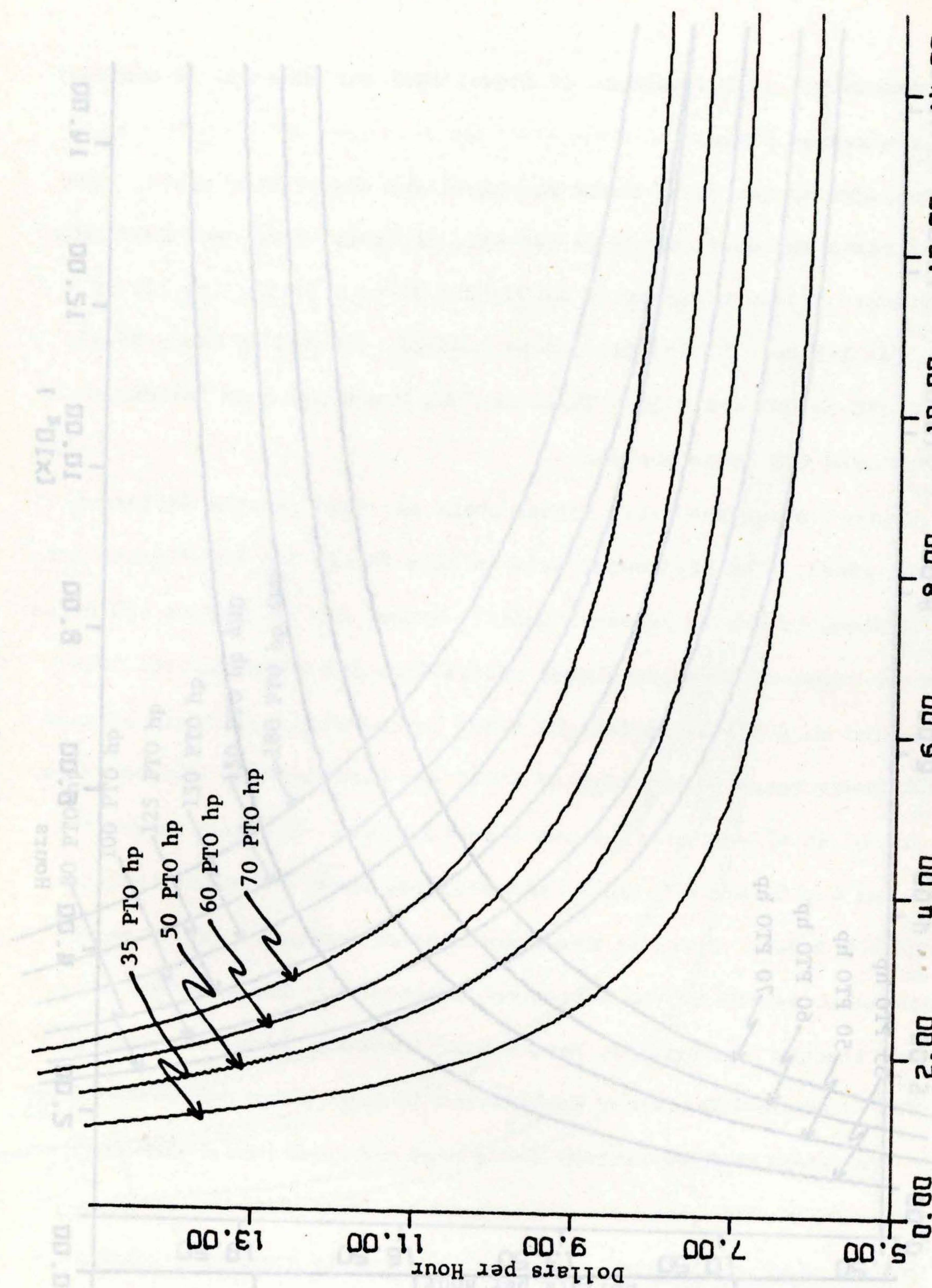

Figure 1. Cost per hour for utility model gasoline tractors

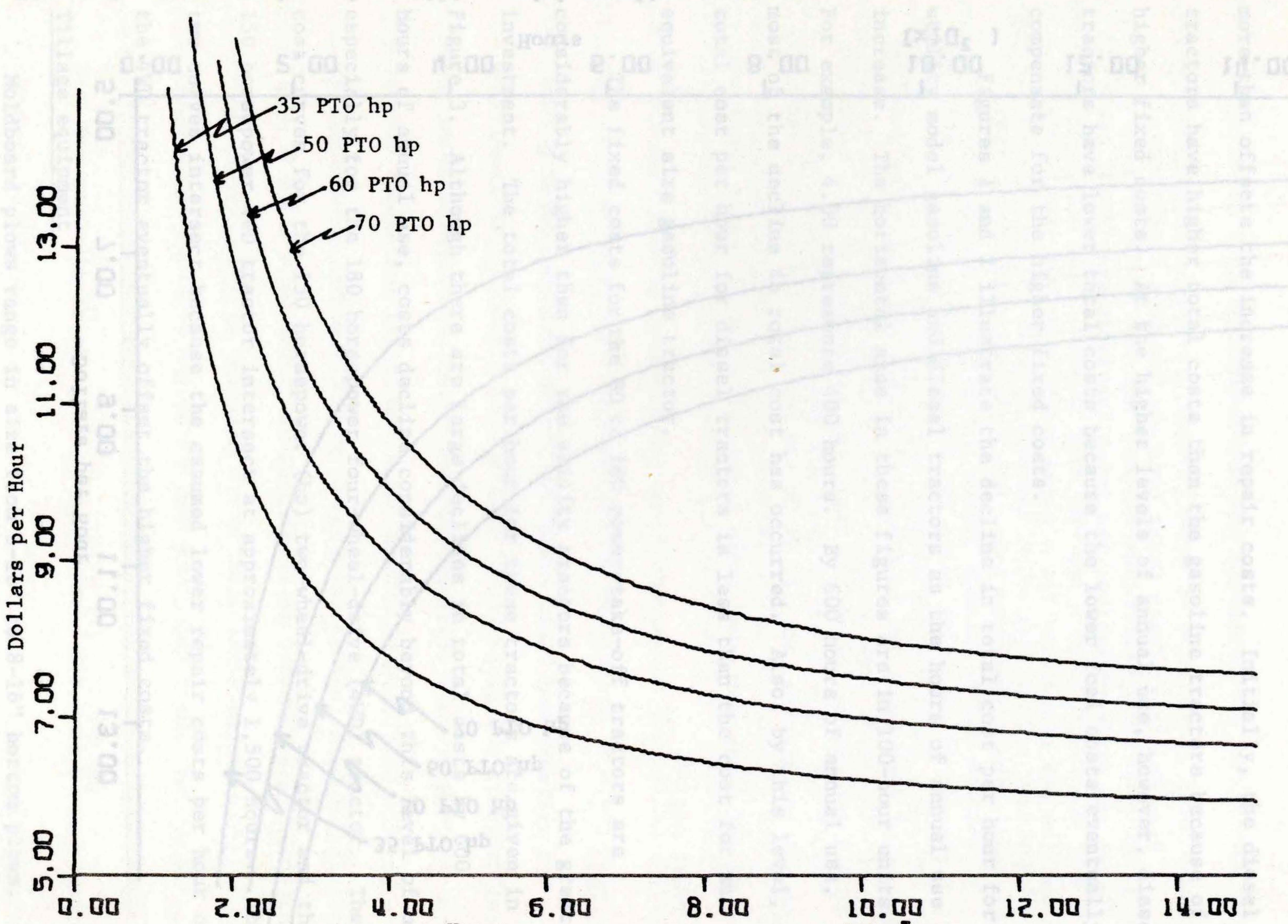

Figure 2. Cost per hour for utility model diesel tractors

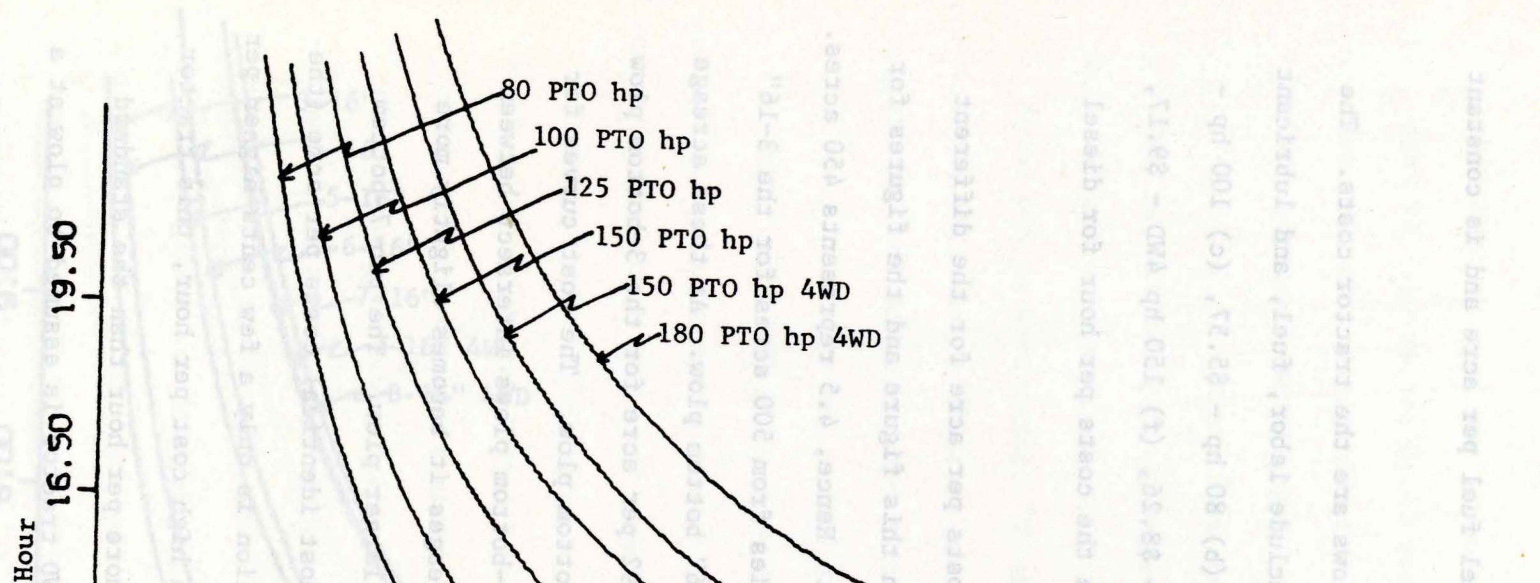

Figure 3. Cost per hour for diesel tractors

fuel consumption is 1.9 gallons of diesel fuel per acre and is constant for all sizes of plows.

Included in the total costs for plows are the tractor costs. The tractor costs per hour, which do not include labor, fuel, and lubricant costs, are: (a) 50 hp diesel - \$2.99, (b) 80 hp - \$5.57, (c) 100 hp - \$6.33, (d) 125 hp - \$7.29, (e) 150 hp - \$8.26, (f) 150 hp 4WD - \$9.17, and (g) 180 hp 4WD - \$10.18. These are the costs per hour for diesel tractors used 600 hours per year.

Figure 4 shows the total annual costs per acre for the different sizes of plows. The horizontal axis in this figure and the figures for other implements are in 100-acre units. Hence, 4.5 represents 450 acres. The upper limit on acreages plowed varies from 500 acres for the 3-16" bottom plow to 1,125 acres for the 8-16" bottom plow. At these acreage limits, costs range from a high of \$5.92 per acre for the 3-bottom plow to a low of \$5.47 per acre for the 8-bottom plow. The cost curves for the 3- and 4-, 5- and 6-, and 7- and 8-bottom plows intersect between 300 and 400 acres. Thus, at these acreages it becomes slightly more profitable to switch to the next size larger plow. The two 7-bottom plow and tractor combinations have almost identical costs per acre (the 7-bottom plow and 4WD tractor combination is only a few cents higher per acre). Although the 4WD tractor has a high cost per hour, this tractor and plow combination plows 0.2 acres more per hour than the standard tractor and plow combination. (The 4WD tractor is assumed to plow at a higher speed because of less slippage). The fuel and lubricant costs

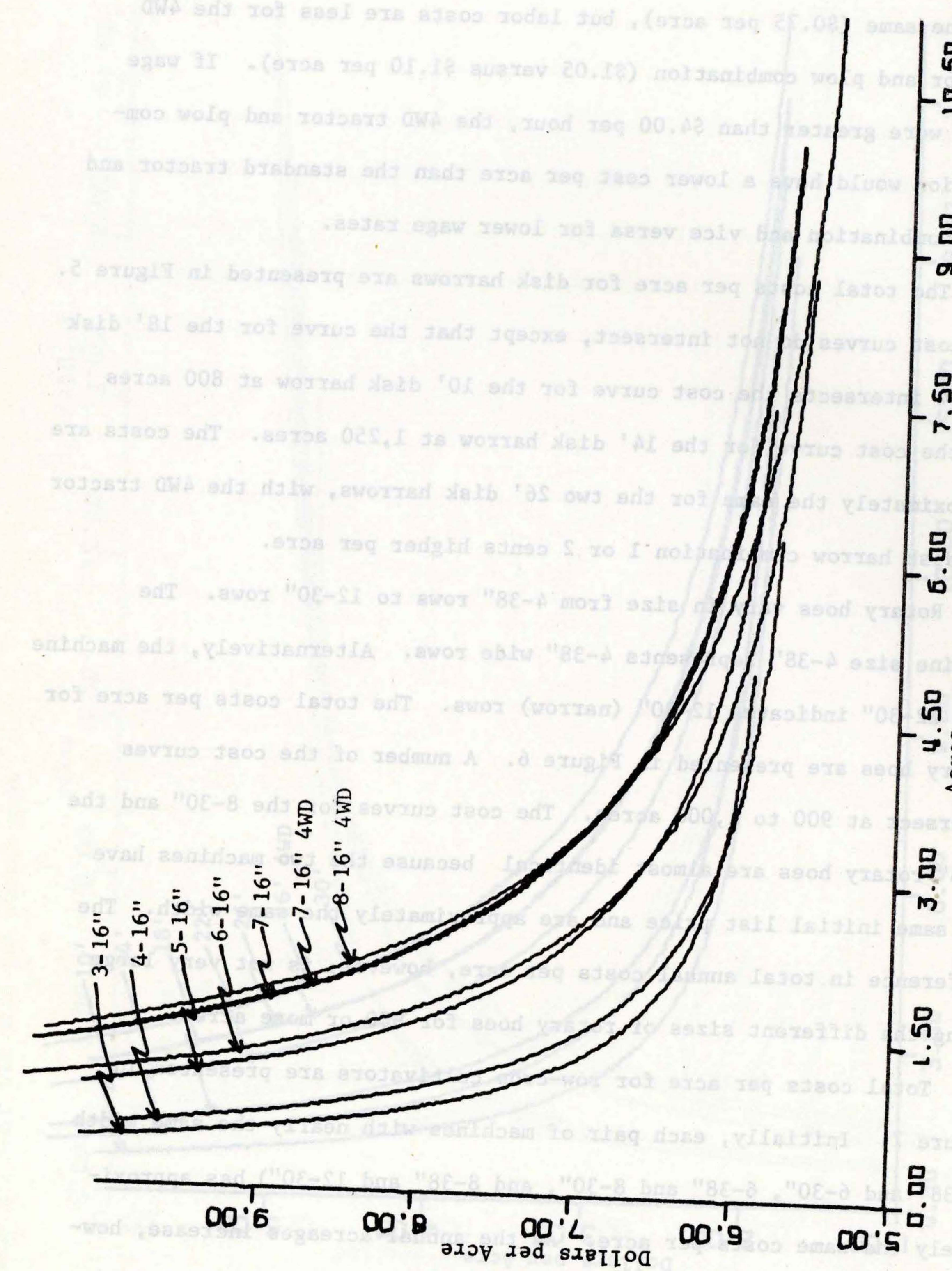

Figure 4. Cost per acre for moldboard plows

are the same ($0.75 per acre), but labor costs are less for the 4WD tractor and plow combination ($1.05 versus $1.10 per acre). If wage rates were greater than $4.00 per hour, the 4WD tractor and plow combination would have a lower cost per acre than the standard tractor and plow combination and vice versa for lower wage rates.

The total costs per acre for disk harrows are presented in Figure 5. The cost curves do not intersect, except that the curve for the 18' disk harrow intersects the cost curve for the 10' disk harrow at 800 acres and the cost curve for the 14' disk harrow at 1,250 acres. The costs are approximately the same for the two 26' disk harrows, with the 4WD tractor and disk harrow combination 1 or 2 cents higher per acre.

Rotary hoes vary in size from 4-38" rows to 12-30" rows. The machine size 4-38" represents 4-38" wide rows. Alternatively, the machine size 12-30" indicates 12-30" (narrow) rows. The total costs per acre for rotary hoes are presented in Figure 6. A number of the cost curves intersect at 900 to 1,000 acres. The cost curves for the 8-30" and the 6-38" rotary hoes are almost identical because the two machines have the same initial list price and are approximately the same width. The difference in total annual costs per acre, however, is not very large among the different sizes of rotary hoes for 900 or more acres.

Total costs per acre for row-crop cultivators are presented in Figure 7. Initially, each pair of machines with nearly the same width (4-38" and 6-30", 6-38" and 8-30", and 8-38" and 12-30") has approximately the same costs per acre. As the annual acreages increase, however, the narrow-row equipment has lower costs per acre than the wide-row equipment because of slightly greater capacities in acres per hour.

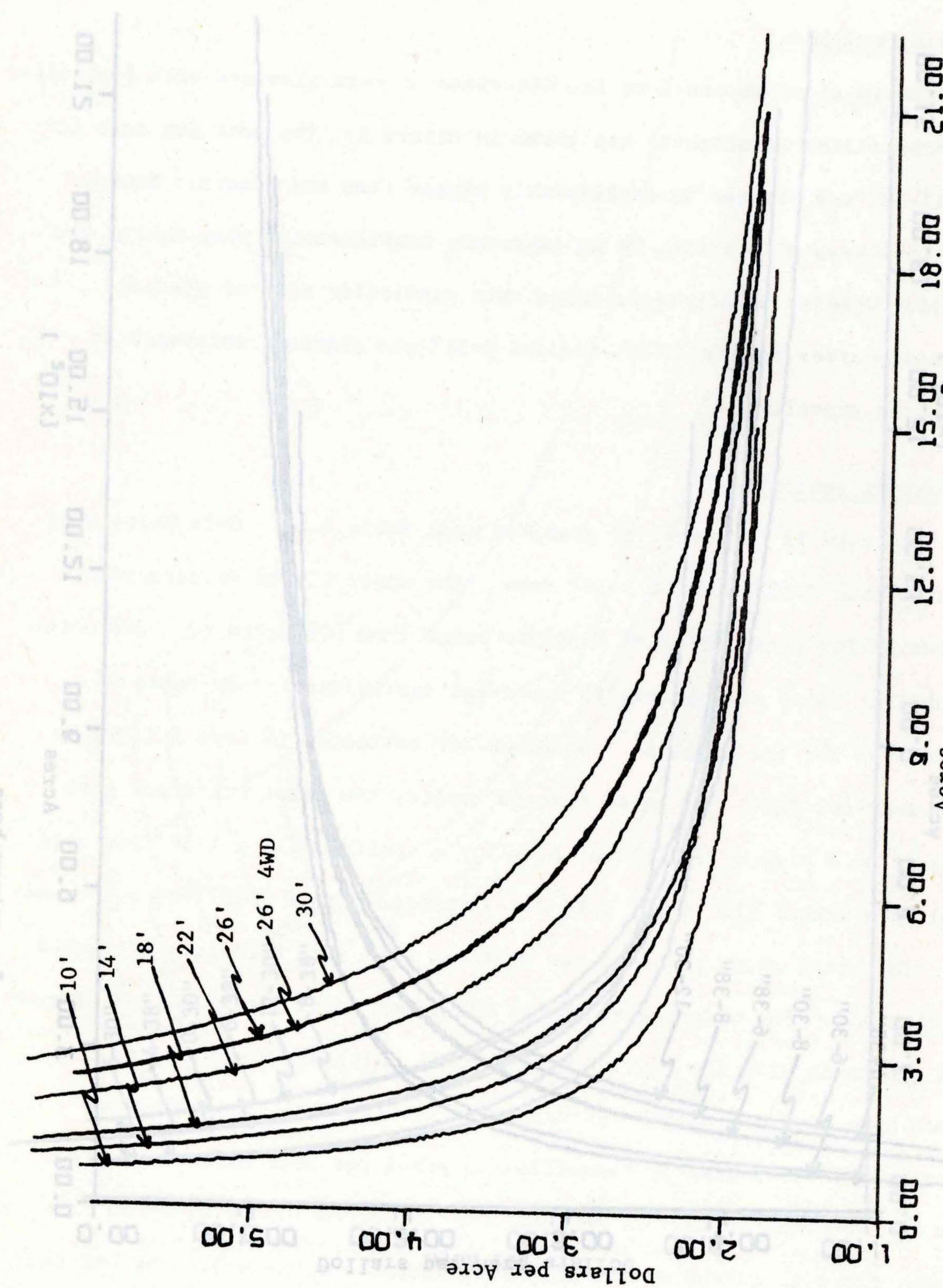

Figure 5. Cost per acre for disk harrows

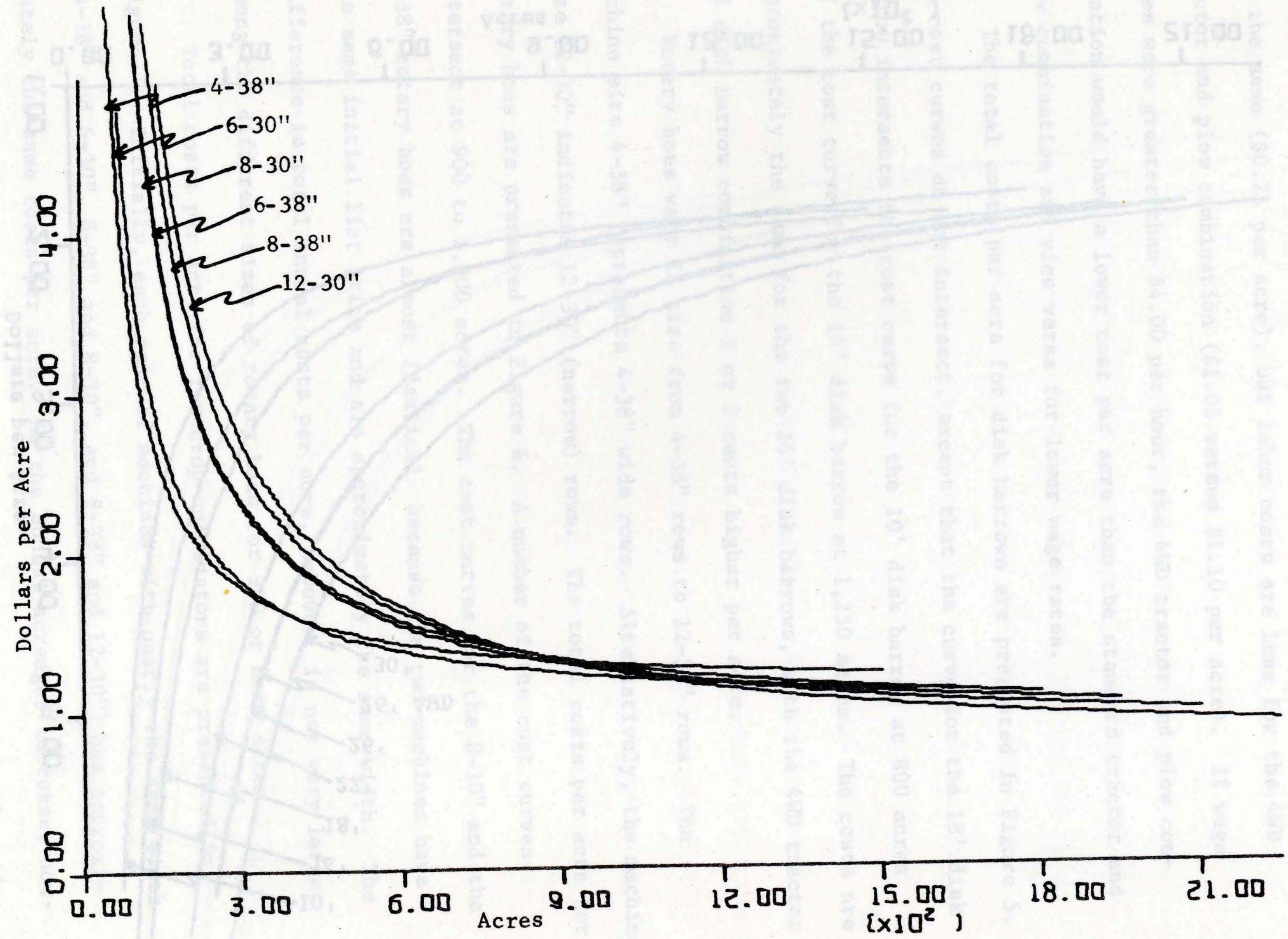

Figure 6. Cost per acre for rotary hoes

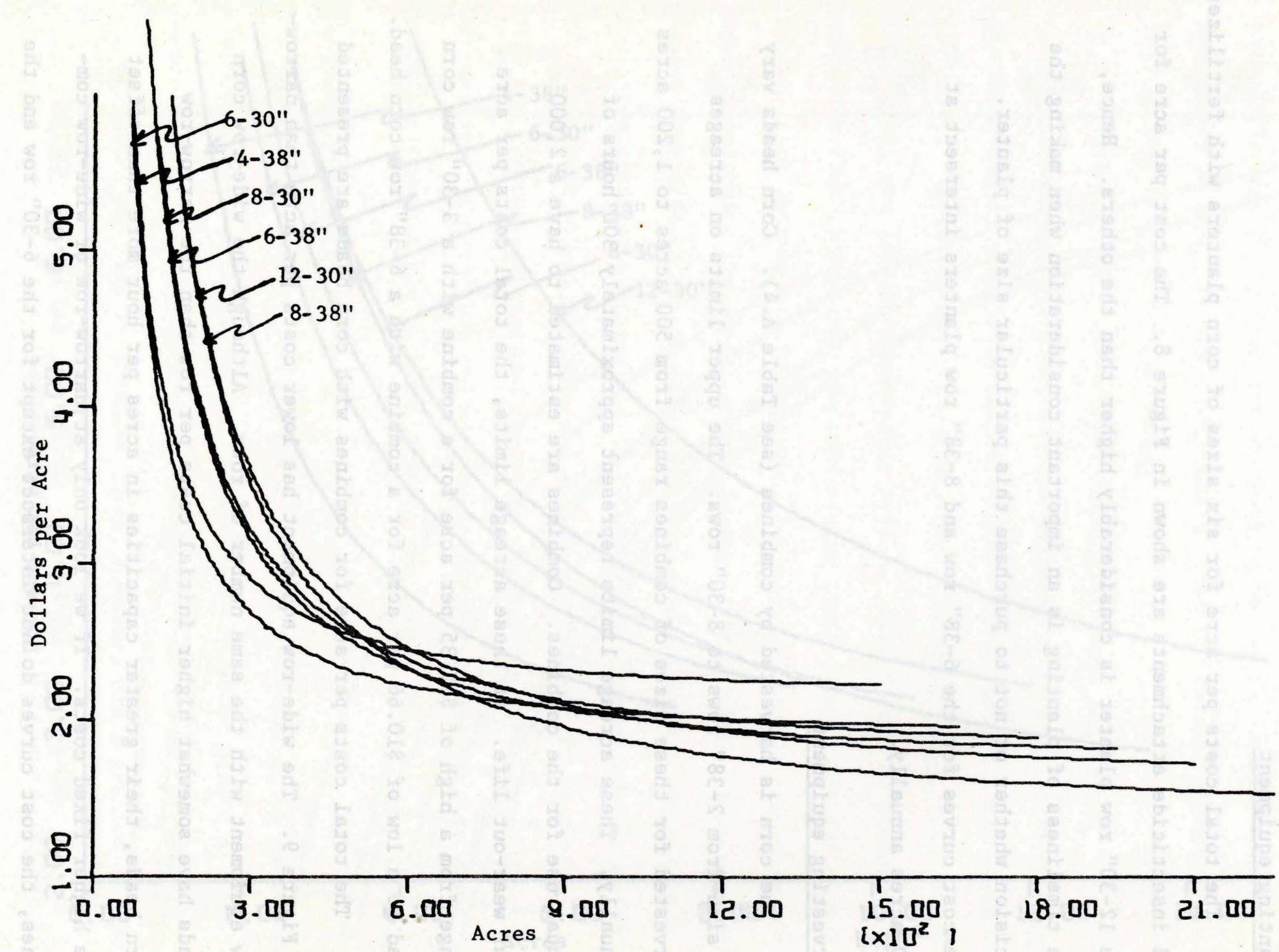

Figure 7. Cost per acre for row crop cultivators

Planting equipment

The total costs per acre for six sizes of corn planters with fertilizer and insecticide attachments are shown in Figure 8. The cost per acre for the 12-30" row planter is considerably higher than the others. Hence, the timeliness of planting is an important consideration when making the decision whether or not to purchase this particular size of planter. The cost curves for the 6-38" row and 8-38" row planters intersect at 850 acres annually.

Harvesting equipment

The corn is harvested by combines (see Table A.4). Corn heads vary in size from 2-38" rows to 8-30" rows. The upper limits on acreages harvested for these sizes of combines range from 500 acres to 1,200 acres annually. These acreage limits represent approximately 300 hours of annual use for the combines. Combines are estimated to have a 2,000 hour wear-out life. At these acreage limits, the total costs per acre range from a high of $15.35 per acre for a combine with a 3-30" row corn head to a low of $10.66 per acre for a combine with a 6-38" row corn head.

The total costs per acre for combines with corn heads are presented in Figure 9. The wide-row equipment has lower costs per acre than narrow-row equipment with the same number of rows. Although the wide-row corn heads have somewhat higher initial costs per row than the narrow-row corn heads, their greater capacities in acres per hour more than offset the higher fixed costs. If we look only at narrow-row or wide-row combines, the cost curves do not intersect except for the 6-30" row and the 8-30" row combines, which intersect at approximately 700 acres. The

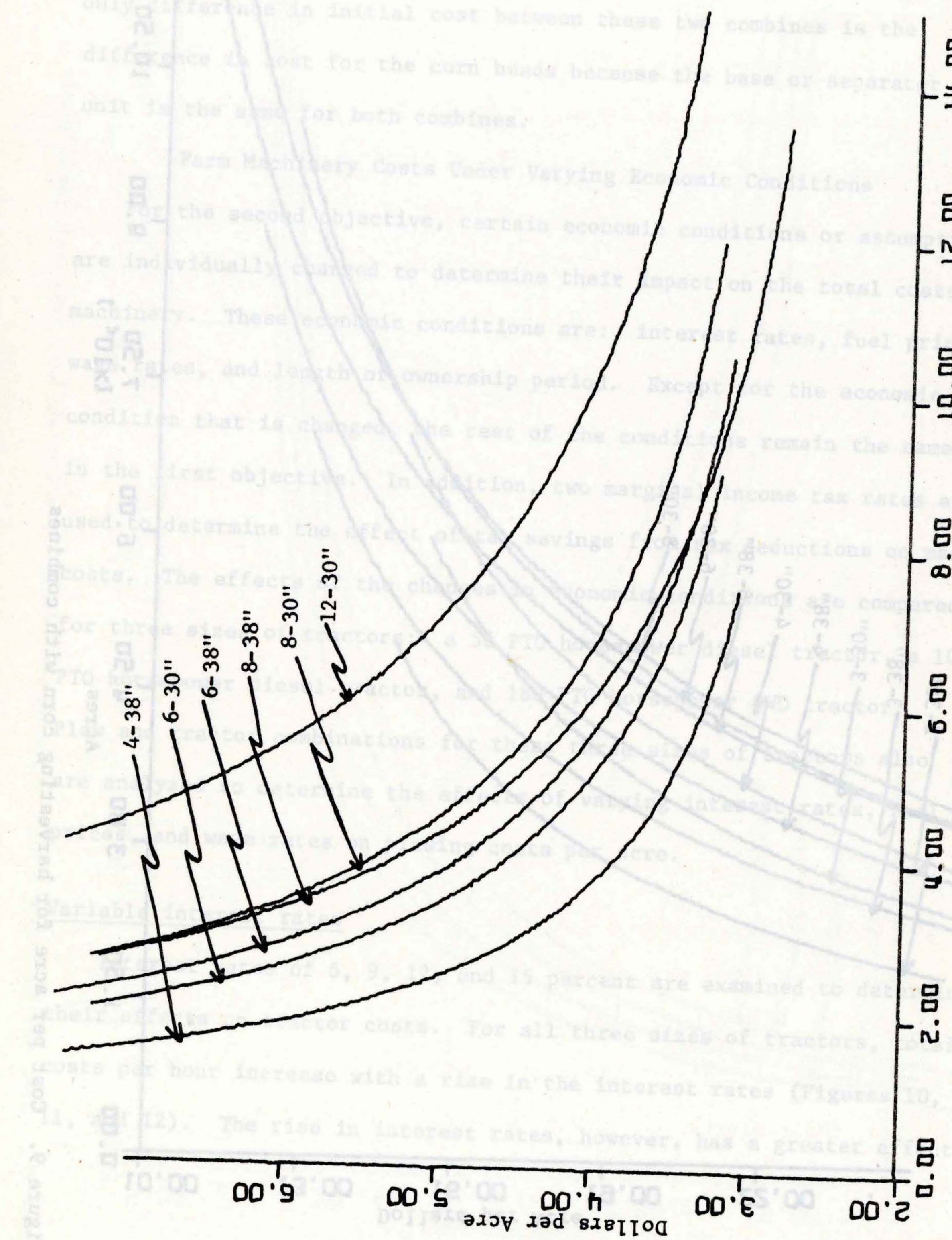

Figure 8. Cost per acre for planting corn with planters

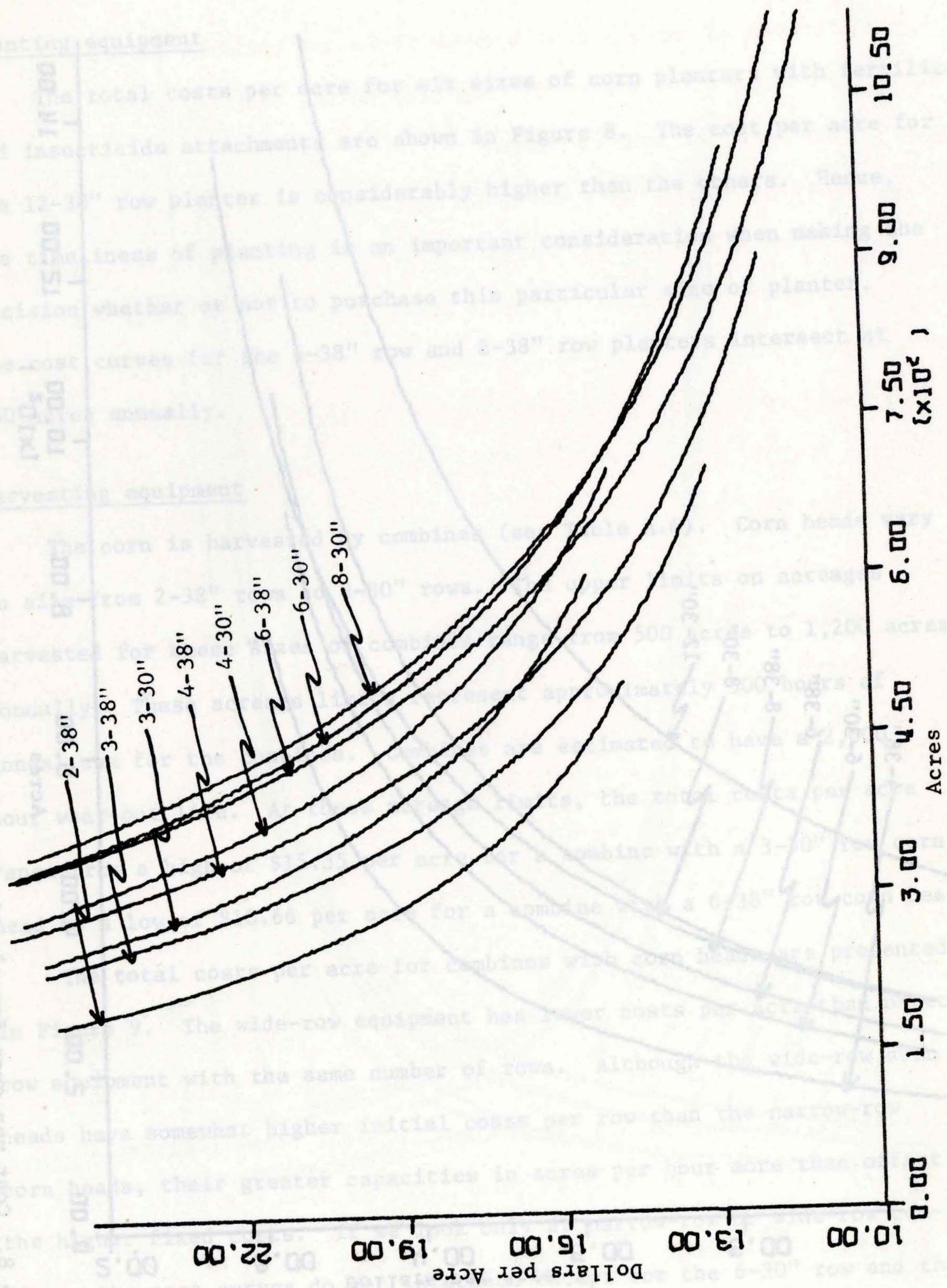

Figure 9. Cost per acre for harvesting corn with combines

only difference in initial cost between these two combines is the difference in cost for the corn heads because the base or separator unit is the same for both combines.

Farm Machinery Costs Under Varying Economic Conditions

For the second objective, certain economic conditions or assumptions are individually changed to determine their impact on the total costs of machinery. These economic conditions are: interest rates, fuel prices, wage rates, and length of ownership period. Except for the economic condition that is changed, the rest of the conditions remain the same as in the first objective. In addition, two marginal income tax rates are used to determine the effect of tax savings from tax deductions on machinery costs. The effects of the changes in economic conditions are compared for three sizes of tractors: a 50 PTO horsepower diesel tractor, a 100 PTO horsepower diesel tractor, and 180 PTO horsepower 4WD tractor. Plow and tractor combinations for these three sizes of tractors also are analyzed to determine the effects of varying interest rates, fuel prices, and wage rates on plowing costs per acre.

Variable interest rates

Interest rates of 6, 9, 12, and 15 percent are examined to determine their effects on tractor costs. For all three sizes of tractors, total costs per hour increase with a rise in the interest rates (Figures 10, 11, and 12). The rise in interest rates, however, has a greater effect

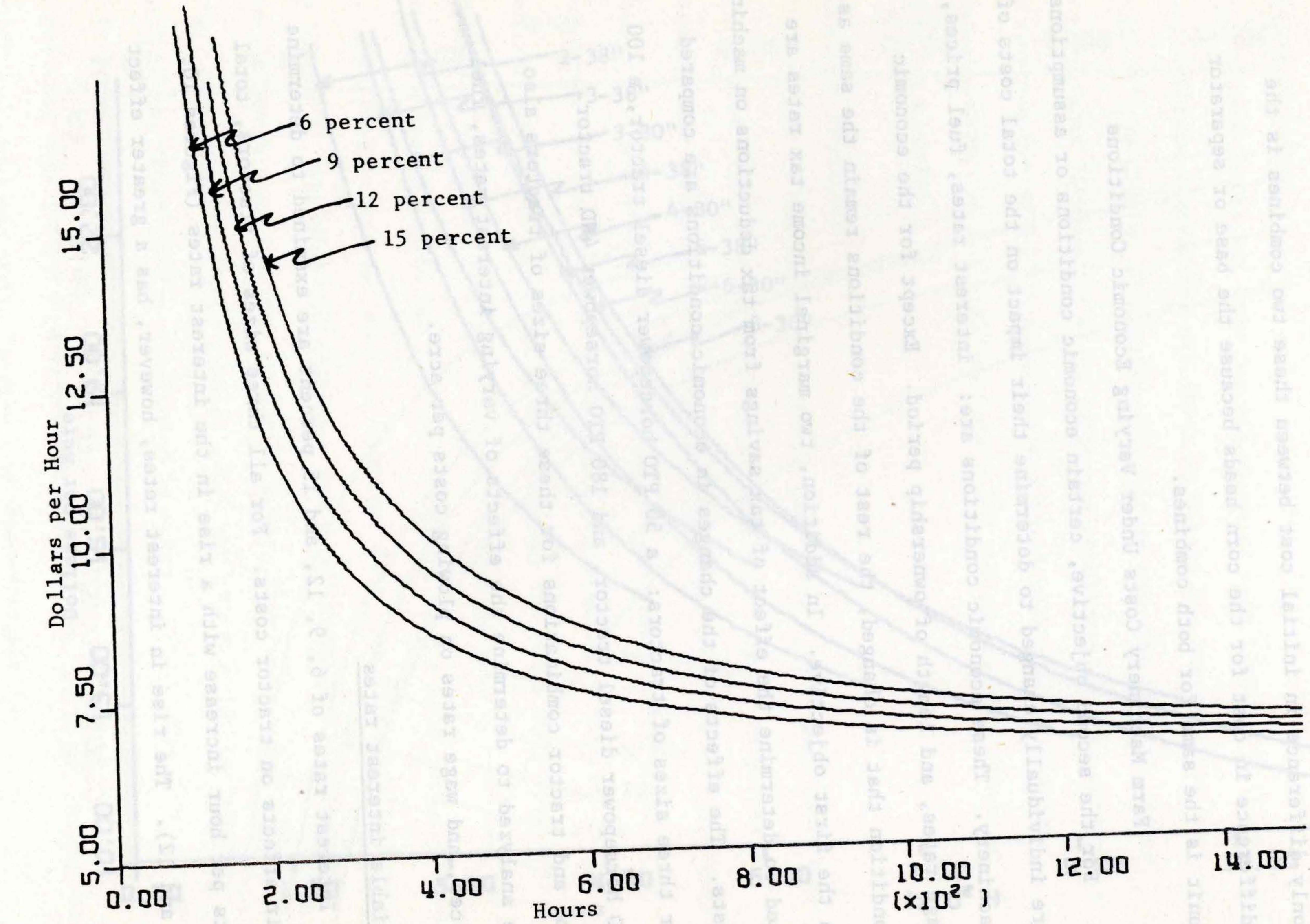

Figure 10. Cost per hour for a 50 PTO horsepower diesel tractor at four interest rate levels

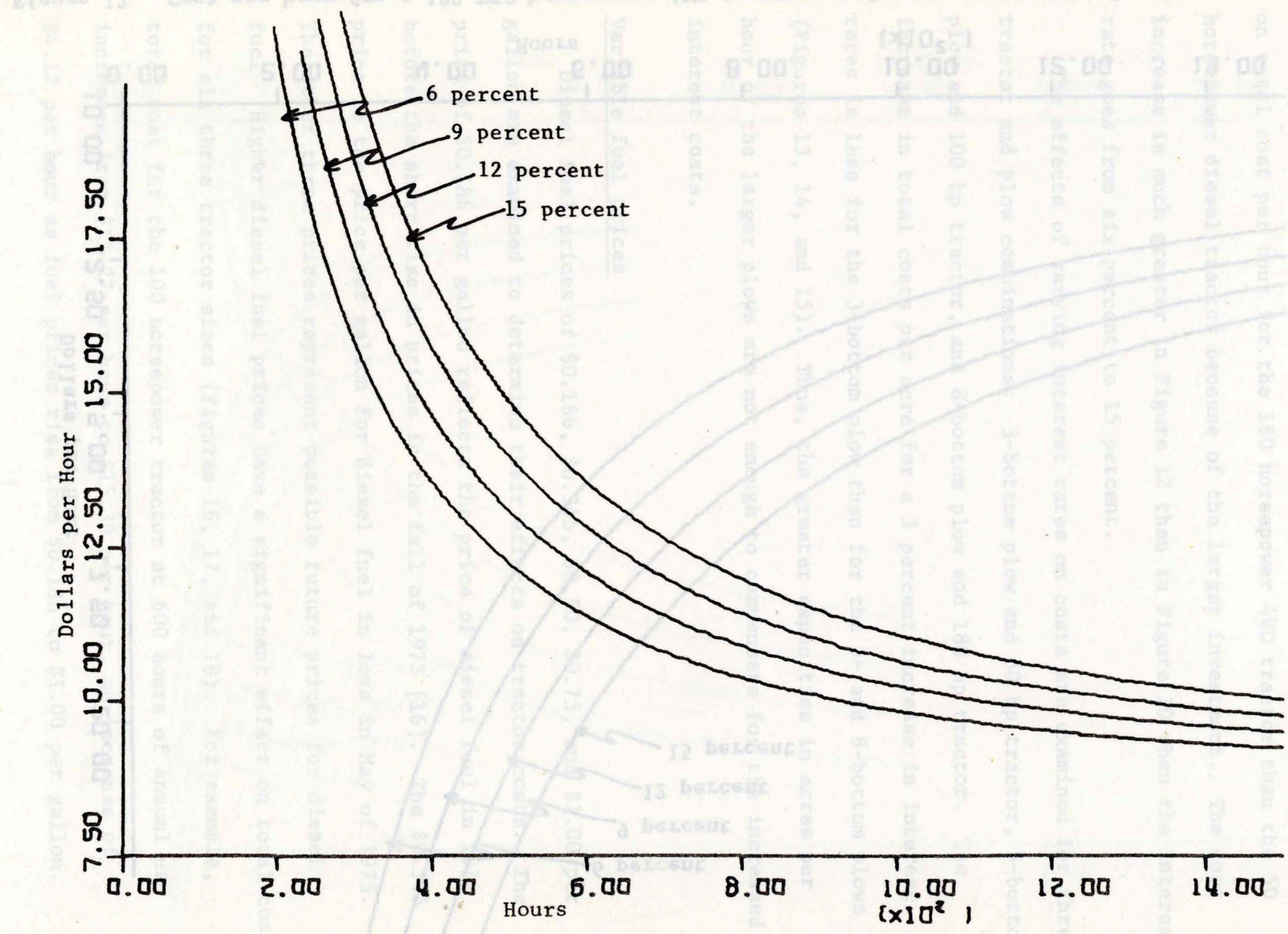

Figure 11. Cost per hour for a 100 PTO horsepower diesel tractor at four interest rate levels

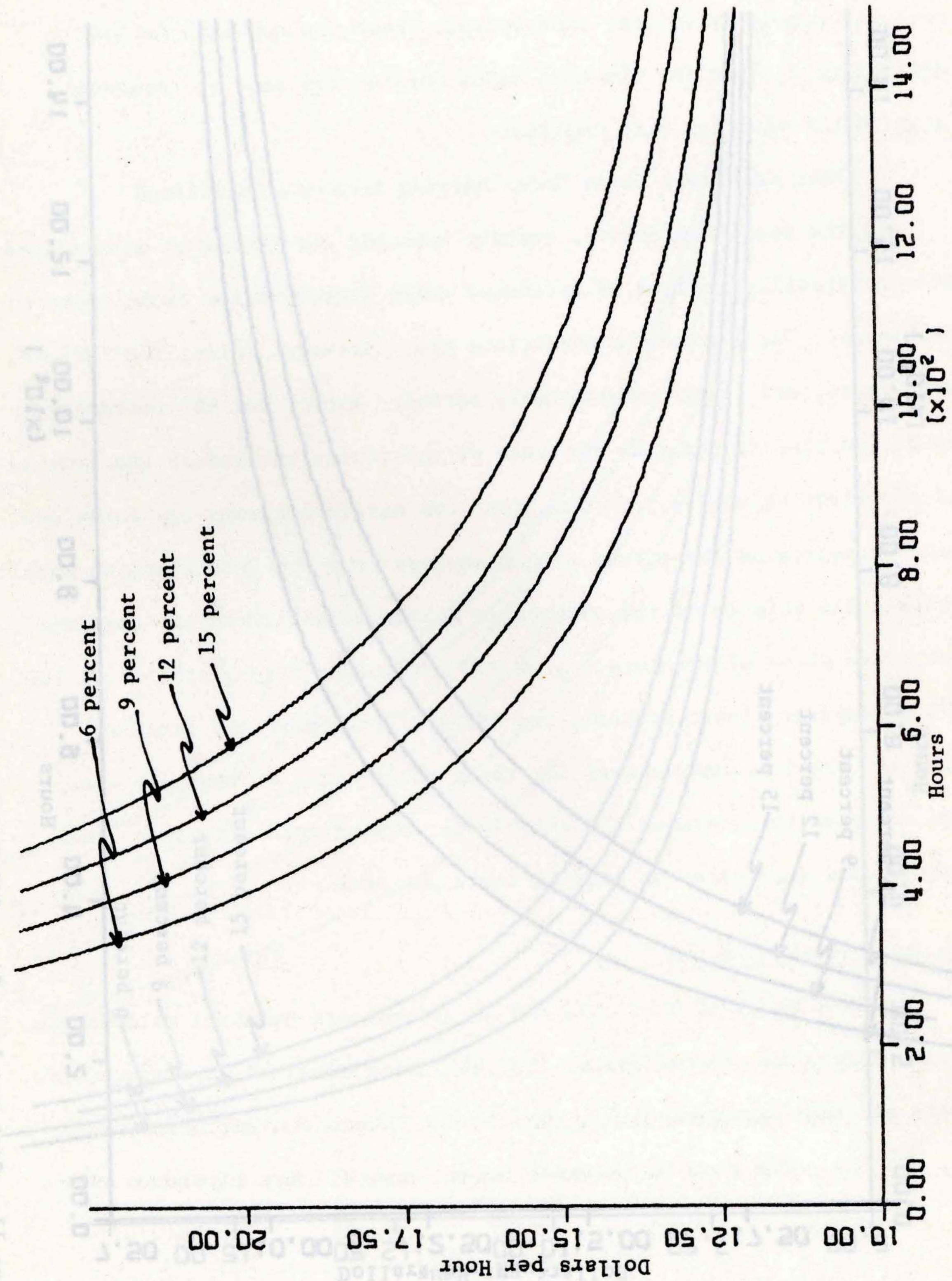

Figure 12. Cost per hour for a 180 PTO horsepower 4WD tractor at four interest rate levels

on total cost per hour for the 180 horsepower 4WD tractor than the 50 horsepower diesel tractor because of the larger investment. The cost increase is much greater in Figure 12 than in Figure 10 when the interest rate goes from six percent to 15 percent.

The effects of varying interest rates on costs are examined for three tractor and plow combinations: 3-bottom plow and 50 hp tractor, 5-bottom plow and 100 hp tractor, and 8-bottom plow and 180 hp tractor. The increase in total costs per acre for a 3 percent increase in interest rates is less for the 3-bottom plow than for the 5- and 8-bottom plows (Figures 13, 14, and 15). Thus, the greater capacities in acres per hour of the larger plows are not enough to compensate for the increased interest costs.

Variable fuel prices

Diesel fuel prices of $0.186, $0.345, $0.50, $0.75, and $1.00 per gallon are examined to determine their effects on tractor costs. The price of $0.186 per gallon reflects the price of diesel fuel in 1972 before the sharp rise in prices in the fall of 1973 [16]. The $0.345 price is the price per gallon for diesel fuel in Iowa in May of 1975. The other three prices represent possible future prices for diesel fuel. Higher diesel fuel prices have a significant effect on total costs for all three tractor sizes (Figures 16, 17, and 18). For example, total cost for the 100 horsepower tractor at 600 hours of annual use increases from $11.27 per hour to $15.39 per hour, an increase of $4.12 per hour as fuel prices rise from $0.186 to $1.00 per gallon.

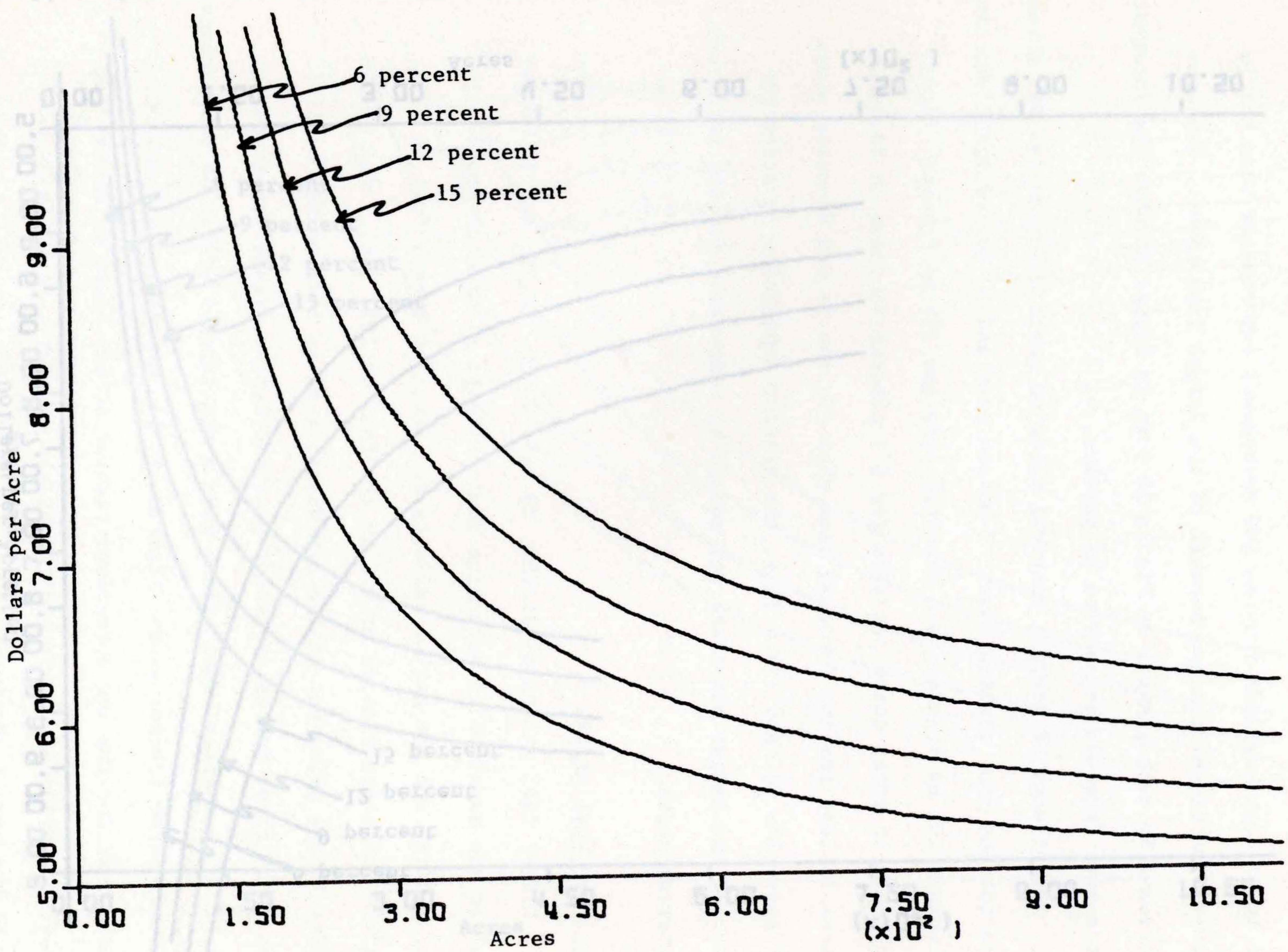

Figure 15. Cost per acre for an 8-16" moldboard plow at four interest rate levels

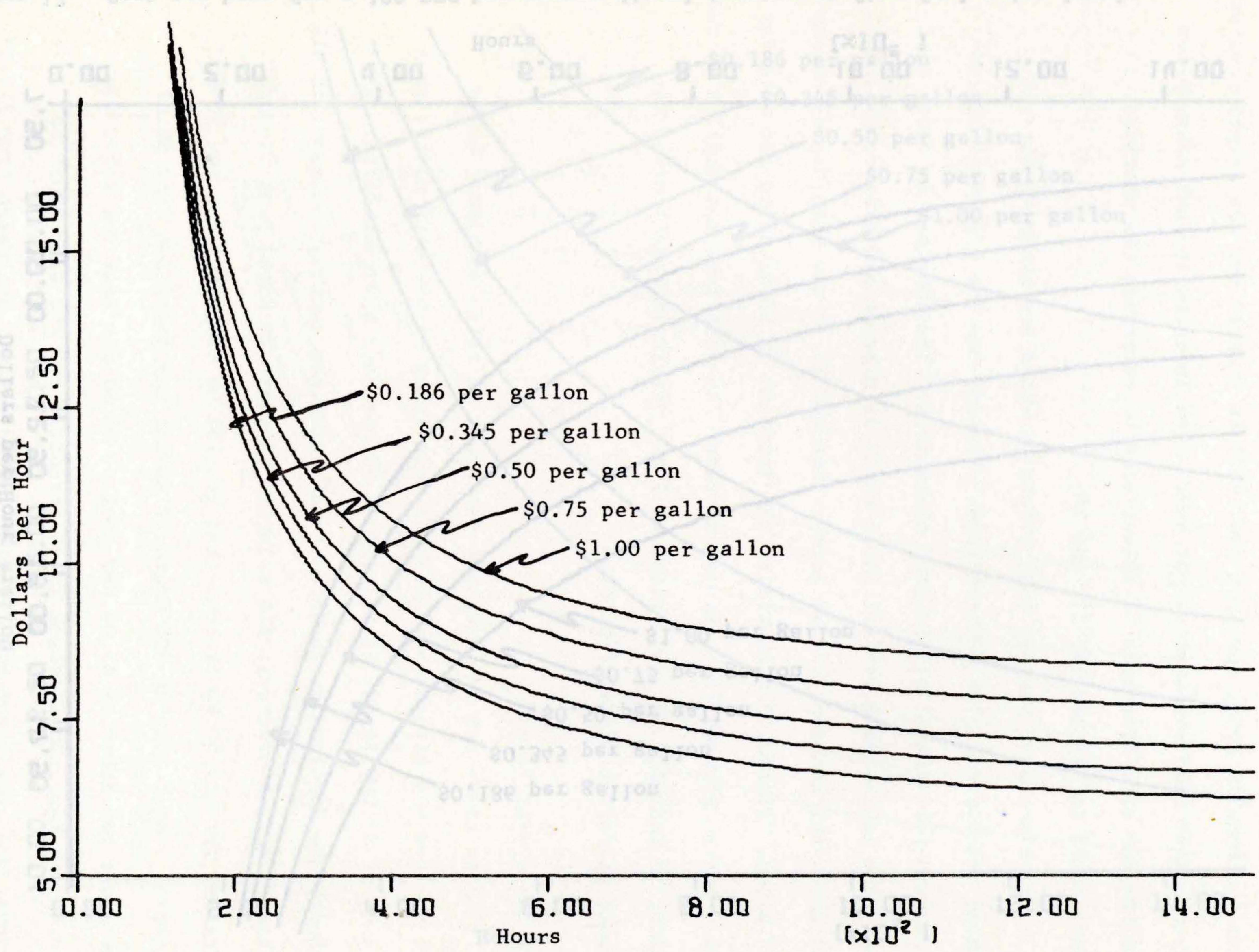

Figure 16. Cost per hour for a 50 PTO horsepower diesel tractor at five fuel price levels

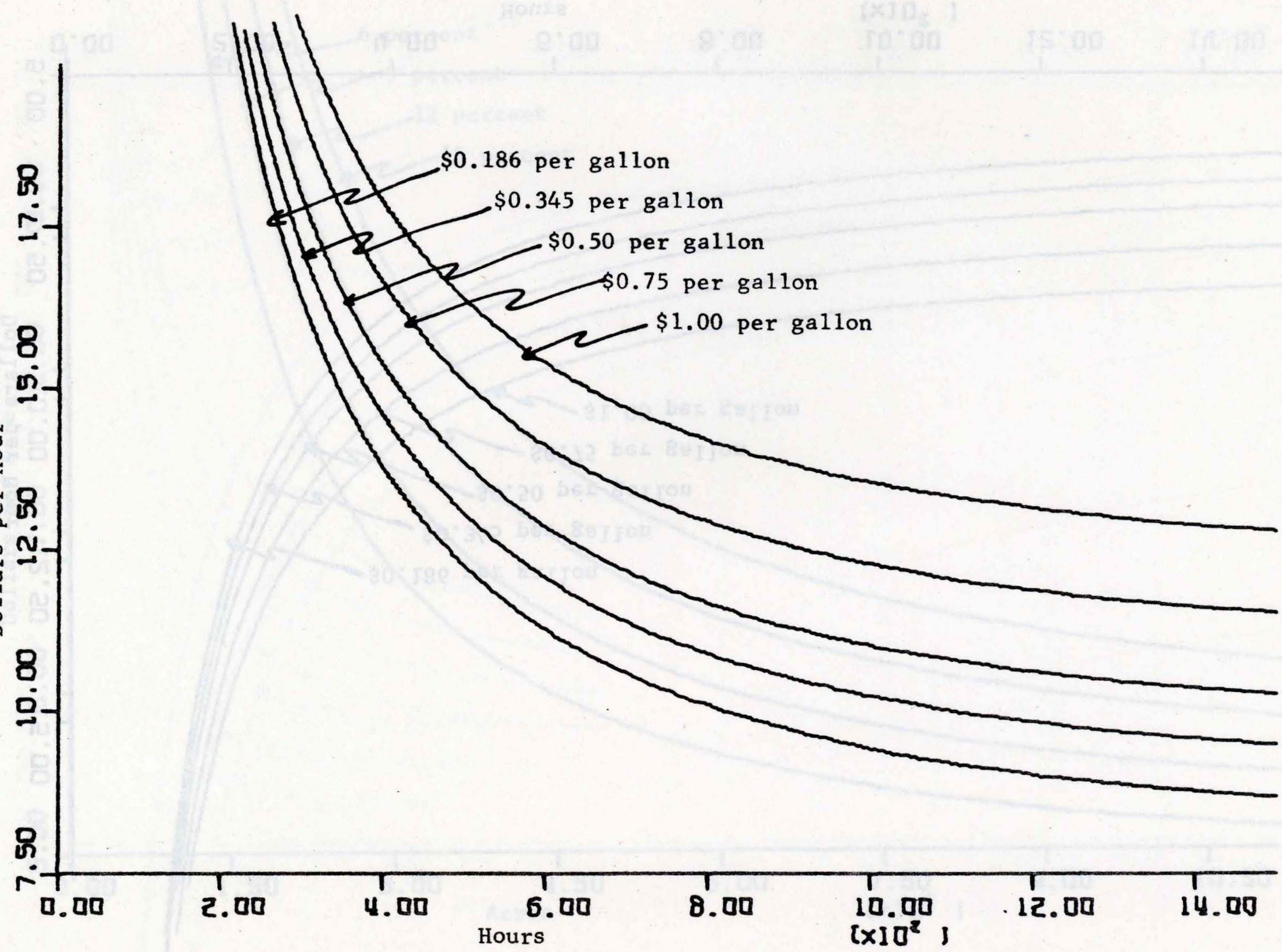

Figure 17. Cost per hour for a 100 PTO horsepower diesel tractor at five fuel price levels

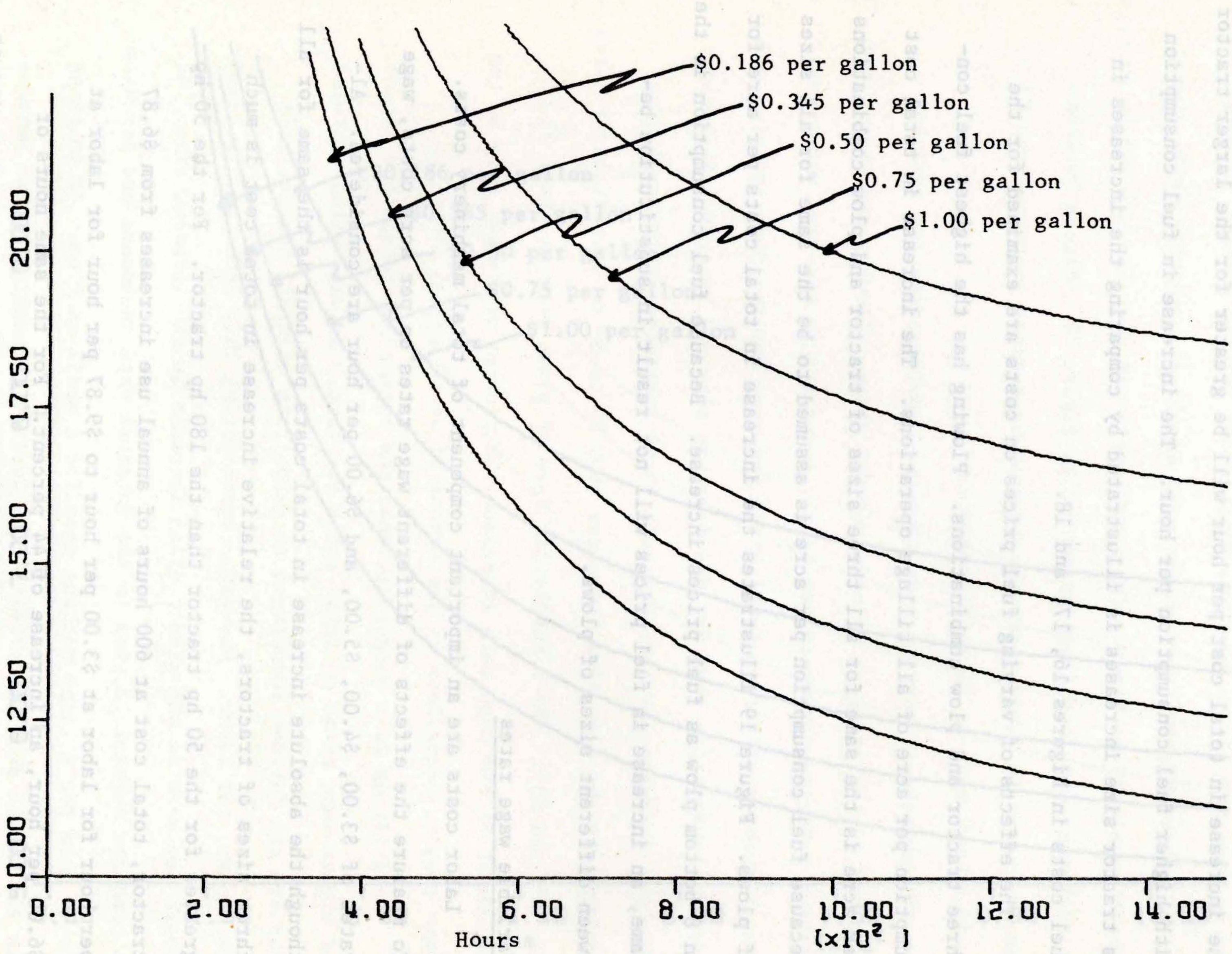

Figure 18. Cost per hour for a 180 PTO horsepower 4WD tractor at five fuel price levels

The increase in total cost per hour will be greater for the larger tractor with higher fuel consumption per hour. The increase in fuel consumption as tractor size increases is illustrated by comparing the increases in fuel costs in Figures 16, 17, and 18.

The effects of varying fuel prices on costs are examined for the three tractor and plow combinations. Plowing has the highest fuel consumption per acre of all tillage operations. The increase in total cost per acre is the same for all three sizes of tractor and plow combinations because fuel consumption per acre is assumed to be the same for all sizes of plows. Figure 19 illustrates the increase in total costs per acre for an 8-bottom plow as fuel prices increase. Because fuel consumption is the same, an increase in fuel prices will not result in substitution between different sizes of plows.

Variable wage rates

Labor costs are an important component of total machinery costs. To measure the effects of different wage rates on per acre costs, wage rates of \$3.00, \$4.00, \$5.00, and \$6.00 per hour are considered. Although the absolute increase in total costs per hour is the same for all three sizes of tractors, the relative increase in total cost is much greater for the 50 hp tractor than the 180 hp tractor. For the 50 hp tractor, total cost at 600 hours of annual use increases from \$6.87 per hour for labor at \$3.00 per hour to \$9.87 per hour for labor at \$6.00 per hour, an increase of 44 percent. For the same hours of annual use, the total cost for the 180 hp tractor increases from \$16.33

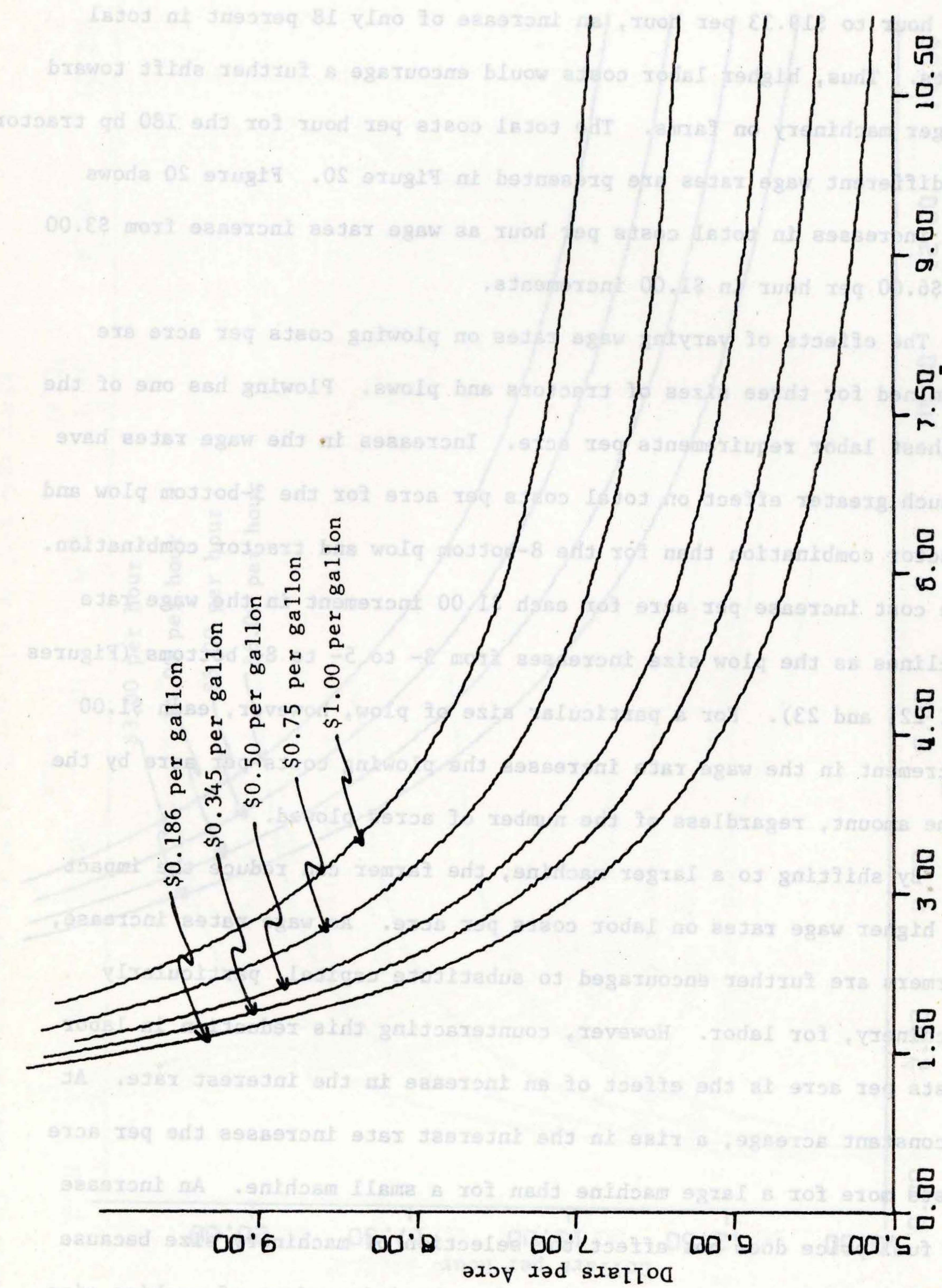

Figure 19. Cost per acre for an 8-16" moldboard plow at five fuel price levels

per hour to $19.33 per hour, an increase of only 18 percent in total costs. Thus, higher labor costs would encourage a further shift toward larger machinery on farms. The total costs per hour for the 180 hp tractor at different wage rates are presented in Figure 20. Figure 20 shows the increases in total costs per hour as wage rates increase from $3.00 to $6.00 per hour in $1.00 increments.

The effects of varying wage rates on plowing costs per acre are examined for three sizes of tractors and plows. Plowing has one of the highest labor requirements per acre. Increases in the wage rates have a much greater effect on total costs per acre for the 3-bottom plow and tractor combination than for the 8-bottom plow and tractor combination. The cost increase per acre for each $1.00 increment in the wage rate declines as the plow size increases from 3- to 5- to 8- bottoms (Figures 21, 22, and 23). For a particular size of plow, however, each $1.00 increment in the wage rate increases the plowing costs per acre by the same amount, regardless of the number of acres plowed.

By shifting to a larger machine, the farmer can reduce the impact of higher wage rates on labor costs per acre. As wage rates increase, farmers are further encouraged to substitute capital, particularly machinery, for labor. However, counteracting this reduction in labor costs per acre is the effect of an increase in the interest rate. At a constant acreage, a rise in the interest rate increases the per acre costs more for a large machine than for a small machine. An increase in fuel price does not affect the selection of machinery size because fuel consumption per acre is assumed to be independent of machine size.

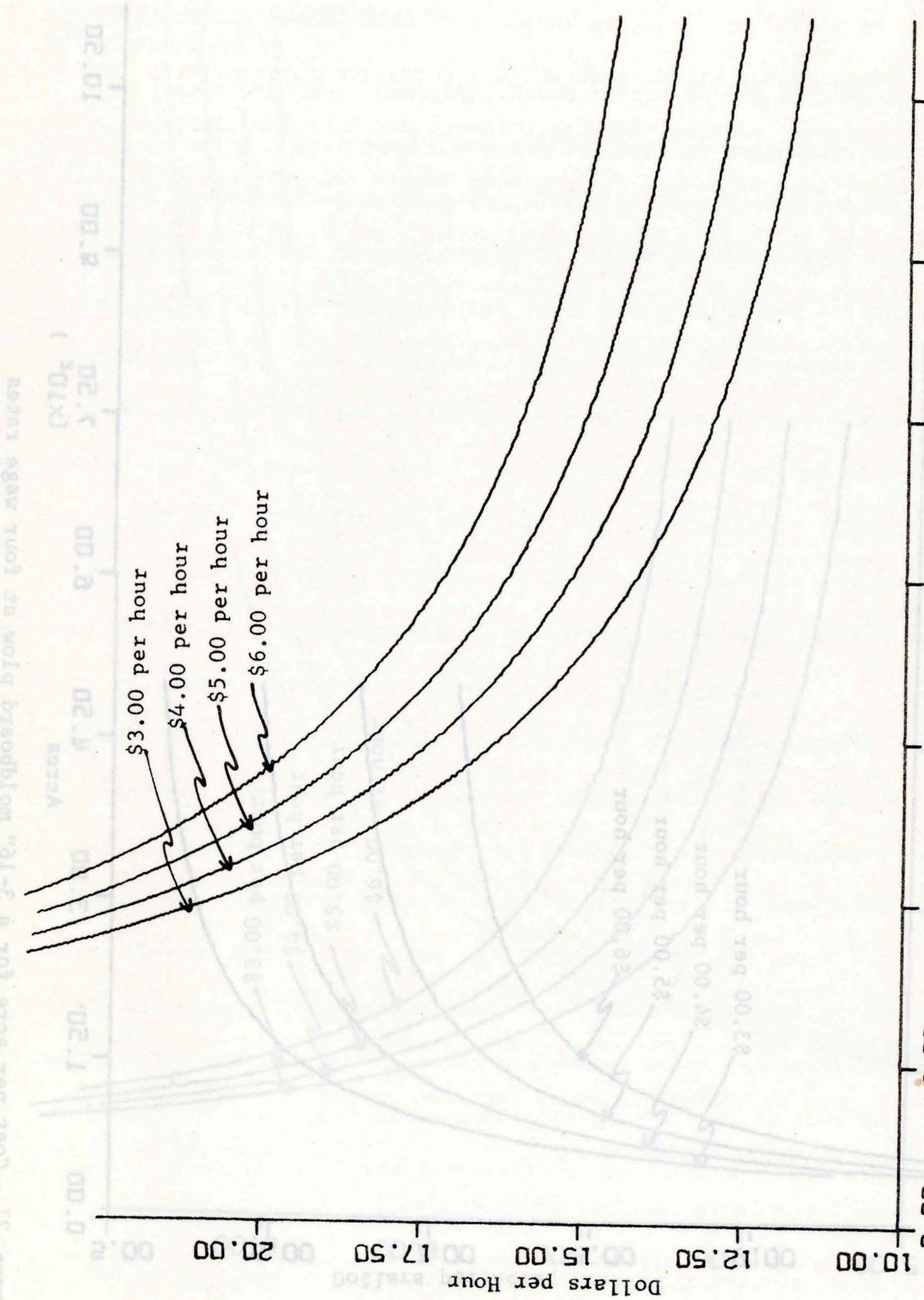

Figure 20. Cost per hour for a 180 PTO horsepower 4WD tractor at four wage rates

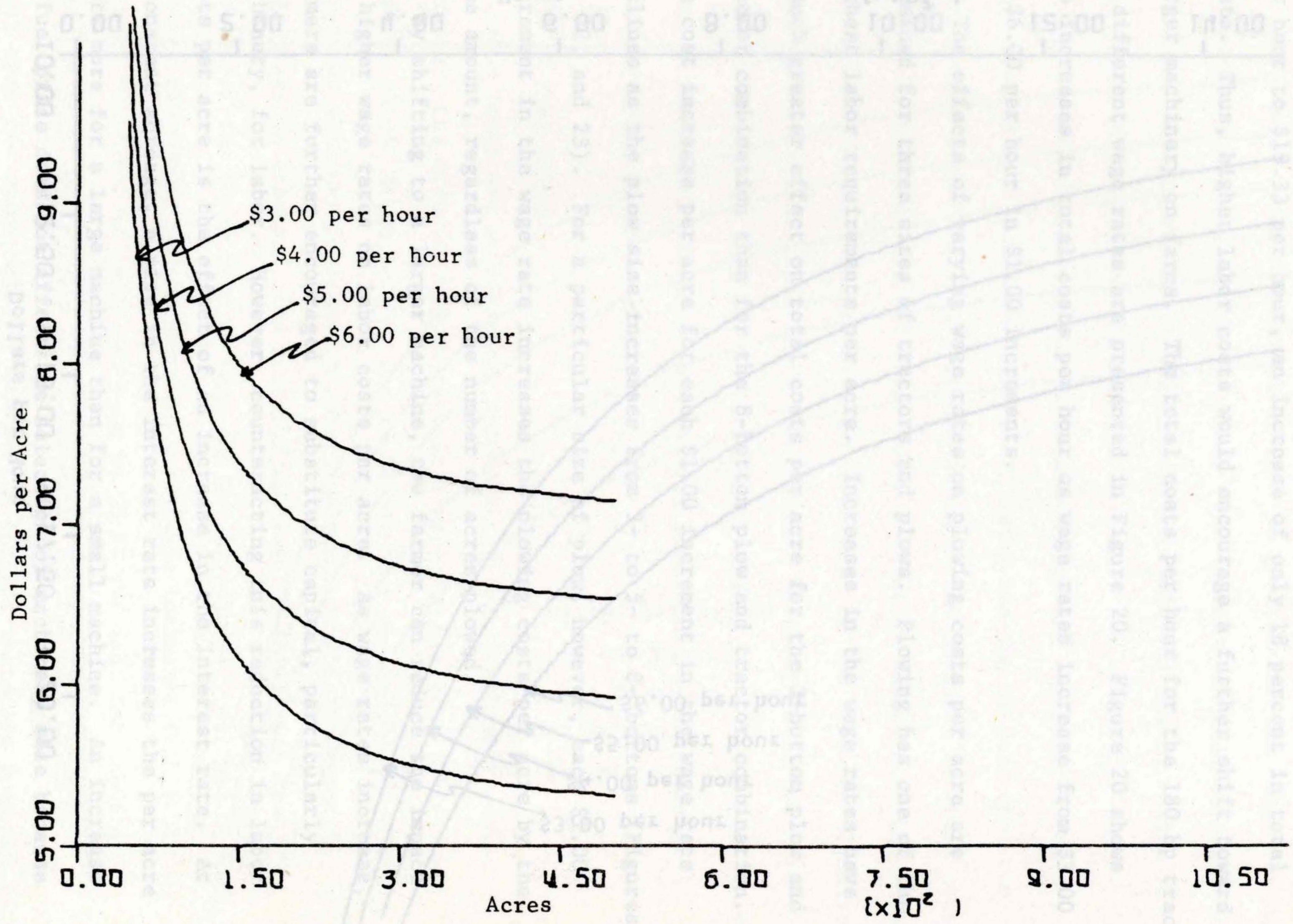

Figure 21. Cost per acre for a 3-16" moldboard plow at four wage rates

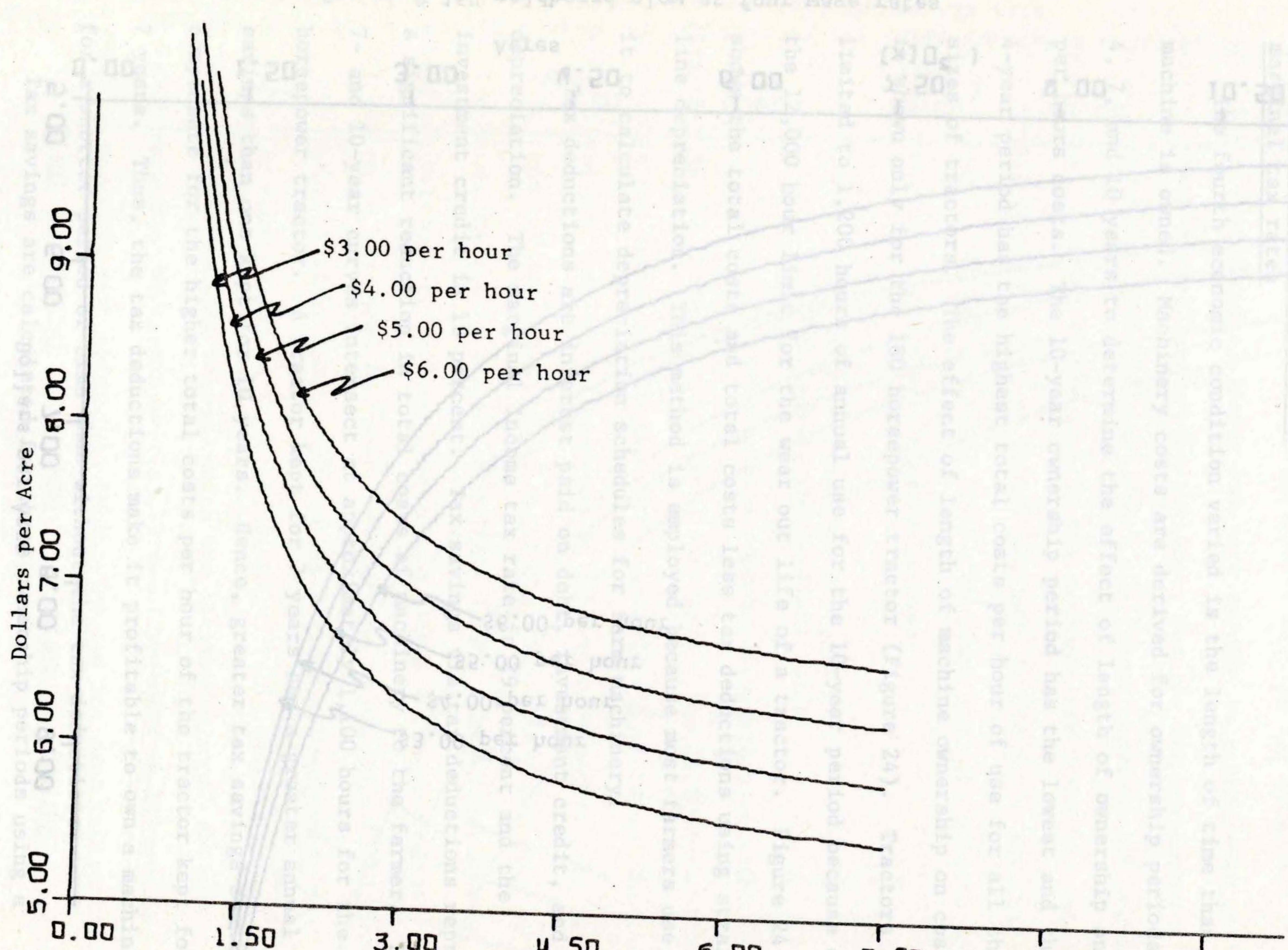

Figure 22. Cost per acre for a 5-16" moldboard plow at four wage rates

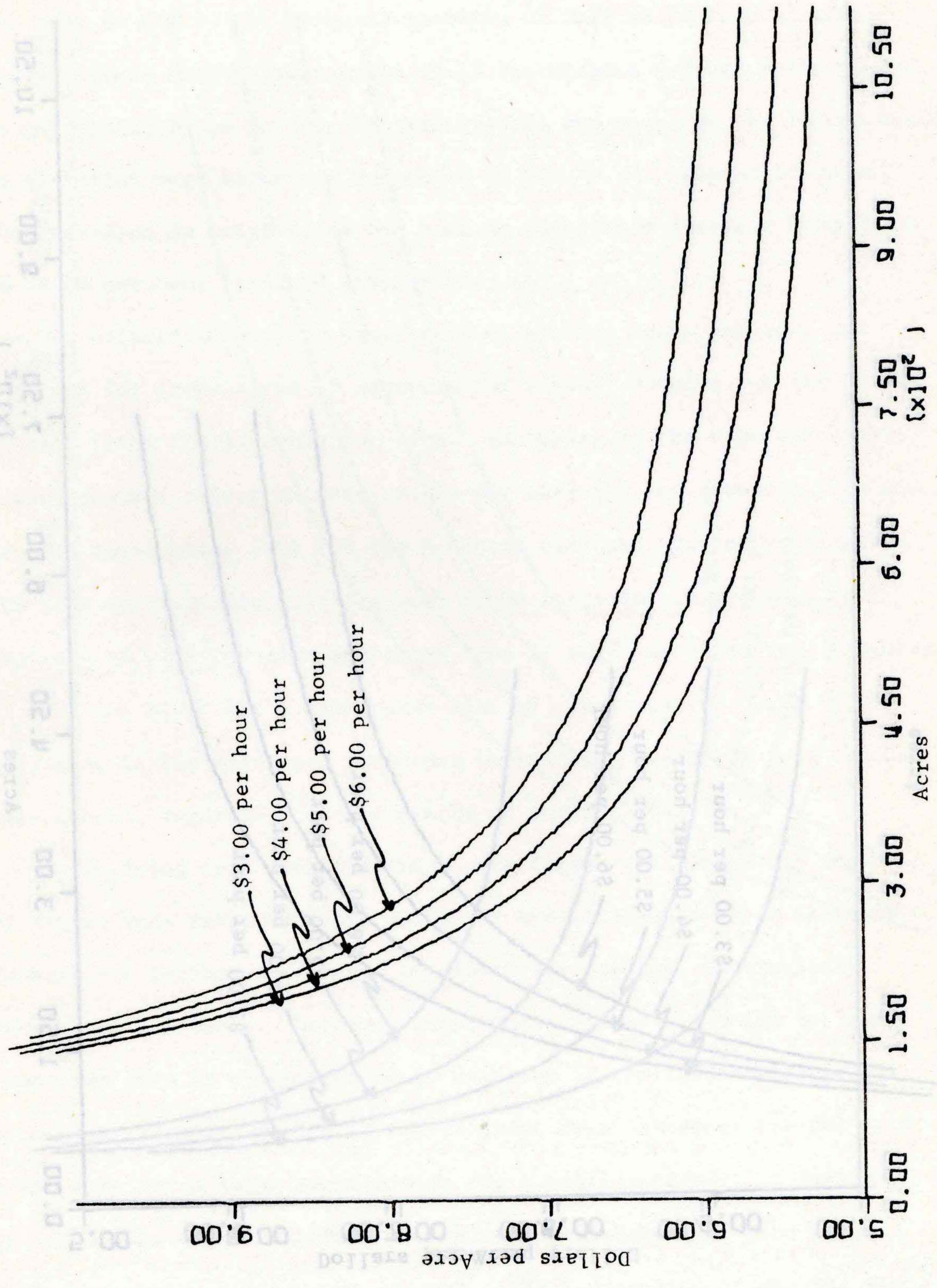

Figure 23. Cost per acre for an 8-16" moldboard plow at four wage rates

Variable ownership periods and marginal tax rates

The fourth economic condition varied is the length of time that a machine is owned. Machinery costs are derived for ownership periods of 4, 7, and 10 years to determine the effect of length of ownership on per hours costs. The 10-year ownership period has the lowest and the 4-year period has the highest total costs per hour of use for all three sizes of tractors. The effect of length of machine ownership on costs is shown only for the 180 horsepower tractor (Figure 24). Tractors are limited to 1,200 hours of annual use for the 10-year period because of the 12,000 hour limit for the wear out life of a tractor. Figure 24 shows the total costs and total costs less tax deductions using straight-line depreciation. This method is employed because most farmers use it to calculate depreciation schedules for farm machinery.

Tax deductions are interest paid on debt, investment credit, and depreciation. The marginal income tax rate is 29 percent and the investment credit is 10 percent. Tax savings via tax deductions represent a significant reduction in total costs of machinery to the farmer. The 7- and 10-year curves intersect at approximately 1,100 hours for the 180 horsepower tractor. A tractor kept for 7 years has a greater annual tax savings than one kept for 10 years. Hence, greater tax savings eventually compensate for the higher total costs per hour of the tractor kept for 7 years. Thus, the tax deductions make it profitable to own a machine for a shorter period of time than without the tax deductions.

Tax savings are calculated for three ownership periods using a marginal income tax rate of 39 percent. The total costs and total costs

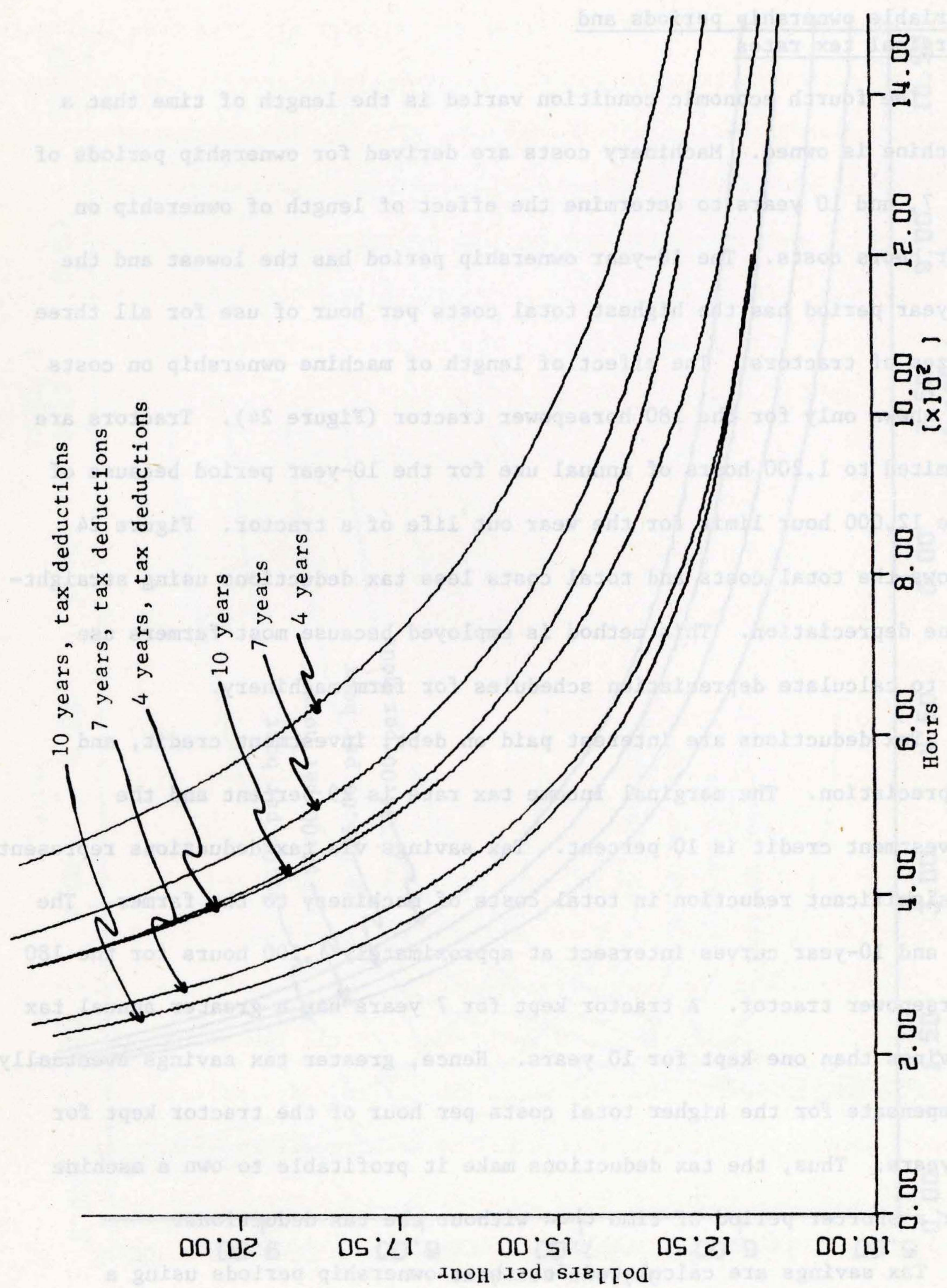

Figure 24. Cost per hour for a 180 PTO horsepower 4WD tractor for three ownership periods, with and without tax deductions at a 29 percent marginal income tax rate

less tax deductions for the 180 horsepower tractor are presented in Figure 25. The higher marginal income tax rate results in greater tax savings to the farmer for all three time periods. For the 180 horsepower tractor, the 10-year curve intersects with the 7-year curve at 900 hours of annual use. Because of the greater tax savings, the curve intersects at a lower number of hours of annual use than it did for a marginal tax of 29 percent. Hence, the level of the marginal tax rate affects the annual number of hours that a machine is used.

Machinery Combination Costs, Value of Yield Losses, and Combined Costs

The total costs for each machinery combination are calculated by aggregating the costs for each field operation. The individual field operations are summarized in the method of analysis section. The costs are derived for a series of acreages in 25-acre increments. The process is repeated for a particular machinery combination for each restriction on the number of suitable field days: average and average minus one standard deviation. The acreage limit for each machinery combination is dependent on these restrictions on suitable field days.

The value of yield losses from untimely field operations is calculated for corn priced at $2.00 per bushel. Yield losses include both planting and harvesting losses, which are determined simultaneously. These losses are calculated over a series of acreages in 25-acre increments for each machinery size combination and for each restriction on the number of suitable field days. The loss values are added to the total costs for the particular machinery combination to obtain the combined costs of machinery and yield losses.

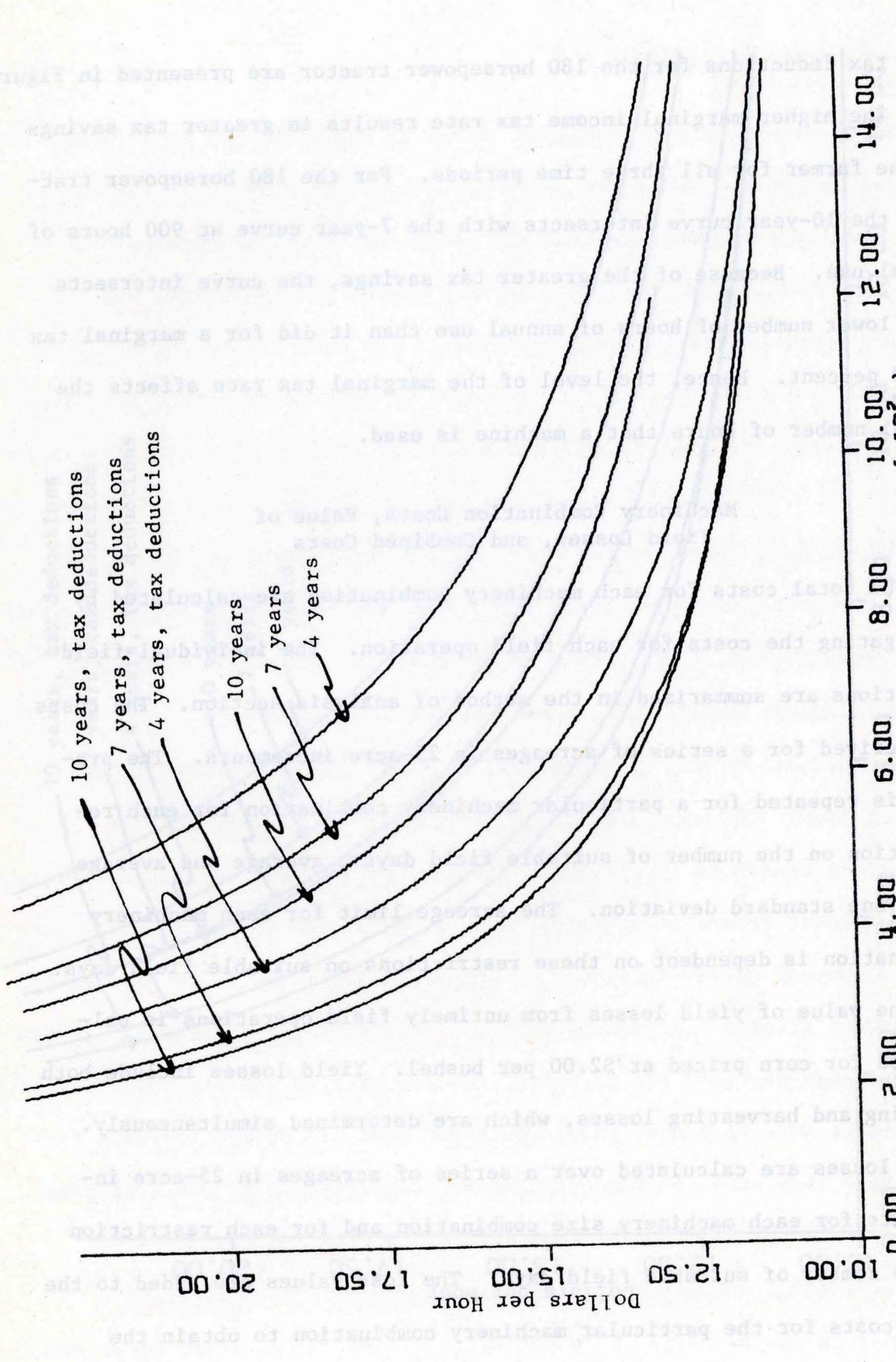

Figure 25. Cost per hour for a 180 PTO horsepower 4WD tractor for three ownership periods, with and without tax deductions at a 39 percent marginal income tax rate

Average number of suitable
field days

Total costs are calculated for different sizes of narrow- and wide-row machinery combinations (Table A.1). The total costs for the narrow-row and wide-row machinery combinations are compared separately. The wide-row machinery combinations are 4-38" row, 6-38" row, and 8-38" row equipment for planting and tillage, and 2-38" row, 3-38" row, and 4-38" row equipment for harvesting. The machinery costs per acre and the combined costs per acre are illustrated in Figure 26 for corn priced at $2.00 per bushel. The machinery cost curves is the lower set of curves in Figure 26. These lower smoothly declining curves are per acre costs of machinery alone and have the same general meaning as similar curves presented in previous figures. The upper set of curves in Figure 26 is the combined costs per acre of machinery and yield losses. In other words, the value of yield losses at each acreage level has been added to the per acre machinery costs (the smoothly declining bottom curves) to determine the three upper curves.

The combined cost curves are "step-like," that is, they have discrete jumps because at the acreages where the jumps occur there is a change in the yield loss. Because the yield loss data are for discrete time periods of a week or several weeks, there are significant differences in yield losses between periods. Yield losses on a per day basis would result in a smoother combined cost curve but would significantly increase the number of restrictions in the program. Also, day to day losses, particularly harvesting losses, are difficult to

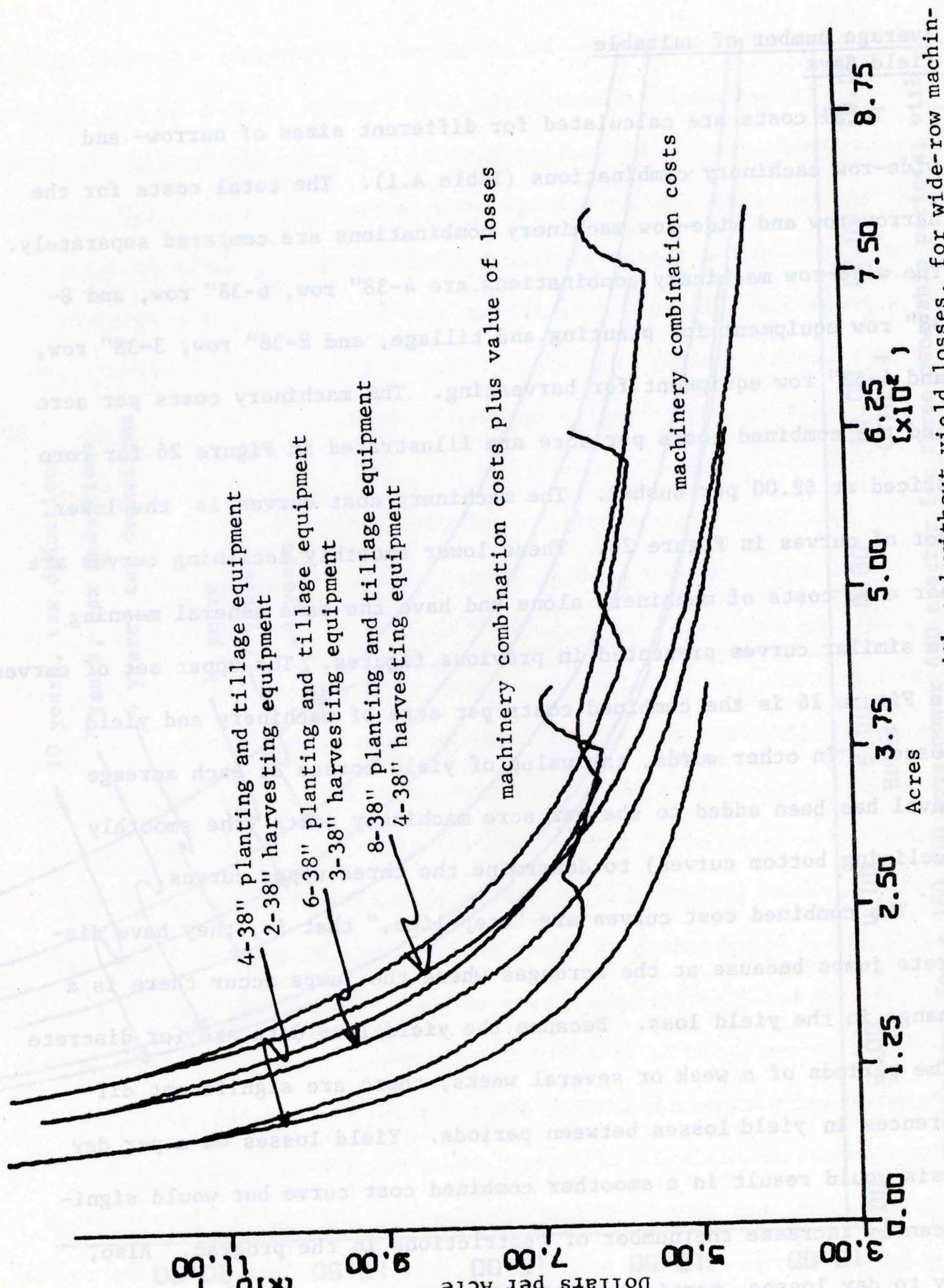

Figure 26. Machinery combination costs per acre, with and without yield losses, for wide-row machinery combinations, with corn at $2.00 per bushel, and average number of suitable field days

estimate. Thus, the combined cost curves are not smooth because of the discrete nature of the yield losses. For example, the 4-38" combined cost curve "turns upward" at between 250 and 275 acres because corn harvesting has shifted from the second to the third harvesting period. In moving from the second to third periods, yield losses increase from 3 to 6 bushels per acre. From 275 to 375 acres, the combined costs decline because machinery costs continue to decline and yield losses remain constant at 6 bushels per acre. From 375 to 400 acres, the 4-38" combined cost curve "turns up" sharply because planting losses of 4 bushels per acre are also incurred.

The machinery cost curves in Figure 26 do not intersect. Thus, the smaller machinery combination is cheaper up to its acreage limit when there are no yield losses. The acreage limit is reached when hours of total labor in the spring or fall, tractor hours in the spring or fall, or combine hours in the fall are exhausted. For the average number of suitable field days, the hours of fall harvesting labor limit the acreage farmed for the three machinery combinations. The acreage limits for the three machinery combinations are: 425 acres, 625 acres, and 800 acres. The machinery costs respectively for these acreage limits are: $47.94 per acre for the 4-38" row combination, $44.87 per acre for the 6-38" row combination, and $41.64 per acre for the 8-38" row combination. Hence, the larger machines do result in lower machinery costs per acre but only for larger acreages. Thus, there are economies of size for farm machinery.

The selection of machinery size on the basis of the combined cost curve is complicated for certain acreages. Up to 325 acres, the 4-38" row combination has the lowest costs per acre with corn priced at $2.00 per bushel (Figure 26). If corn is priced at a higher price, say $3.00 per bushel, the 4-38" row combination is the least cost only up to 250 acres [11]. The higher price for corn results in greater value of yield losses than for corn priced at $2.00 per bushel. Hence, the greater value in yield losses offsets to a greater extent the decline in machinery costs. From 375 to 600 acres, the 6-38" row and the 8-38" row combinations alternate as the least cost machinery combinations. Above 600 acres, the 8-38" row combination is least cost for corn priced at $2.00 per bushel.

The narrow-row machinery combinations have 6-30" row, 8-30" row, and 12-30" row planting and tillage equipment, and 3-30" row, 4-30" row, and 6-30" row harvesting equipment respectively. The machinery costs per acre and the combined costs per acre are illustrated in Figure 27 for $2.00 per bushel corn. The lower set of curves in Figure 27 is the per acre costs of machinery alone and the upper set of curves is the combined cost per acre of machinery and value of yield losses.

The machinery cost curves do not intersect. Thus, the smaller machinery combination is cheaper up to its acreage limit when there are no yield losses. The fall harvesting labor limits the acreage farmed for the three sizes of machinery combinations. These acreage limits are for continuous corn production. Farmers raising both corn and soybeans will have different acreage limits because field operations are not the

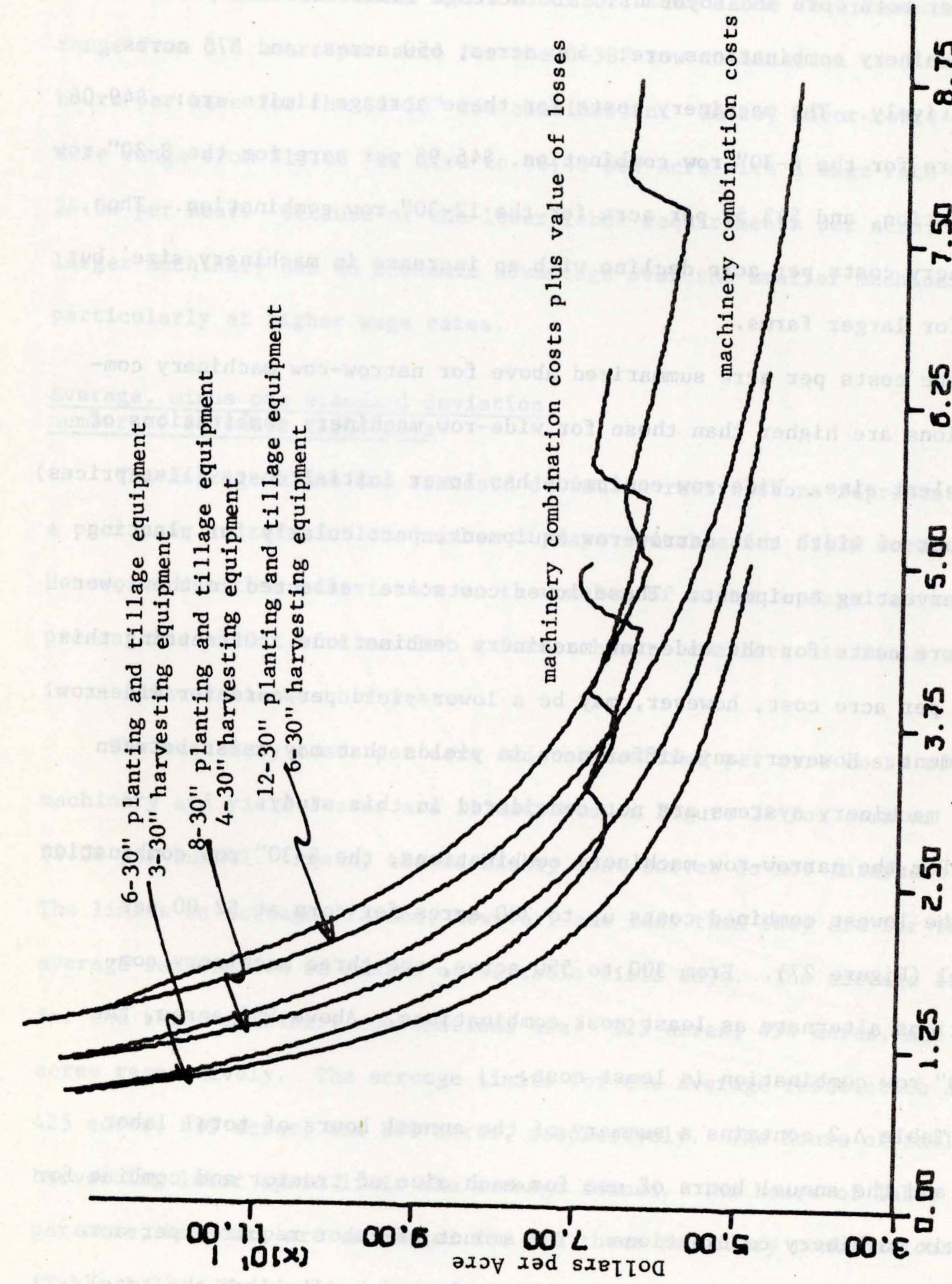

Figure 27 Machinery combination costs per acre, with and without yield losses, for narrow-row machinery combinations, with corn at $2.00 per bushel, and average number of suitable field days

same for both corn and soybeans. The acreage limits for the three narrow-row machinery combinations are: 500 acres, 650 acres, and 875 acres respectively. The machinery costs for these acreage limits are: $49.06 per acre for the 6-30" row combination, $46.98 per acre for the 8-30" row combination, and $43.51 per acre for the 12-30" row combination. Thus, machinery costs per acre decline with an increase in machinery size but only for larger farms.

The costs per acre summarized above for narrow-row machinery combinations are higher than those for wide-row machinery combinations of equivalent size. Wide-row equipment has lower initial costs (list prices) per foot of width than narrow-row equipment, particularly for planting and harvesting equipment. These lower costs are reflected in the lower per acre costs for the wide-row machinery combinations. Offsetting this lower per acre cost, however, may be a lower yield per acre for wide-row equipment. However, any differences in yields that may exist between these machinery systems are not considered in this study.

For the narrow-row machinery combinations, the 6-30" row combination has the lowest combined costs up to 300 acres for corn at $2.00 per bushel (Figure 27). From 300 to 550 acres, the three machinery combinations alternate as least cost combinations. Above 550 acres, the 12-30" row combination is least cost.

Table A.2 contains a summary of the annual hours of total labor used and the annual hours of use for each size of tractor and combine for the six machinery combinations. The amount of labor required per acre for each machinery combination can be estimated by dividing the total

acres farmed into the total hours of labor. The labor requirements range from 3.4 hours per acre for the 4-38" row combination to 1.6 hours per acre for the 12-30" row combination. Hence, labor costs per acre range from $13.60 per acre to $6.40 per acre with a wage rate of $4.00 per hour. Because of the lower labor requirements per acre, the larger machinery has an economic advantage over the smaller machinery, particularly at higher wage rates.

<u>Average, minus one standard deviation, number of suitable field days</u>

The average minus one standard deviation restrictions represents a poor year in terms of the number of days suitable for field work. Hence, we use this restriction on the number of suitable days to represent the amount of time that a farmer has to complete his field work in an unfavorable weather year.

The machinery costs per acre and the combined per acre costs of machinery and yield losses are illustrated in Figure 28 for corn at $2.00 per bushel. Again, the machinery cost curves do not intersect. The limits on acreages farmed, however, are less than they are for the average restriction on number of suitable field days. The acreage limits for the three machinery combinations are: 325 acres, 450 acres, and 600 acres respectively. The acreage limits for the average restriction are 425 acres, 625 acres, and 800 acres, respectively. The hours of fall harvesting labor again limit the acreage farmed. The hours of labor per acre, however, are unchanged for the three machinery combinations (Table A.2). The machinery costs for these acreage limits are respectively:

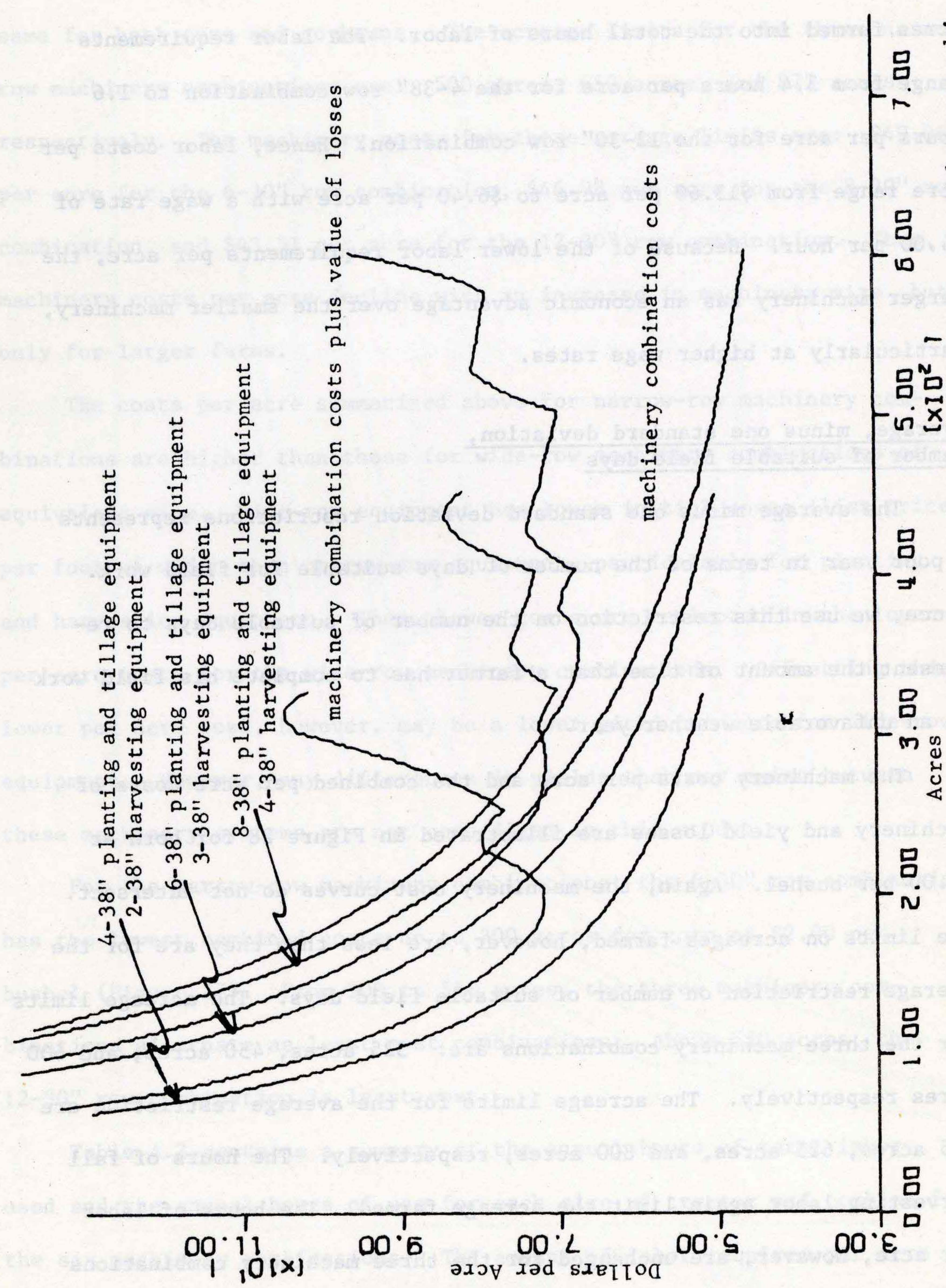

Figure 28. Machinery combination costs per acre, with and without yield losses, for wide-row machinery combinations, with corn at $2.00 per bushel, and average, minus one standard deviation, number of suitable field days

$51.85 per acre for the 4-38" row combination, $50.27 per acre for the 6-38" row combination, and $46.14 per acre for the 8-38" row combination. The costs are $4.00 to $5.00 per acre higher than they are for the average restriction because of the fewer number of acres farmed.

Up to 200 acres, the 4-38" row combination has the lowest combined costs per acre with corn at $2.00 per bushel (Figure 28). From 200 to 275 acres, the 6-38" row combination is least cost. Above 275 acres, the 8-38" row combination has the lowest costs per acre.

For narrow-row equipment, the machinery costs per acre and the combined costs per acre of machinery and yield losses are presented in Figure 29 for corn priced at $2.00 per bushel. The acreage limits for the three narrow-row machinery combinations are: 375 acres, 475 acres, and 650 acres, respectively. The acreage limits for the average restriction on number of suitable field days are: 500 acres, 650 acres, and 875 acres, respectively. Fall harvesting labor limits the acreage farmed. The hours per acre are unchanged, but the total hours of labor decline (Table A.2). The machinery costs for these acreage limits are respectively: $54.02 per acre for the 6-30" row combination, $52.67 per acre for the 8-30" row combination, and $49.01 per acre for the 12-30" row combination. The corresponding costs per acre for the average restriction are: $49.06 per acre, $46.98 per acre, and $43.51 per acre, respectively. In Figure 29, the 6-30" row combination has the lowest combined costs per acre up to 225 acres with corn at $2.00 per bushel. Between 225 acres and 300 acres, the 8-30" row combination has the

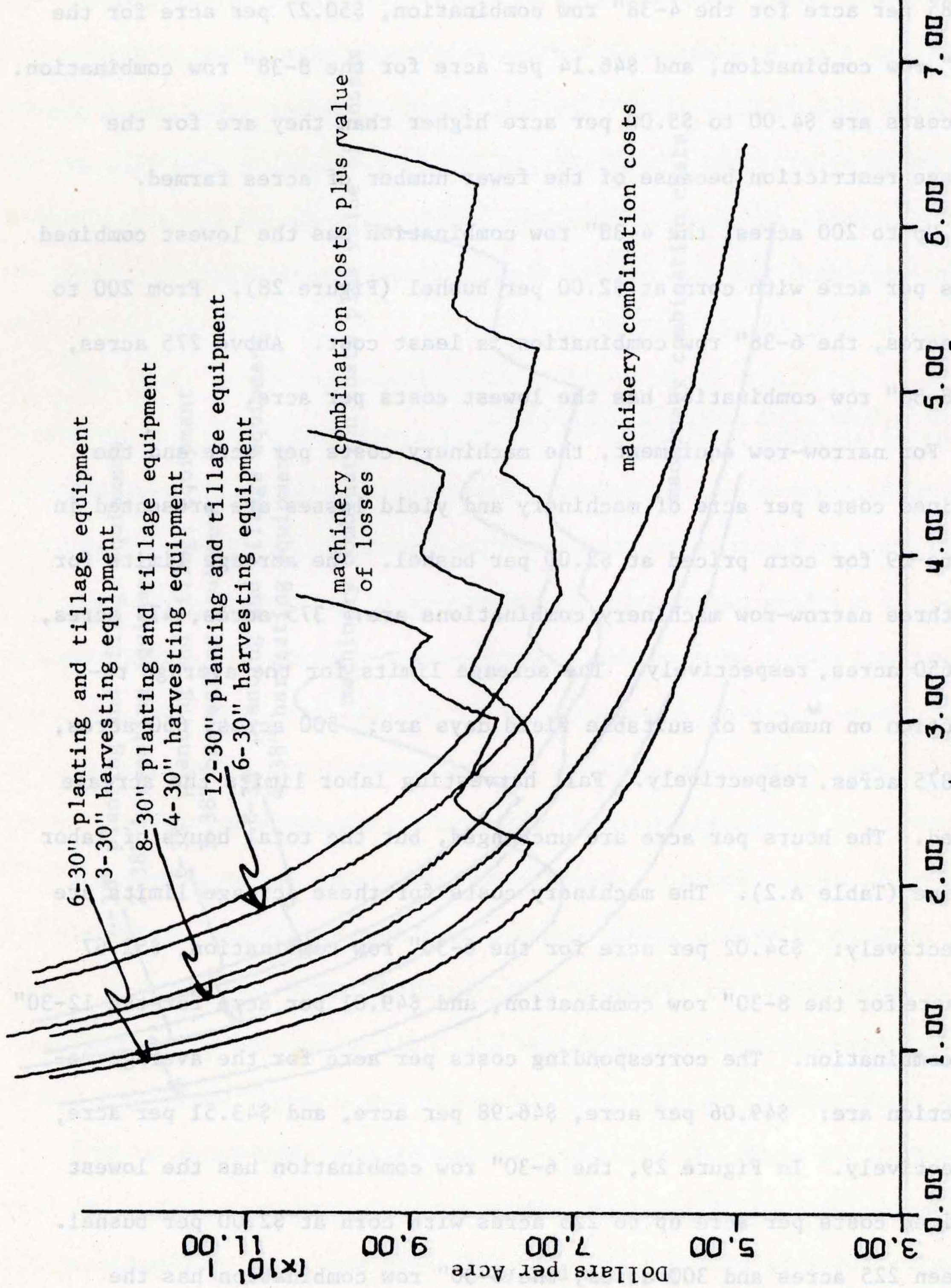

Figure 29. Machinery combination costs per acre, with and without yield losses, for narrow-row machinery combinations, with corn at $2.00 per bushel, and average, minus one standard deviation, number of suitable field days

least cost per acre. Above 300 acres, the 12-30" row combination has the lowest combined costs per acre.

The average minus one standard deviation restriction on the number of suitable field days results in a reduction in acres which could be farmed for the different machinery combinations. The acreage reductions are: 100 and 125 acres for the 4-38" and 6-30" row combinations, 175 acres for the 6-38" and 8-30" row combinations, and 200 and 225 acres for the 8-38" and 12-30" row combinations. Weather certainly has an impact on the number of acres farmed. Hence, in addition to machinery costs, weather is an important consideration in machinery selection.

SUMMARY AND CONCLUSIONS

The structure of American agriculture is continually changing. Capital inputs, particularly machinery and fertilizer, have substituted for labor and land. The average farm size in Iowa and the United States is increasing in terms of both acres and farm income. As farm size has increased, farm machinery also has increased in size. Thus, there is a need to determine the costs for these new sizes of machines. Also, machinery costs have risen dramatically in the last several years because of high inflation rates. There also is a need to determine the effects of higher wage rates, interest rates, and fuel prices on machinery operating costs.

The overall purpose of this study is to determine the economies of size of farm machinery in central Iowa. The specific objectives of the study are: (a) to derive the total (fixed and variable) costs for farm machinery for a given set of economic conditions; (b) to derive the total (fixed and variable) costs for selected farm machinery under varying economic conditions; and (c) to derive total machine costs, the value of yield losses, and the combined costs per acre for different sizes of machinery combinations for two different restrictions on the number of suitable field days.

The fixed or ownership costs of farm machinery consist of depreciation, interest on investment, sales and property taxes, insurance, and housing. The variable or operating costs include repairs and maintenance, fuel, engine oil and filters, and labor. Tax savings are

calculated for these tax deductions: interest paid on debt, investment credit, and depreciation. The interest rate, the fuel price, the wage rate, the length of ownership, and the marginal income tax rate are varied separately for the second objective above.

The number of suitable field days per week are taken from records kept by the Iowa Crop and Livestock Reporting Service for the years 1958 to 1974. The average number of days suitable for field work is calculated for each climatic week. One standard deviation is subtracted off the average to obtain a range in the number of suitable field days. The total hours of labor per week are determined by multiplying the total hours of labor available per day times the number of suitable days. The total amount of labor available per day consists of the operator and a 15-year-old son on a part-time basis and one hired employee on a full-time basis. The hours of machine time per week for each tractor and combine are calculated by multiplying the hours available per day times the number of suitable field days. The weekly hours of labor and machine time are aggregated into planting and harvesting periods.

Yield losses in terms of bushels per acre are determined for five planting periods and three harvesting periods. The yield losses increase progressively over the later periods. Value of yield losses are calculated for corn priced at $2.00 per bushel.

Two sets of machinery combinations are analyzed. The narrow-row machinery combinations are 6, 8, and 12 row planting and tillage equipment, and 3, 4, and 6 row harvesting equipment. The wide-row machinery combinations are 4, 6, and 8 row planting and tillage equipment, and 2, 3, and 4 row harvesting equipment.

The variable and fixed costs per hour are determined for utility model gasoline and diesel tractors, standard and four-wheel-drive (4WD) tractors. Costs per acre are calculated for moldboard plows, disk harrows, rotary hoes, and row-crop sweep cultivators, six sizes of corn planters with fertilizer and insecticide attachments , and combines with corn heads.

The effects of changes in economic conditions are compared for three sizes of tractors: 50 horsepower, 100 horsepower, and 180 horsepower. Plow and tractor combinations for these three sizes of tractors are analyzed to determine the effects of varying interest rates, fuel prices, and wage rates on plowing costs per acre. Interest rates of 6, 9, 12, and 15 percent are analyzed to determine the effects of different rates on machinery costs. Total machinery costs increase with a rise in the interest rate. The rise in the interest rate, however, has a greater effect on the total cost per hour for the 180 horsepower tractor than the 50 horsepower tractor because of the larger investment. Similarly, the rise in interest rates results in a larger increase in costs per acre for the 8-bottom plow then for the 3-bottom plow.

Diesel fuel prices of $0.186, $0.345, $0.50, $0.75, and $1.00 per gallon are analyzed to determine the effects of varying fuel prices on machinery costs. Higher diesel fuel prices increase total costs per

hour for all three tractor sizes. However, the increase is greatest for large tractors because of higher fuel consumption per hour.

Labor costs are an important component of total costs. Hence, the effects of different labor costs are analyzed. Wage rates of $3.00, $4.00, $5.00, and $6.00 per hour are analyzed in relation to total costs. Although the absolute increase in total cost per hour is the same for all three sizes of tractors, the relative increase in total cost is much greater for the 50 horsepower tractor than the 180 horsepower tractor. Higher wage rates have a greater effect on total costs per acre for the 3-bottom plow and tractor combination than the 8-bottom plow and tractor combination. Thus, higher labor costs are expected to favor the shift toward larger machinery.

The length of ownership of a machine is varied to determine the effect that this variable has on total machinery costs. Ownership periods of 4, 7, and 10 years are examined. The analysis shows that tax deductions make it profitable to own a machine for a shorter period of time than if the tax deductions did not exist.

The total costs for each of the six machinery combinations are calculated by aggregating the total costs for each field operation. The combined costs per acre are obtained by adding the value of yield losses per acre to the machinery costs. (In other words, the value of yield losses is considered a cost.) Yield losses are expected when the number of acres operated by a tractor of given size and its machine complement is increased sufficiently to cause untimeliness of field operations.

For the average restriction in number of days suitable for field work, the acreages farmed for the six machinery combinations are limited by the hours of fall harvesting labor. For the three wide-row combinations, the number of acres farmed are 425, 625, and 800 acres respectively. The machinery costs at these acreages are: $47.94 per acre for the 4-38" row combination, $44.87 per acre for the 6-38" row combination, and $41.64 per acre for the 8-38" row combination. The acreages which could farmed for the three narrow-row machinery combinations are 500, 650, and 875 acres respectively. The machinery costs for these acreages are $49.06 per acre for the 6-30" row combination, $46.98 per acre for the 8-30" row combination, and $43.51 per acre for the 12-30" row combination. Hence, machinery costs per acre decline with an increase in machinery size, but only for larger acreages. Thus, there are economies of size for farm machinery.

The machinery combination cost curves do not intersect for either the wide-row or narrow-row combinations. Thus, the smaller machinery combination is lower cost up to its acreage limit when there are no yield losses. This is not, however, the situation for the combined costs when the value of yield losses is considered as a cost and is added to machinery costs. For corn priced at $2.00 per bushel, the 4-38" row combination is least cost up to 325 acres. From 375 to 600 acres, the 6-38" row and the 8-38" row combinations alternate as least cost machinery combinations. Above 600 acres, the 8-38" row combination has the lowest costs per acre. A similar situation exists for the

narrow-row machinery combinations. The $3.00 price per bushel for corn affects these acreages somewhat but leaves the general relationships the same [11].

The least cost machinery combination for a particular acreage is also the maximum profit machinery combination if the only farm enterprise is corn production. If there are other enterprises, however, then the returns to labor and capital from these enterprises may result in a different optimal size machinery combination. Also, the level of "off-farm" employment income may influence machinery size. If the farm operator can earn more than $4.00 per hour for his labor from other enterprises or from off-farm employment, then a larger size machinery combination may be more profitable.

The labor requirements per acre in corn production range from 3.4 hours per acre for the 4-38" row combination to 1.6 hours per acre for the 12-30" row combination. With a wage rate of $4.00 per hour, the labor costs per acre range from $13.60 per acre for the 4-38" row combination to $6.40 per acre for the 12-30" row combination. Because of the lower labor requirements per acre, the larger machinery has an economic advantage over the smaller machinery, particularly at higher wage rates.

For the average minus one standard deviation restriction on number of suitable field days, the acreages farmed are also limited by the hours of fall harvesting labor. This restriction results in a reduction in acres farmed for the different machinery combinations. The acreages are reduced to 325 and 375 acres for the 4-38" an 6-30" row combinations, 450 and 475 acres for the 6-38" and 8-30" row combinations, and 600 and 650 acres for the 8-38" and 12-30" row combinations, respectively. The machinery combination costs for these acreage limits are $4.00 to $5.00 per acre higher than they are for the average weather restriction because of the smaller number of acres farmed. With corn at $2.00 per bushel, the 4-38" row combination is least cost. Above 275 acres the 8-38" row combination has the lowest combined costs per acre. These acreages are less than they are for the average weather restriction. A similar reduction in acreage limits occurs for the narrow-row combinations. Hence, weather has a significant impact on the number of acres farmed and deserves important consideration in machinery selection. Weather is also important in determining machinery and acreage combinations which result in lowest per acre costs of production.

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APPENDIX

Table A.1. Machinery combinations

Machine	Wide row equipment: Machine size I	III	V	Tractor or engine horsepower I	III	V[a]	Narrow row equipment: Machine size II	IV	VI	Tractor or engine horsepower II	IV	VI[a]
Disk harrow	14'	22'	26'	80	125	150	18'	22'	30'	100	125	180
Moldboard plow	4-16"	6-16"	7-16"	80	125	150	5-16"	6-16"	8-16"	100	125	180
Anhydrous ammonia applicator	5-38"	7-38"	9-38"	80	100	125	7-30"	9-30"	9-30"	100	125	125
Sprayer	21'	35'	47'	50	80	80	28'	35'	47'	50	80	80
Planter	4-38"	6-38"	8-38"	50	80	100	6-30"	8-30"	12-30"	50	80	100
Rotary hoe	4-38"	6-38"	8-38"	80	100	125	6-30"	8-30"	12-30"	80	100	125
Cultivator	4-38"	6-38"	8-38"	80	100	125	6-30"	8-30"	12-30"	80	100	125
Combine	2-38"	3-38"	4-38"	75	100	120	3-30"	4-30"	6-30"	100	120	145
Gravity-flow wagon	2-165 bu.	3-225 bu.	3-325 bu.	50	100	125	3-165 bu.	3-250 bu.	3-375 bu.	80	100	125

[a]The 150 horsepower tractor is a standard two-wheel drive tractor, whereas the 180 horsepower tractor is a four-wheel drive tractor.

Table A.2. Annual hours of total labor used and annual hours of use for each size of tractor and combine for each of the machinery combinations [11].

Machinery combination	Tractor size horsepower	Combine engine size horsepower	Hours of annual use for the two different restrictions on the number of suitable field days: Average	Average minus one standard deviation
4-38" planting and tillage equipment	50		413.1	315.9
and 2-38" harvesting equipment	80		574.6	439.4
		75	283.3	216.7
Total labor			1437.9	1099.7
Total acres			425	325
Hours per acre			3.4	3.4
6-30" planting and tillage equipment	50		126.0	94.5
and 3-30" harvesting equipment	80		438.0	328.5
	100		410.0	307.5
		100	277.8	208.3
Total labor			1417.2	1062.9
Total acres			500	375
Hours per acre			2.8	2.8
6-38" planting and tillage equipment	80		125.0	90.0
and 3-38" harvesting equipment	100		532.5	383.4
	125		335.0	241.2
		100	284.1	204.6
Total labor			1448.0	1042.7
Total acres			625	450
Hours per acre			2.3	2.3

Table A.2. Continued

Machinery combination	Tractor size horsepower	Combine engine size horsepower	Hours of annual use for the two different restrictions on the number of suitable field days: Average	Average minus one standard deviation
8-30" planting and tillage equipment	80		127.4	93.1
and 4-30" harvesting equipment	100		442.0	323.0
	125		436.8	319.2
		120	282.6	206.5
Total labor			1464.2	1070.3
Total acres			650	475
Hours per acre			2.2	2.2
8-38" planting and tillage equipment	80		44.8	33.6
and 4-38" harvesting equipment	100		76.8	57.6
	125		521.6	391.2
	150		374.4	280.8
		120	275.9	206.9
Total labor			1461.8	1096.6
Total acres			800	600
Hours per acre			1.8	1.8
12-30" planting and tillage equipment	80		49.0	36.4
and 6-30" harvesting equipment	100		73.5	54.6
	125		539.0	400.4
	180		339.5	252.2
		145	273.4	203.1
Total labor			1444.5	1073.0
Total acres			875	650
Hours per acre			1.6	1.6

Table A.3. The size, price[a] and average fuel consumption per hour for farm tractors [11]

Tractor	Size PTO horsepower	Price dollars	Fuel consumption gallons per hour
Utility model gas tractors	35	5,700	2.10
	50	7,750	3.00
	60	9,150	3.60
	70	10,500	4.20
Utility model diesel tractors	35	6,550	1.54
	50	8,700	2.20
	60	10,100	2.64
	70	11,500	3.08
Standard diesel tractors	80	16,200	3.52
	100	18,400	4.40
	125	21,200	5.50
	150	24,000	6.60
4WD diesel tractors	150	28,000	6.60
	180	31,100	7.92

[a] Farm machinery manufacturers list prices for 1974-75.

Table A.4. The size, price[a], acres per hour, fuel consumption per acre, and labor efficiency for combines to harvest corn [2, 3, 8]

Machine	Engine horsepower	Price dollars	Corn head size	Price dollars	Acres per hour	Fuel consumption gallons per acre	Labor efficiency percent
Separator or base unit	gas 75	16,600	2-38"	2,850	1.5	2.35	116.0
Separator or base unit	diesel 100	22,200	3-30"	4,525	1.8	1.60	116.0
			3-38"	4,775	2.2	1.60	116.0
Separator or base unit	diesel 120	27,000	4-30"	5,800	2.3	1.60	116.0
			4-38"	6,100	2.9	1.60	116.0
Separator or base unit	diesel 145	31,600	6-30"	8,050	3.2	1.60	116.0
			6-38"	8,850	3.9	1.60	116.0
			8-30"	10,700	3.8	1.60	116.0

[a] Farm machinery manufacturers list prices for 1974-75.

Table A.5. The size, price[a], tractor size, acres per hour, fuel consumption per acre, and labor efficiency for various farm machines [2, 3, 8]

Machine	Size	Price dollars	Tractor size PTO horsepower	Acres per hour	Fuel consumption gallons per acre	Labor efficiency percent
Moldboard plows (spring trip)	3-16"	1175	50	1.8	1.90	110.0
	4-16"	1525	80	2.5	1.90	110.0
	5-16"	2700	100	3.0	1.90	110.0
	6-16"	3150	125	3.5	1.90	110.0
	7-16"	4250	150	4.0	1.90	110.0
	7-16"	4250	150	4.2	1.90	110.0
	8-16"	4700	180	4.8	1.90	110.0
Disk harrows (plowed field)	10'	1675	50	5.6	0.65	110.0
	14'	2450	80	7.8	0.65	110.0
	18'	3200	100	9.7	0.65	110.0
	22'	5300	125	11.7	0.65	110.0
	26'	6400	150	13.7	0.65	110.0
	26'	6400	150	14.4	0.65	110.0
	30'	7550	180	16.4	0.65	110.0
Rotary hoes (rear mounted)	4-38"	1175	80	10.1	0.15	108.0
	6-30"	1450	80	11.7	0.15	108.0
	6-38"	2450	100	14.7	0.15	108.0
	8-30"	2450	100	15.3	0.15	108.0
	8-38"	3000	125	19.1	0.15	108.0
	12-30"	3400	125	22.4	0.15	108.0
Row crop cultivators (sweep)	4-38"	1500	80	5.7	0.45	110.0
	6-30"	1550	80	6.6	0.45	110.0

[a]Farm machinery manufacturers list prices for 1974-75.

Table A.5 Continued

Machine	Size	Price dollars	Tractor size PTO horsepower	Acres per hour	Fuel consumption gallons per acre	Labor efficiency percent
Row crop cultivators (sweep)	6-38"	2700	100	8.2	0.45	110.0
	8-30"	2675	100	8.5	0.45	110.0
	8-38"	3625	125	10.6	0.45	110.0
	12-30"	3750	125	12.4	0.45	110.0
Corn planters (air or plateless) insecticide and fertilizer attachments	4-38"	4125	50	5.4	0.50	120.5
	6-30"	5900	50	6.2	0.50	120.5
	6-38"	6550	80	7.8	0.50	120.5
	8-30"	7750	80	8.1	0.50	120.5
	8-38"	8050	100	10.3	0.50	120.5
	12-30"	13200	100	11.8	0.50	120.5
Trailer sprayers (200 gal.)	21.0'	830	50	8.3	0.07	110.0
(300 gal.)	28.0'	1000	50	11.0	0.07	110.0
(400 gal.)	35.0'	1775	80	13.8	0.07	110.0
(500 gal.)	47.0'	1900	80	18.5	0.07	110.0
Gravity-flow wagons[b]	2-165 bu.	2100	50	1.5	0.20	116.0
	3-165 bu.	3150	50	1.8	0.20	116.0
	3-225 bu.	3875	80	2.2	0.35	116.0
	3-250 bu.	5400	80	2.3	0.35	116.0
	3-325 bu.	5700	100	2.9	0.50	116.0
	3-375 bu.	9550	125	3.2	0.50	116.0
	3-475 bu.	9850	125	3.9	0.65	116.0
	3-475 bu.	9850	125	3.8	0.65	116.0

[b]Acres per hour for the gravity-flow wagons are based on the acres per hour for various sizes of combines. For larger farms, the corn is hauled over greater distances. Fuel consumption increases 0.15 gallons per acre for each additional mile. These fuel consumption figures are for hauling the corn to farm storage.

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