Effects of Diversification and Cropping System on Machinery Costs[1/]

by

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Introduction

The purpose of this paper is to estimate differences in machinery ownership and operating costs for different cropping systems. In particular, the analysis is directed to the costs of diversified cropping systems which generally are hypothesized to have higher machinery costs compared to specialized cropping systems. In recent years more interest has been given to crop diversification and rotations by both farm management analysts and producers. The economics of cropping systems centers on profit potential as well as the risk implications of these systems. To adequately analyze the economics of these systems sound estimates of machinery costs for various cropping systems are needed. In many cases such estimates do not exist and machinery costs are either ignored or assumptions made of these costs.

From a short-run or fixity framework the estimation of at least part of machinery ownership costs (capital investment) is irrelevant and such costs can be assumed as fixed. However, when such short-run models are employed, capacities of the existing machine set must be specified such that alternative cropping systems do not exceed the fixed machine capacity.

A longer-run perspective is assumed in this study in which average annual total machine costs are estimated for each cropping system. Thus, machinery costs (both ownership and operating) are estimated for that set of machinery appropriate to a specified cropping system. In the absence of such estimates three methods are commonly employed in cropping system studies. The first is to "build up" machinery ownership and operating costs for the system from per acre estimates for individual crops. Standard per acre costs are based on an assumed machinery complement for a farm or crop. Unfortunately such general per acre costs estimates cannot be "carried across" widely different cropping systems. A second and better approach is to assume a different machinery mix for each cropping system. In some cases "reasonable" machinery mixes can be estimated based on meeting machinery operations in a timely manner. However, unless the machinery selection method is optimal, no guarantee exists that the assumed machinery set is necessarily a close estimate of the optimal machinery set for that system. A third approach has been to ignore machinery ownership costs in cropping system studies. As previously mentioned, the only condition under which such an assumption can hold is a short-run or fixity framework, not a longer-run framework. In this third case ignoring machinery investments will not even necessarily result in correct estimates of operating costs. This occurs because per acre estimates of operating costs for a crop are dependent upon a given machinery set and an assumed machinery set is not necessarily the optimal set for the crop mix analyzed.

It is commonly suggested that crop diversification increases total machinery ownership and operating costs of a farm. Reasons for this are 1) fewer acres of more crops increases total machinery investment and 2) with smaller, less efficient machinery, operating costs rise. However, a counter force can result from diversification. Spreading machinery operations across more crops reduces the machinery needed to complete operations in a timely manner. Thus, aggregate machinery investment per farm may not significantly increase as diversification increases and could conceivably decrease.

In this study optimal machinery combinations are determined for the tillage operations for different cropping systems in east-central Nebraska. The results from this analysis are useful in profit and risk studies where net returns of alternative cropping systems are to be compared.

Procedure

A 640 crop acre farm was assumed for this analysis. The farm was assumed to be a one-man family farm located in east-central Nebraska. Eight cropping systems were analyzed with respect to ownership and operating costs per acre. These eight systems involved 1) three continuous row crop systems [continuous corn (CC), continuous soybeans (CSB), and continuous grain sorghum (CGS)], 2) three row crop systems diversifying in two crops [corn-soybeans (C-SB), corn-grain sorghum (C-GS), and grain sorghum-soybeans (GS-SB)], 3) one three crop system using row crops [corn-grain sorghum-soybeans (C-GS-SB)], and 4) a four year, three crop system employing a small grain [corn-corn-soybeans-oats (C-C-SB-O)]. The least-cost set of machinery necessary to complete tillage operations with a given degree of probability within critical time periods was determined by mixed integer programming for all systems. Ownership and operating costs for each system were determined so that per acre machinery cost comparisons could be made between systems.

The Model

Following Kletke and Griffin and Pfeiffer and Peterson, a zero-one mixed integer programming model was constructed. The advantage of using this type of model is that it eliminates problems associated with indivisibilities and rounding off of machinery decision variables. In addition, it allows the user the opportunity to examine the components of total machinery costs. For example, the modeling procedure allows the treatment of fixed costs (taxes, insurance, etc.) as discrete decision variables and variable cost (fuel, lubricants, repairs, etc.) as continuous decision variables. The optimizing algorithm was IBM's MPSX/369 with its Mixed Integer Program/370 feature.

Methodology

The method used to find optimal machinery sets for all the crops and crop rotations considered in this study required the following:

Workdays Model

Available field working time is defined as the working days in a scheduled period in which field operations can be performed. Classification of a working day for field operations depends on the trafficability of the surface of the soil. This study used two procedures to determine the number of working days in each critical period. The first by Meng is for periods I and II (April 15-May 12, and May 13-June 9, respectively) chooses soil moisture as the indicator of trafficability. This procedure is multiphased. Since soil continually receives water through precipitation and irrigation events, and since it continually losses water through surface runoff, evapotranspiration, and drainage events, Meng's model simulated this daily process. This model can be represented mathematically as follows:

$$SM(i) = SM(i - 1) + P_s = P_r + I + C - Q - ET - D$$

where SM(i) = soil moisture content on the i'th day, P_s = precipitation from snow, P_r = precipitation from rainfall, I = irrigation water, C = capillary rise, Q = runoff, ET = evapotranspiration, and D = drainage.

In this model, Meng divided the soil profile into six layers, each 1.97 inches deep. By applying field working day criteria (which he defined as a soil moisture percent of field capacity) to the simulated soil moisture contents, the suitability of days for field work were identified. If the soil moisture contents of the top two layers are above this criterion (90.7% for layer 1 and 96.5% for layer 2 for the soils of this study), a day is considered to be a working day. The results of this procedure were validated and were found to be cite specific. Since this study required estimation of the expected minimum number of field working days for periods not considered by the study by Meng, a second procedure was considered. This procedure estimated number of work days for period III and IV (November 8-December 5 and March 29-April 14 respectively). This method used weather data from three weather stations in and around the study area. The criterion used was to consider a field work day to be a day when less than 0.10 inches of precipitation had occured. A total of 84 years of weather data were analyzed in order to obtain distributions for periods III and IV.

The expected number of field working days generated from these two methods were for three levels of timeliness; 75 percent, 85 percent, and 95 percent. Boisvert et. al. mention that farmers with a preference for at least an 80 percent timeliness level may be identified as risk averters and those with a preference for a 75 percent level or less as risk takers.

Tillage System

Based on surveys by Dickey et. al. 69% of the farmers in the study area use disking as their primary tillage practice. Dickey et. al. also mentioned in their study that 31 percent of fields in the disk tillage system had three rather than four operations. In order, these were: 1) disking, 2) a secondary tillage operation such as field cultivation or disking, and 3) planting. Since disking comprised the largest share of all tillage systems, this paper uses disking as its primary tillage method. The system that this paper uses has the same sequence of operation as mentioned above with the exception of using a field cultivator instead of a disk in the secondary tillage operation. Also, this system can be perceived as conservation tillage since it does not require a fall moldboard plowing operation or any other kind of tillage method. Since this study utilizes four week periods (except for period IV which is a one-half month period), it was necessary to determine in which period each operation occurs. Table 1 below does this by assigning numbers of acres to the period in which a certain kind of field operation is to take place. The information in Table 1 is based on historical data (Nebraska Crops and Weather, 1982) which provided information on the percentage of acreage planted or drilled during the two four-week spring periods for Saunders County. This in turn was used as a criterion to determine the percentages of acres to be disked and field cultivated since both of these activities needed to be carried out prior to planting. The only time this criterion was not used was in the determination of number of acres of corn to be planted before May 12. While Nebraska Crops and Weather showed that based on a five year average (1977-1981), around 49% of all grain corn is planted before this date, the study required 88% of the corn (563 acres) to be planted before the end of May 12. The reason for this is that with this assumption on hand, the farmer would be left with only 77 acres to finish planting after May 12 and before May 15, where May 15 is assumed to be the date after which yields begin to decrease.[1/] Even the smallest size tractor and the smallest size planter that this study considers can achieve this in a timely fashion. Table 1 shows also the kind of crops and crop rotations considered in the study. This paper assumes that fertilizers, pesticides, and herbicides are applied at the time of field cultivation. It is also assumed that harvesting of all crops is custom hired.

Cost Calculation

The costs of the machinery were calculated using appropriate formulas (Reff) representing an average cost for a specific piece of machinery. Since not all the tractor and implement sizes that were considered in this study were carried by the machinery dealers in the general area of the farm situation, and since machinery prices have not significantly changed for the last four years, existing 1983 published price listings were used in the

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1/ This date has been adopted even though it is usually used for corn planted in the cornbelt region and not in Nebraska. On the other hand, it is considered to be a good approximation to what the actual figure might be since, as Borrows et. al. mention (1974, p. 2), there is little, if any, influence of factors other than the latitude of the location on this date.

computation of fixed and variable costs (Duey). In calculating the fixed costs, the capital recovery method (at 3% real interest rate) of inputting the annual charge for depreciation and interest was used. Purchase prices were discounted 6.5 percent from list prices and salvage values based on 10 years of economic life for tractors and 8 years for implement were calculated. Fixed costs for sales tax, insurance and housing were combined and assumed to be equal to 2% of average investment. All tractors were assumed to be diesel power and a county price for diesel of 56 cents per gallon was used. An estimate of diesel consumption and lubrication, repair, and maintenance was computed based on estimated accumulated hours of use. For tractors, an average use of 600 hours per year was assumed and for implements, use was determined from the number of acres covered per year divided by the implement field capacity (acres/hour) determined their annual hours of use. While no charges were imposed on operator's labor, hired labor was charged $5.50 per hour. All fixed and average costs were then broken down to a per hour cost estimate. The procedure used to match the size of ground engaging implements to tractor power and to calculate field capacities is given in the Agricultural Engineers Yearbook (ASAE 1971).

Weather model data was used to restrict the total number of working days available under certain timeliness levels for each specific period, as well as the constraints on time available for implements and labor availability. The study assumes that tractor hours equal 1.1 times implement hours and labor hours equal 1.1 times tractor hours (Kletke et. al.). Information from Table 1 was used to specify the acreage for each type of field operation under a specified timeliness level. Also, data on field capacity that were calculated from the Agricultural Engineers Yearbook (ASAE 1971) were used as input-output coefficients for various sized machines. Using transfer rows, fixed cost activities associated with implements were tied to their variable cost activities. The model allowed for hiring additional labor if additional labor was needed. One programming run was done for each cropping system for each timeliness level.

Results

The total cost per acre of each of the eight systems is presented in Table 2 below. The results are discussed in terms of crop differences, completion probability effects, and diversification impacts. Space prevents detailed discussion of machinery sets, labor use, and operating vs. ownership cost relationships.

Crop Differences

Cost differences of crops are the most important factor explaining cost differences by system. Grain sorghum costs are the lowest of the three individual crops analyzed on a continuous crop basis ($10.02 per acre). Soybean costs are higher than grain sorghum costs only at the 90% probability completion level. However, machinery costs of corn are significantly higher than for grain sorghum and soybeans at all probability completion levels.

With these individual crop cost differences most of the difference between system costs can be explained. Those systems with a relatively high (50%) proportion of corn (C, C-C-SB-O, C-GS, and C-SB) have high costs. Similarly those systems with a relatively high proportion of grain sorghum (if not combined with corn) which include GS and GS-SB have low machinery costs. The same phenomenon occurs for soybeans as for grain sorghum when examining costs of GS and GS-SB.

Completion Probabilities

Total per acre machinery costs range from $10.02 to $15.91 per acre at the 75% completion level vs. $10.02 to $17.77 at the 90% level. This spreading conforms with the expectation that some crops or systems are more severely impacted by timeliness than others. From the 75% to 90% completion probability level, costs rose for six of the eight systems. This impact was most noticeable for soybeans by examining continuous soybean costs at those completion probabilities. Corn costs were only slightly increased while grain sorghum costs remained constant as completion probability increased. Only one system which included soybeans did not have higher costs at higher completion probability levels and that was soybeans in association with grain sorghum. All systems which included corn experienced increased costs for higher completion probabilities. All diversified systems involving two or more crops had higher costs at higher completion probability levels except GS-SB. This suggests that grain sorghum in combination with soybeans involves less timeliness pressure than other crops or systems.

Diversification

From Table 2 it can be seen that those cropping systems involving combinations of crops have both lower and higher costs than single crop systems, depending upon the crop. It is obvious that the cost for any system is influenced by what crops are included in that system.

In quantifying the independent influence of combining crops into systems on cost two factors must be taken into account. One of these is that the per acre cost of any cropping system involving two or more crops is affected by what crops comprise the system. The second is that enterprise size must also be accounted for. For example, suppose the diversification impact of combining corn and soybeans into a system is to be isolated. The cost per acre (90% completion probability) of that system is $15.63. From Table 2 the per acre cost of continuous corn is $17.60 and continuous soybeans is $13.74. However, a simple averaging of these two single crops is not adequate in developing an "undiversified" comparison base to compare against the corn-soybean system. In addition, the average of the single crops must account for the effect of size. Thus, a preferable cost comparison to the corn-soybean system is the average of 320 acres of continuous corn and 320 acres of continuous soybeans. While space does not allow a reporting of the single crop costs or various acreages, the costs for this examples are $17.33 per acre for both corn and soybeans when singly grown at 320 acres. Hence, the diversification impact in this example is $17.33 - $15.63 or $1.70. This is a positive value indicating a $1.70 per acre benefit of diversification. This occurs because of the spreading of tillage operations in the two systems requiring less total machinery investment.

All diversification effects are positive in this analysis. At 90% completion probability the per acre diversification benefit for GS-SB, C-GS, C-SB, C-SB-GS, and C-C-SB-O are $7.31, $1.71, $1.70, $11.59, and $6.68 respectively. These estimates are based on system comparisons to individual crop costs when individual crop costs are averaged at the appropriate acreage. These results are somewhat at odds with common thought that diversification involves cost sacrifices because of higher aggregate machinery investments.

Summary and Conclusions

In this study optimum (least cost) tillage systems were selected for eight cropping systems by mixed integer linear programming. The systems differ by crop type and level of diversification. Three alternative levels of timeliness were assumed in the selection process. Ownership and operating costs of the optimal machinery set for each cropping system were determined.

The results show that corn has higher costs relative to grain sorghum and soybeans. As completion probability increased, six of the eight systems had higher costs because of higher investments in larger machinery. As diversification increased, machine cost decreased after removing the effect of crop type and enterprise size.

Table 1. Field Operations and Their Periods of Completion; Crops and Crop Rotations in East-Central Nebraska.

Crop	C		Sb		Sg		CSb		CSg		SbSg		CSgSb		CCSbO			
Period	I	II	I	II	I	II	I	II	I	II	I	II	I	II	I	II	III	IV
<u>Operation Performed Acres</u>)																		
Disk	640	---	640	---	640	---	640	---	640	---	640	---	640	---	640	---	---	---
Field Cultivate	640	---	73	567	80	560	388	252	392	248	76	564	285	355	370	270	---	---
Plant	563	77	58	582	64	576	310	330	314	326	61	579	228	412	296	184	---	---
Drill	---	---	---	---	---	---	---	---	---	---	---	---	---	---	136	24	---	---
Manure Spreading	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	320	160

a. I. April 15-May 12, II. May 13-June 9, III. November 8-December 5, and IV. March 29-April 14.
b. C = Corn, Sb = Soybean, Sg = Grain Sorghum, O = Grain Oats.
c. Area planted for SbSg in Period I = 320 x 0.09 + 320 x 0.10 = 61 acres, where 0.09 and 0.10 are percentages planted by May 12 of soybean and sorghum respectively in Saunders County (<u>Nebraska Crops and Weather, 1982</u>). The rest of acres planted for other crops and rotations is figured in similar fashion.

Table 2. Estimated Labor Requirements, Ownership Costs and Operating Costs for Eight Cropping Systems for Three Completion Probability Levels. (Numbers may not add due to rounding.)

Cropping System	C			SB			GS			C-SB		
% Completion Probability	75	85	90	75	85	90	75	85	90	75	85	90
Labor - hr./acre	.44	.43	.42	.47	.47	.40	.47	.47	.47	.40	.44	.44
Ownership Cost $ per acre	12.62	13.45	13.82	7.31	7.31	10.62	7.31	7.31	7.31	10.62	12.62	12.62
Operating Cost $ per acre	3.29	3.59	3.78	2.71	2.71	3.12	2.71	2.71	2.71	3.12	2.85	3.00
Total Cost $ per acre	15.91	17.05	17.60	10.02	10.02	13.74	10.02	10.02	10.02	13.74	15.47	15.63

Table 2. (Continued)

Cropping System	C-GS			GS-SB			C-GS-SB			C-C-SB-O		
% Completion Probability	75	85	90	75	85	90	75	85	90	75	85	90
Labor - hr./acre	.40	.44	.44	.47	.47	.47	.47	.40	.40	.39	.44	.42
Ownership Cost $ per acre	10.62	12.62	12.62	7.31	7.31	7.31	7.31	10.63	10.63	12.61	14.29	14.62
Operating Cost $ per acre	3.11	2.84	3.00	2.71	2.71	2.71	2.71	3.13	3.13	3.09	3.05	3.15
Total Cost $ per acre	13.73	15.47	15.62	10.02	10.02	10.02	10.02	13.77	13.77	15.70	17.34	17.77

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