ECONOMIC IMPLICATIONS OF SUBSTITUTING LABOR FOR MACHINERY IN MECHANIZED FIELD OPERATIONS

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INTRODUCTION

Labor and machinery are two resource inputs to mechanized farm tasks that can, within limits, be substituted for one another. The economic implications of this substitution are of interest to a farm operator who wishes to minimize the cost of mechanized operations.

In this paper, the mathematical interrelationships among these two inputs and other associated variables are discussed, particularly as they relate to two parameters which can be controlled by the farm operator. These two parameters are length of workday and length of work season. Other associated parameters include task size, wage rate, timeliness penalties, and the effect of cultural practice on the cost of the machinery input. The theoretical significance of the identified interactions is then related to Western Canadian farm conditions by attaching estimates to each variable.

Although the principles discussed may be applied to mechanized farm operations in general, the discussion is restricted to field work and concentrates on tillage and seeding operations.

RELATIONSHIPS AMONG VARIABLES

Four relationships among the variables associated with the input of labor and machinery to field operations may be identified. The first is that the total annual fixed cost for machinery \((Z_M)\) may, for many purposes, be adequately represented \((?)\) as the linear function

\[ Z_M = CY \]  \hspace{1cm} (1)

where \(C\) is the annual fixed cost per unit capacity (e.g., annual fixed cost/acre/h or cost/ha/h) and \(Y\) is the capacity (acres/h or ha/h) of the machinery system. The second is that machinery capacity is given by

\[ Y = A/DH \]  \hspace{1cm} (2)

where \(A\) is the task size (acres or hectares), \(D\) is the number of workdays available for task \(A\), and \(H\) is the number of work hours available per workday. The third is that the cost of labor \((Z_L)\) is given by

\[ Z_L = WDH \]  \hspace{1cm} (3)

where \(W\) is the wage rate ($/h). The fourth relationship is that the total cost \((Z)\) of completing a given task is given by

\[ Z = Z_M + Z_L + Z_p + Z_q \]  \hspace{1cm} (4)

where \(Z_p\) is the timeliness penalty cost associated with the number of days used to complete a task and \(Z_q\) is the operating cost for the machinery system.

Operating costs are normally a function of task size \((?)\). Hence, for purposes of examining the effect of changing the length of either the workday or the work season, operating costs may be ignored. Also, since there are no known timeliness penalties associated with varying the length of workday during tillage and seeding operations, \(Z_p\) can be assumed zero for the discussion of varying the length of workday during tillage and seeding operations. Given these assumptions and equations \((1)\) to \((3)\), equation \((4)\) may be rewritten as

\[ Z = \frac{CA}{DH} + WDH \]  \hspace{1cm} (5)

A number of interactions among the variables in this problem are noteworthy. From equation \((5)\) observe that:

(i) \(Z\) is a nonlinear function of \(H\) and has a minimum for positive values of \(C, A, D, W\) and \(H\). The minimum occurs because, as \(H\) increases, the first term (machinery cost) decreases at a decreasing rate whereas the second term (labor cost) increases linearly.

(ii) As the labor input increases \((H\) or \(D\) increases), the wage rate increases in importance to \(Z\) while the cost of machinery per unit capacity and the size of task decrease in importance (i.e., the first term of equation \((3)\) loses importance to \(Z\) whereas the second term gains importance).

(iii) The same effect on \(Z\) may be obtained by either doubling the cost of machinery per unit capacity \((C)\) while holding task size \((A)\) constant, or doubling task size while holding the cost of machinery constant.

(iv) If written on a per acre or per hectare basis, equation \((5)\) becomes

\[ Z/A = \frac{C}{DH} + WDH/A \]  \hspace{1cm} (6)

and a given percent increase in task size \((A)\) will permit the same percent increase in the wage rate \((W)\) while keeping the cost per unit of task \((Z/A)\) constant. In other words, one can afford to increase the wage rate by the same percent as the task size increases. Conversely, if the wage rate remains constant, costs per unit of task will decrease as the task size increases. Machinery costs per acre do not change because although the actual system size (by equation \((2)\)) and, therefore, cost of the machinery system must increase as the task size increases, the size of task also increases.

The value of \(H\) for minimum \(Z\) may be found by finding the partial derivative of...
Z with respect to \( H \) (equation (5)), setting it to zero and solving for \( H \):

\[
\frac{\partial Z}{\partial H} = -CA/WD^2 + WD = 0 \quad \ldots \ldots \ldots \ldots (7)
\]

and

\[
H_{\text{min}} = \sqrt{CA/WD^2} \quad \ldots \ldots \ldots \ldots (8)
\]

From equation (8) observe that:

(i) Since the number of hours per workday is bounded \((0 \leq H \leq 24)\), the value of \( H \) for a minimum value of \( Z \) will be outside the limits for \( H \) for many sets of values for \( C, A, W \) and \( D \).

(ii) If either (or both) the task size \( A \) or the cost of machinery per unit capacity \( C \) increases relative to the wage rate \( W \), the number of work hours per workday \( H \) will increase to keep total cost \( Z \) a minimum.

(iii) As the wage rate \( W \) approaches zero, the value of \( H \) for minimum total cost \( Z \) approaches infinity. In other words, as labor costs decrease, labor must be substituted for machinery to minimize total cost.

(iv) If there is a differential wage rate (one rate for day labor and a higher rate for night labor) that causes the effective wage rate \( W \) to increase as the number of work hours per workday increases, the value of \( H \) for minimum total cost \( Z \) will decrease relative to the value of \( H \) for a constant wage rate.

(v) If there are no timeliness penalty costs associated with the number of workdays \( D \) and the number of workdays increases, then the minimum total cost \( Z \) will occur at a smaller number of work hours per workday.

WORKDAY LENGTH VARIATION

Tillage and Seeding Operations

Farmers in Western Canada may be able to profit by extending their workday during periods such as tillage and seeding. The extent of any benefits may be estimated by first establishing values for the variables \( C, A, W \) and \( D \) and then calculating equation (5) for ranges of values for the variables \( W \) and \( H \).

The amount of machinery required for a tillage and seeding machinery system of a given overall capacity is dependent upon the cultural practice followed. Since cultural practice can vary considerably from farm to farm, the cost of machinery per unit capacity \( C \) can also vary considerably from farm to farm, even under the condition of constant machinery prices. For example, a machinery system of a given capacity comprised a tractor, chisel-plow, tandem disk, and press drill on a farm with a cultural practice of cultivate-disk-seed will cost more per unit capacity than a similar system omitting the tandem disk and disk operation. In a recent study (3, 5), the costs per acre per hour capacity \( C \) of the overall tillage and seeding machinery systems for a number of farms in Alberta ranged from about $200 to $1,000 ($495 to $2,475/ha/h).

Another variable that can range widely from farm to farm is \( A \), the number of crop acres. In Alberta, for example, the 1971 census (7) indicated that 22% of the farms reported fewer than 128 acres (52 ha) under crops whereas 3% reported over 947 acres (383 ha).

Since both \( C \) and \( A \) can range widely, the product of these two variables will be used in this analysis as a basis for defining a benchmark. This procedure permits a single graph to show the effects of varying work hours per workday \( H \) and the wage rate \( W \) for many possible farm situations.

The number of workdays \( D \) is a variable relating to the length of work season and will be discussed later in the paper. For the discussion of varying the length of workday, \( D \), will be arbitrarily set at 25 days.

Given any constant \( CA \) product, a change in \( C \) requires a change in \( A \). Since \( C \) varies with cultural practice, the magnitude of \( A \) for a given \( CA \) product also varies with cultural practice. For this reason, the capacity of the machinery system (7) required for a given \( H \) varies with cultural practice (equation (2)).

Because \( Y \) is dependent upon \( C \) and \( C \) can vary widely, machinery system size will be referred to as an index. Index 100 is defined as the size of system required for a labor input of 10 h/day.

The effect on costs of substituting labor for machinery is shown (Figure 1) for a benchmark farm with the product of \( C \) and \( A \) set at 500,000. Note that due to the inverse relationship between labor and machinery, a linear increase in labor results in a nonlinear decrease in machinery size requirement and hence a nonlinear total (labor plus machinery system) cost curve. To emphasize the effect of the nonlinear relationship on the total cost curve, the labor charge was established at the rate that would make the total cost at 20 h/day equal to the total cost at 10 h/day. At this wage, the minimum cost labor input (about 14 h/day) has a total cost of about 6% less than the total cost at either 10 or 20 h/day.

The total cost curves for varying hourly labor rates and for including the cost of the total time spent operating the machinery are shown (Figure 2). Total cost curves for including the cost of only the overtime labor (i.e., time beyond the initial 10 h/day) are also shown (Figure 3). These figures are for a benchmark farm with a \( CA \) product of 500,000. If the ranges of values for \( C \) and \( A \) suggested earlier for Alberta are typical of Western Canada in general, the figures could be representative of farms ranging in size from 500 to 2,500 crop acres (202 to 1,010 ha) with corresponding \( C \) values ranging from $1,000 to $200/acre/h capacity ($2,475 to $495/ha/h). In such cases, costs could be reduced if overtime labor were available at a rate less than $4/h (Figures 2 and 3).

Effects of varying the product of \( C \) and \( A \)

The selection of 500,000 as the product of \( C \) and \( A \) for a benchmark has a significant effect on the potential savings from substituting labor for machinery. The extent of this effect becomes evident when a \( CA \) product of 1,000,000 is used (Figures 4 and 5). As \( A \) increases for a constant \( C \) (or \( C \) increases for a constant \( A \)), the potential for saving from more intensive machinery utilization increases (cf. Figures 4 and 2, and Figures 5 and 3). The opposite also holds. In fact, if the task size is small and the opportunity cost of labor is high, the most profitable course of action could be to reduce field time by increasing the machinery system size.
Annual cost of machinery (fixed costs only) and labor for varying inputs of labor and machinery: product of $C$ and $A$ is $500,000$; only overtime labor costs are included.

![Graph 1](image1)

**Figure 1.** Annual cost of machinery (fixed costs only) and labor for varying inputs of labor and machinery: product of $C$ and $A$ is $1,000,000$; only overtime labor costs are included.

Potential cost savings during grain harvesting

One way to reduce the number of harvesting days for a given task is to unload the combine hopper "on the go," rather than drive the combine to a parked truck or wagon. Another way that "extra" operating hours may be obtained is to have another operator relieve the regular operator for coffee breaks and meals rather than have the machine idle. If the potential saving is 1 h in a 10-h operating day, the time saving would be 10%.

How realistic a 10% time saving is will depend on the particular situation and the rate at which the operator himself works. If the operator is working by himself and has to stop the combine during favorable combining weather to unload a truck or swath other standing grain, the potential reduction in the length of harvest period through increased labor input could be much greater than 10%. There may also be harvest days in which there is little or no overnight dew, permitting the combine to be operated up to 24 h/day.

Farm size may also be a significant factor in determining the potential for time saving. For example, the hiring of another man to drive a truck for unloading on the go may not be economically justifiable for a one combine operation but for several combines operating in the same field, the savings in time could be very significant.

Harvesting Operations

In Western Canada, the number of operating hours in a day cannot likely be extended for harvesting operations to the same extent that it may for seeding operations. Operating hours are likely to be restricted in most situations because the moisture content of the crop normally increases throughout the night to slow or stop harvesting. However, even given the restriction that harvesting may not be possible throughout all 24 h in a day, there may be opportunities for reducing harvesting costs through hiring additional labor. Savings could arise by simply improving the utilization of the machinery system in the hours of the day that are available. Improved utilization of machinery could reduce the length of harvesting season, given a particular machinery system size, and thereby reduce the timeliness penalty costs associated with harvesting a crop at other than the time for maximum gross returns.

**Discussion**

This analysis is based on the assumption that machine depreciation is a function of machine age but not usage. The potential savings through extending the workday are reduced in a situation where depreciation is a function of machine usage as well as age.

Some operators may have little interest in operating on an overtime basis because they view the operation of machinery at night as a form of reserve capacity to be retained for years with exceptionally unfavorable weather. Other operators may not consider this form of reserve capacity necessary if they have the alternative of custom hiring another machine or are willing to accept a late seeding penalty.

There are a number of other things to consider in a decision to operate on an overtime basis. One is lower visibility at night, although this potential problem can be greatly reduced by the use of effective lights. Other considerations are the availability of suitable labor for short periods of time and the relative availability of capital for labor compared to capital for machinery. Any potential savings from extending the workday can only be realized if these considerations do not present insurmountable problems.

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Potential cost savings during grain harvesting operations

A study completed in 1968 may be used as a basis for examining potential dollar savings from a reduction in the length of grain harvest period through more efficient use of each day. Russell and MacHardy (4) estimated the opti-
mum length of harvesting period at Edmonton, Alberta, to be 14 (10-h) days. The cost associated with this optimum (1968 basis) was $2/acre ($4.94/ha) for machinery fixed cost plus $1.88/acre ($4.64/ha) for average penalty cost due to adverse weather. If the requirement for field time is reduced after a farmer has made the decision to purchase a particular size of combine, then a reduction in the average weather penalty cost is possible. Using the weather penalty curve given by Russell and MacHardy (4) as an estimate, an average reduction of about $0.25/acre ($0.62/ha) may be obtained by reducing the total number of harvesting days by 1.4 (10% of 14). For a combine capacity of 50 acres (20 ha)/10-h day, the amount would be $12.50/harvest day or $175 for the 14-day harvesting period. The penalty distribution curves in this study (4) suggest that there is the potential for a much larger dollar saving if the combine is small compared to the size of the field (a long harvest period) than if the combine is relatively large (a short harvest period).

As indicated above, the potential for more effective utilization of labor will probably vary considerably from farm to farm. No data are available to permit an accurate assessment of the potential for time saving on particular types of farms. Hence, the potential in Western Canada for reducing harvesting costs through more effective utilization of labor and machinery cannot be estimated except in theoretical terms as has been done above.

WORK SEASON LENGTH VARIATION

The same nonlinear relationship between machinery system size and labor input that was discussed in relation to day-length variation exists for variation in the work season length. Unlike the analysis of day-length variation, however, there may be timeliness penalty costs associated with varying the work season length for both seeding and harvesting operations. This timeliness cost is the cost incurred as a result of performing a task at other than that time yielding maximum gross returns. For example, yield data collected at Melfort, Saskatchewan (1) suggest that cereals seeded on or near May 15 will have, on average in the long run, a higher yield than cereals seeded earlier or later (Figure 6).

Since crop yield data and, therefore, timeliness penalty cost data are associated with the dates on which tasks are performed, timeliness cost ($Z_p$) must be associated with this variable. Hence, $Z_p$ is given by:

\[ Z_p = \int_{t_1}^{t_2} P(t) A(t) \, dt \]  

(9)

where $t$ is the calendar day within the period $t_1$ to $t_2$ and $A(t)$ is the average number of work hours on the particular date. In the long run, the average number of work hours on the particular date will be a function of the potential number of hours ($H$) and the probability that the date will be a workday ($P(t)$). Therefore:

\[ A(t) = Y H P(t) \]  

(10)

and

\[ A = \int_{t_1}^{t_2} A(t) \, dt = Y H \int_{t_1}^{t_2} P(t) \, dt \]  

(11)

The total number of workdays ($D$) in the period $t_1$ to $t_2$ is related to $P(t)$ by:

\[ D = \int_{t_1}^{t_2} P(t) \, dt \]  

(12)

Equation (4) may now be written (ignoring $Z_0$) as:

\[ Z = CA/H \int_{t_1}^{t_2} P(t) \, dt + WH \int_{t_1}^{t_2} P(t) \, dt + \int_{t_1}^{t_2} B(t) A(t) \, dt \]  

(13)

Observe from equation (13) that:

(i) The addition of timeliness penalty costs does not change the effects that were observed earlier in this paper concerning variations in the length of workday ($H$).

(ii) If there is any timeliness penalty (i.e., $B(t)$ is positive) and if $C$, $A$, $H$, and $W$ are positive and constant, then $P(t)$ is positive, both labor and penalty costs will increase whereas machinery costs will decrease as the length of season ($t_2 - t_1$) increases. The converse also holds.

Since $P(t)$ is not likely to be a function that can be easily integrated, the effect on total cost of varying work-season length will be assessed by approximating $Z$ for changes in season length ($t_2 - t_1$) using estimates of both $P(t)$ and $B(t)$ corresponding to incremental changes in $t$. Values for the other variables will be defined for a benchmark farm and then varied to assess the sensitivity of $Z$ to each variable.

Tillage and Seeding Operations

A benchmark tillage and seeding machinery system may be defined as one costing $600/acre/h or $60/acre/day capacity ($1,480/ha/h or $148/ha/day). (A system with capacity of 50 acres or 20 ha/10 h workday and requiring $3,000/yr in fixed costs to maintain would cost $60/acre/day or $148/ha/day capacity.) A benchmark for a timeliness penalty cost may be defined as the cost that would be incurred if maximum potential receipts per acre are $60 ($148/ha) and the realized per acre receipts for crops seeded on various dates are as given by curve "M" (Figure 6). The penalty for seeding prior to the maximum-yield date is assumed to be zero since, with sequence operations, cultivation can continue while seeding is delayed to near the date for maximum expected yield.

The discussion of the implications of varying the machinery input to a given task can be facilitated by referring to machinery size changes relative to some base size. A convenient base is defined as the minimum size needed to complete a given task before any timeliness penalty costs are incurred. This size is designated "Index 100" in the following discussion.

Cost variations with machinery-labor substitution

The cost per acre for various relative levels of machinery input are shown (Figure 7). The cost estimates are based on the following data and assumptions. The number of available workdays is that calculated using calendar days from the first of May and workday probabilities for medium to heavy soils for Edmonton, Alberta (6). The latest seeding date for maximum yield is May 15 and the index-100 machinery size is calculated as the
size required to complete tillage and seeding operations in 10.52 workdays (15 calendar days, May 1-15). The timeliness penalty for a particular machine size index is that calculated by finding the difference between maximum potential revenue ($60/acre or $148/ha) and the actual revenue for an acre seeded on a particular date (derived from curve "M" (Figure 6)) and averaging the penalty over all acres seeded. Machinery costs for a given size index are based on a cost per acre per day capacity of $60 ($148/ha/day). Labor is charged at $40 per workday ($4/h) and averaged over 526 acres (212 ha). (A machinery system with capacity of 50 acres/day (20 ha/day) can complete 526 acres (212 ha) in 10.52 10-h workdays.)

Note that for a given machinery size index, a task size that is double would require double the actual machinery capacity and, therefore, double the cost (since the machinery system cost is a linear function of capacity) from that shown (Figure 7). Doubling the acreage would also cause the acreage seeded with each particular date (derived from curve "M" (Figure 6)) and averaging the penalty over all acres seeded. Machinery costs for a given size index are based on a cost per acre per day capacity of $60 ($148/ha/day). Labor is charged at $40 per workday ($4/h) and averaged over 526 acres (212 ha). (A machinery system with capacity of 50 acres/day (20 ha/day) can complete 526 acres (212 ha) in 10.52 10-h workdays.)

An increase in potential per acre revenue will both increase the magnitude of the timeliness penalty (and hence total costs per acre) for a given machinery size index and increase the magnitude of the least-cost machinery size index (Figure 9). Increasing the cost of the machinery system per unit of overall capacity also increases total costs per acre but decreases the magnitude of the least-cost machinery size index (Figure 10).

The optimum machinery system size

The sum of the machinery, timeliness penalty and labor costs is relatively constant for a wide range of machinery sizes for the benchmark conditions (maximum potential revenue of $60/acre ($148/ha); a revenue function shown as curve "M" in Figure 6; machinery system costs of $60/acre/day capacity ($148/ha/day); and labor costs of $40 per 10-h workday averaged over 526 acres). Under these

Figure 8. Effects on the total cost curve in Figure 7 of either (i) increasing or decreasing labor wage rate or (ii) decreasing or increasing acreage.

Figure 9. Effect on the total cost curve in Figure 7 of varying the level of the timeliness penalty (and hence total costs per acre) for a given machinery size index (Figure 9). Increasing the cost of the machinery system per unit of overall capacity also increases total costs per acre but decreases the magnitude of the least-cost machinery size index (Figure 10).
In the opposite position. In addition to the producer with relatively small machinery has relatively low labor and timeliness penalty costs but has relatively high machinery costs. The producer with relatively small machinery is in the opposite position. In addition to these differences, the producer with an index-76 machinery system is receiving a form of insurance that, in the event of a year with exceptionally unfavorable weather, he will be able to complete more of his seeding before the latest possible seeding date than the producer with a smaller machinery system. This reduction in risk is not an effect that is apparent from a study based on averages but has been observed in other studies (1, 4).

Sensitivity of the optimum to associated variables

The least-cost machinery size is not very sensitive to either changes in the cost of labor or changes in acreage (Figure 8). Even a 5% increase in wage rate from the benchmark $40 per workday does not take the least-cost size out of the index-40 to index-76 range identified as the optimum for a labor cost of $40 per workday. Changing the wage rate or acreage does affect the minimum cost per acre. For example, halving the wage rate or doubling acreage reduces the cost per acre at the least-cost machinery size from $4.90 to $4.20 ($12.10 to $10.40/ha).

Under revenue curve “M” (Figure 6), maximum potential revenue per acre does not appear to be a significant factor in determining the least-cost machinery system size (Figure 9). This is because timeliness penalty is a relatively unimportant cost under these circumstances compared to labor and machinery costs, except at very low levels of machinery input. Under revenue curve “N” (Figure 6), maximum potential revenue per acre would, of course, be more significant.

The extent of the timeliness penalty cost associated with delayed seeding (i.e. the applicable revenue curve) has considerable effect on both the size of the least-cost machinery system and the minimum cost per acre (Figures 10 and 11). For example, at a machinery cost of $60/acre/day ($148/ha/day) capacity, the least-cost machinery size increases from index-55 for revenue curve “M” to index-85 for revenue curve “N,” with a corresponding increase in the minimum cost per acre from $4.90 to $6.20 ($12.10 to $15.30/ha).

The variable that appears to have a considerable effect on the size of the least-cost machinery system and the greatest effect on the minimum cost per acre is the cost of machinery per unit capacity (Figures 10 and 11). For example, under revenue curve “M,” the least-cost machinery size ranges from index-45 for $C = 100$ to index-80 for $C = 20$, with a corresponding decrease in the minimum cost per acre from $6.80 to $2.56 ($16.80 to $6.33/ha).

The machinery cost applicable in any particular situation is affected, to a considerable extent, by the critical practice selected. For example, a minimum tillage system such as once-over with a hoe drill would have a cost in the range of $20 - $40/acre/day capacity ($49 - $99/ha/day). A sequence of cultivate-seed-harrow would have a cost approaching $100/acre/day capacity ($248/ha/day) or even more, depending on the types of implements used and the relative sizes of the implements in the machinery complement. In cases with an extremely high level of tillage input (such as a plow-disk-seed-harrow sequence on soils requiring a relatively high level of power input) the cost per acre per day capacity could be in the order of $200 ($495/ha/day capacity). Under these conditions, the least-cost system size would of course be that which utilizes a relatively high level of labor input. The reader wishing to estimate the overall cost per unit capacity of a proposed system may use the methods outlined by MacHardy (2).

Note that only at a very low machinery cost ($20 - $40/acre/day or $49 - $99/ha/day capacity) and severe timeliness penalty do index-100 machinery systems (i.e., the no-penalty system sizes) become least-cost (Figure 11).

One system compared to multisystem situations

Several independent machinery systems, each with operator crews, may be used in place of a single system. For example, a system comprising a tractor, man, cultivator and seeder (the cultivator and seeder used in sequence) can be replaced by two systems — one with tractor, man and cultivator and the other with tractor, man and seeder. In such a case, the cost of labor effectively doubles but the overall value of $C$ would normally decrease. $C$ would decrease because, although the overall capacity of the machinery in the two alternatives remains unchanged, the sizes of some machines would decrease. In this example, the total amount of tractor power would not change but the sizes of the cultivator and seeder in the two-man operation would be lower.

In general, however, the reduction in machinery costs resulting from a decline in $C$ would not offset the increase in labor costs unless acreage is large, the number of workdays is small, or the labor wage rate is low.
Harvesting Operations

The economic implications of varying the length of work season have been discussed with reference to a tillage and seeding machinery system. Harvesting operations also have timeliness penalty costs associated with late harvesting but, in addition, will normally have timeliness penalties associated with harvesting before the optimum date. For this reason, the curves in Figure 6 are unlikely to be typical of harvesting operations in general. Since the examination of timeliness in harvesting operations is a study in itself (1, 4), no attempt will be made in this paper to examine in detail the economic implications of varying the length of harvesting season.

CONCLUSIONS

The potential for reducing production costs in tillage and seeding operations by extending the workday exists, under any particular set of circumstances, if the value of equation (7) is negative. The length of workday for minimum cost can be determined using equation (5). In general, as labor is substituted for machinery, labor costs increase linearly whereas machinery costs decrease at a decreasing rate.

As an approximate guideline (if there are 25 workdays in the seeding season), an operator can afford to pay up to $1/h for overtime labor beyond 10/day for each 125,000 in the product of C (annual machinery system cost per $/acre/h or ha/h capacity) and A (acreage or number of hectares). For example, if an operator has 1,000 acres (404 ha) and a machinery system that costs $500/yr/acre/h capacity ($1,240/yr/ha/h), the CA product would be 500,000 and he could reduce production costs by substituting labor for machinery for labor wage rates up to $4/h.

Extending the work season will only result in a cost saving if the cost of the machinery system per unit capacity is high and timeliness penalty and labor costs are low. For most combinations of values in the likely ranges for machinery, timeliness and labor costs, there is a very wide range of machinery system sizes (and hence labor inputs) that provide a total cost per acre within 10% of the cost at the least-cost size. However, the minimum cost per acre varies considerably with the cost of machinery and extent of timeliness penalty costs.

The cost of machinery (or cultural practice selected) and extent of timeliness penalty costs appear to be the most significant variables determining the length of the least-cost seeding season. The cost of labor and the number of acres over which the labor cost is spread appear to be the least significant. The per acre value of the crop appears to be significant only if timeliness penalty costs are severe and the work season is long.

SUMMARY

The economic implications of substituting labor for machinery in mechanized field tasks have been assessed primarily as they relate to tillage and seeding operations. A conceptual framework for the discussion was established by examining the mathematical interrelationships among the variables (labor and machinery inputs, task size, labor wage rate, timeliness penalty costs, and cultural practice). The economic implications of the labor-machinery substitution were then examined for Western Canadian farming conditions by attaching estimates to each variable.

The sum of labor and machinery costs for many sets of circumstances can be reduced by increasing the number of work hours in a workday. The length of workday for minimum cost can be determined using the equations presented. In general, as labor is substituted for machinery, labor costs increase linearly while machinery costs decrease at a decreasing rate.

Extending the work season will only result in a cost saving if the cost of machinery per unit capacity is high and timeliness and labor costs are low. For most combinations of values in the likely ranges for machinery, timeliness and labor costs, there is a very wide range of machinery system sizes (and hence labor inputs) that provide a total cost per acre within 10% of the cost at the least-cost size. However, the minimum cost per acre varies considerably with the cost of machinery and extent of timeliness penalty costs.

The cost of machinery (or cultural practice selected) and extent of timeliness penalty costs appear to be the most significant variables determining the length of the least-cost seeding season. The cost of labor and the number of acres over which the labor cost is spread appear to be the least significant. The per acre value of the crop appears to be significant only if timeliness penalty costs are severe and the work season is long.

REFERENCES