RISK-RETURNS CRITERIA IN SELECTING FARM MACHINERY

by

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ABSTRACT

Risk preferences can be introduced into machinery selection by estimating the mean and standard deviation for total costs, including timeliness costs, associated with various machinery sets. Risk-returns criteria tested included E, V and E, S frontiers, cost-variance, upper confidence limits and maximum affordable cost.

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The problem of selecting the proper scale of crop machinery for a given farming operation has always been complicated by the need to consider the effect of timely completion of field operations on harvested yields. The difference between the gross value of crop yields given optimal timing of all field operations and the actual yields has been termed the "timeliness" cost. By adding this cost to the other costs of owning and operating machinery, a total machinery cost can be calculated. Minimization of total machinery costs (including mean timeliness cost), all else constant, has frequently been employed as the criterion for optimizing the size of the machinery set (Boisvert; Burrows and Siemans; McIssac and Lovering; Tulu, Holtman, Fridley and Parsons). However, timeliness costs are stochastically dependent on the number of days suitable for field work during critical periods of each year. Year-to-year variations in weather patterns produce corresponding variations in timeliness costs. Avoidance of extremely high timeliness costs in any one year has often been advanced as a reason for farmers to possess machinery larger than the size which will minimize long-run total machinery costs (Kletke and Griffin).

A machinery cost simulation model was developed to estimate the mean level and degree of variability of total machinery costs due to year to year variations in the number of suitable field days. Several decision criteria were tested to determine the impact of cost variability as well as cost minimization on the selection of optimal machinery size. These criteria included estimation of cost, variance and cost, semivariance frontiers, upper confidence limits for costs, and a maximum affordable cost criterion.

To determine cost variability the dates of completion for planting and harvesting for corn-soybean farms ranging in size from 100 to 1,000 acres for various machinery sets were simulated using the number and distribution of suitable field days in Iowa recorded by the Iowa Crop and Livestock Reporting Service from 1958 through 1977. Timeliness costs and a total cost distribution were calculated for ten machinery sets of different sizes, using accepted engineering equations and parameter values identified from data collected in extension workshops. Each machinery set was identified by the size of the planter (four, six, eight, or twelve rows) and the size of the tillage equipment (small, medium, large or extra large). The size of the tillage equipment was matched to the tractor horse power, and the sizes of weed control and harvesting machinery were matched to the size of the planter. All cost calculations were completed on an after-tax basis and capital recovery procedures were used to properly reflect the present value of fixed costs (Edwards).

Machinery Selection Considering Risk

The hypothesized importance of considering variability as well as mean level of costs in machinery selection is illustrated by Figure 1. Estimated total costs for each year from 1958 through 1977 are shown for two example machinery sets, the six-row medium and the twelve-row extra large machinery complements, for 700 crop acres. Although these two sets were not least-cost at 700 acres (see table 1), their average costs were less than $1.00 (three percent) higher per acre than those of the least-cost set(s). The difference in mean value of total cost per acre for these two sets was not statistically significant at the .01 confidence level. Yet, as seen from the graph, the cost of the six-row set was considerably higher or lower than the cost of the twelve-row set in most years, depending on the number of suitable field days available in each particular year. A risk-averse individual would certainly choose the twelve-row set over the six-row set in this case, because he could reduce the variability without significantly increasing long-run expected cost.

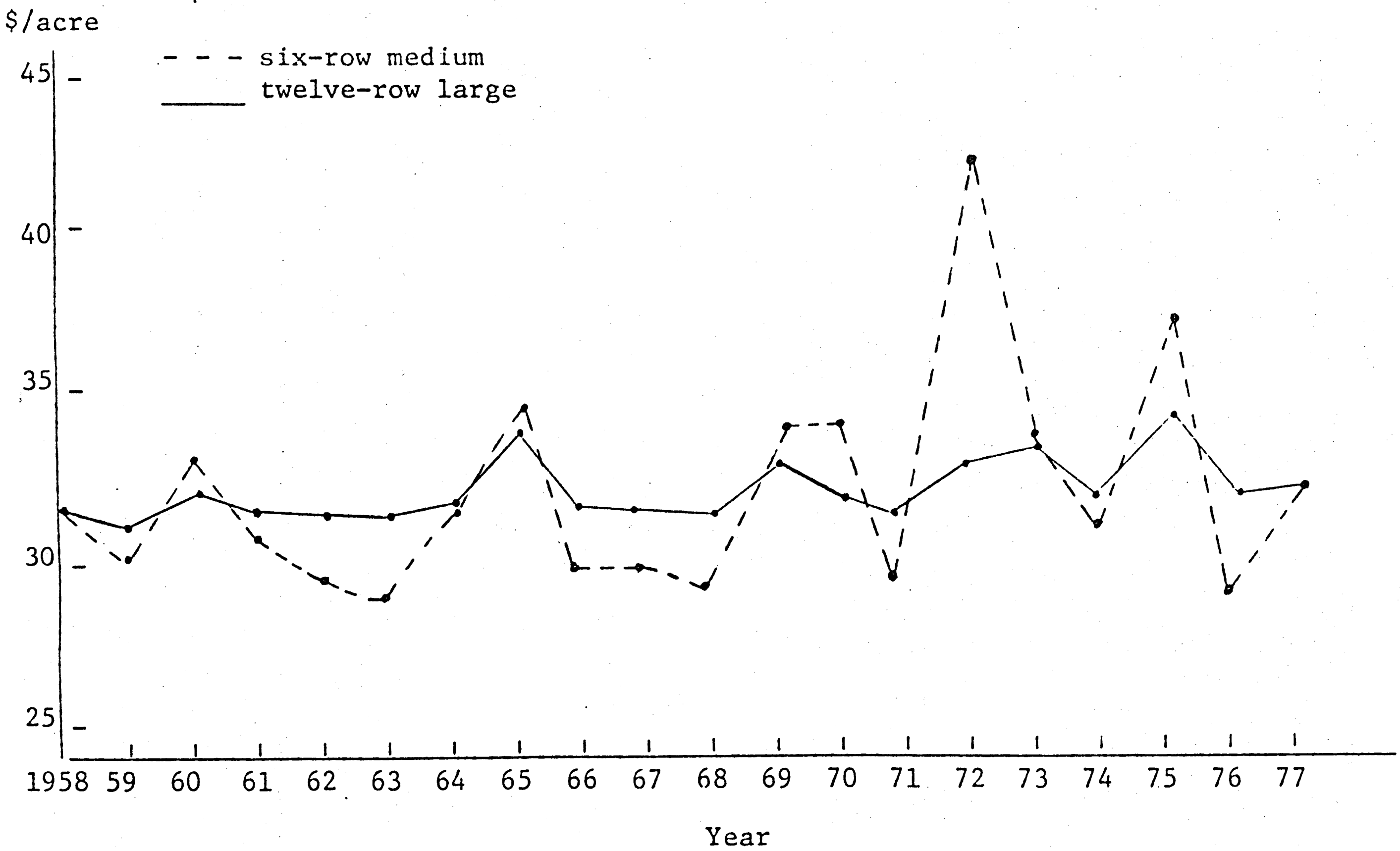

Figure 1. Annual total cost per acre for two machinery sets, 700 crop acres.

Table 2 shows the standard deviation for each machinery set evaluated from 100 to 1,000 acres. Except at the 100 acre level, where variation was very small, the standard deviation was inversely related to the size of the machinery set. The primary source of variation in total costs was the timeliness cost component, and as machinery size increased, timeliness costs became smaller and less variable.

Total machinery costs were adjusted to an after-tax basis by estimating the total amount of income tax due before and after deducting machinery costs, and subtracting these tax savings from pre-tax machinery costs. High machinery costs produced high tax savings and low machinery costs produced low tax savings. The progressive nature of the marginal tax rates magnified this effect. Thus, adjusting total machinery costs for tax savings considerably reduced year-to-year variability.

Table 1. Average total machinery costs per acres ($)[a/].

Machinery set	Crop acres 100	200	300	400	500	600	700	800	900	1000
Four-row small (4S)	214	103	69	51	44	42	57	77	91	104
Four-row medium (4M)	225	107	71	52	43	40	46	65	76	87
Six-row small (6S)	255	118	78	56	44	38	34	33	37	42
Six-row medium (6M)	271	123	80	58	44	37	32	30	29	31
Six-row large (6L)	278	125	81	58	44	37	31	28	26	26
Eight-row medium (8M)	310	138	87	62	47	39	33	28	25	22
Eight-row large (8L)	316	140	88	62	47	38	32	27	23	20
Eight-row extra large (8X)	324	143	90	63	47	38	32	27	22	19
Twelve-row large (12L)	362	161	99	68	52	40	33	27	23	19
Twelve-row extra large (12X)	370	165	101	70	52	40	32	27	22	18

[a]Underlined values indicate the machinery sets having the lowest average total machinery costs for each level of crop acres, at the .05 level of confidence.

Table 2. Standard deviation of total cost distribution.

Machinery set	Crop acres 100	200	300	400	500	600	700	800	900	1000
Four-row small	.7	1.5	2.8	3.0	4.6	9.5	25.0	34.6	35.9	36.3
Four-row medium	.6	1.2	1.7	3.0	3.4	7.5	16.2	30.1	35.0	37.9
Six-row small	.6	1.3	2.0	3.2	2.3	3.2	4.9	10.1	17.0	24.3
Six-row medium	.6	1.0	1.4	1.6	2.0	2.3	3.6	6.4	9.3	13.8
Six-row large	.6	1.3	1.2	1.4	1.8	1.9	2.8	4.9	7.1	10.0
Eight-row medium	.6	1.3	.8	1.2	1.7	1.6	2.2	2.9	3.5	4.1
Eight-row large	.6	1.3	1.1	1.0	1.4	1.4	1.7	2.2	2.6	3.2
Eight-row extra large	.6	1.4	.6	1.7	1.9	1.3	1.4	1.9	2.3	2.9
Twelve-row large	.6	.7	.5	.8	.9	1.3	1.2	1.5	1.7	1.9
Twelve-row extra large	.6	.6	.5	1.2	.7	1.1	1.1	1.2	1.5	1.6

Differences in the optimal choice obtained by including risk as well as mean cost in the selection criterion would occur mostly for farms with 200 to 800 acres. At 100 acres, differences in mean costs among machinery sets were very large while differences in the standard deviations were very small, so that the least-cost machinery set (four-row small) would be chosen as the optimum under nearly any circumstances. Likewise, at 900 and 1,000 acres the twelve-row extra large machinery set had both the lowest mean cost and the lowest standard deviation, and would be considered optimal under any criterion which assumed a negative marginal utility for both costs and variability.

E, V maps

Expected cost, variance maps for several acreage levels were constructed by plotting the combinations of the mean and standard deviation for total costs for each machinery set. Figure 2 illustrates E, V maps for 200 through 700 acres. Those sets having a lower mean and/or a lower standard deviation than each of the other sets at each acreage level were termed "efficient" sets, and were connected by a solid line to project the shape of the E, V frontier. [1/] The optimal machinery set for each acreage level is represented by the point on the respective E, V frontier which touches the cost, variance indifference curve lying closest to the origin (Van Horne).

Although the optimal set cannot be identified without knowing the shape of each farmer's indifference curves, several machinery sets seemed more likely to be chosen than others given the expected shape of a risk averse farmer's indifference curves. In particular the four-row medium, six-row large, eight-row extra large and twelve-row extra large sets would be optimal assuming a broad range of slopes for the indifference curves.

[1/] Use of simulation method also produced mean and variance estimates for "inefficient" machinery sets, in contrast to quadratic programming methods, which identify only those sets on the E, V frontier.

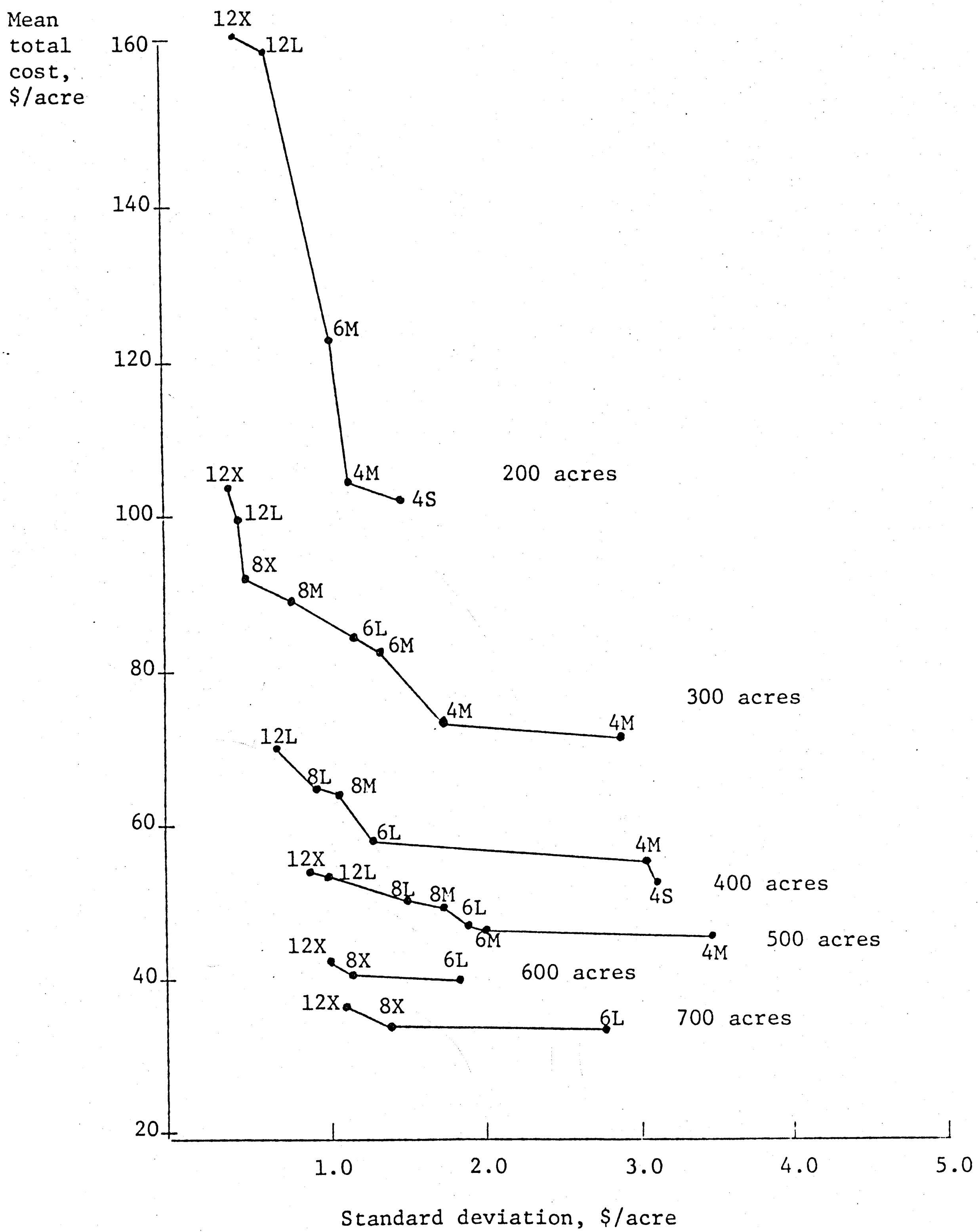

Figure 2. Expected mean cost, variance maps for 200 - 700 acres.

E, S maps

Expected cost, semi-variance frontiers were constructed in a manner similar to the E, V frontiers except that semi-variance, which considers only deviations above the mean, was used as the measure of cost variability (Markowitz). Since the cost distributions for all the machinery sets were skewed in the same direction and to approximately the same degree, this method gave practically the same results as the E, V frontier method. In general, employing either the E, V or E, S criterion to select machinery would result in the choice of machinery sets that are of the same size or larger than those chosen when only the means of the cost distributions are considered.

Cost-variance

Statistical tests were used to decide whether or not the mean cost of each machinery set was significantly higher than the mean cost of the least-cost set. In this manner several sets may be determined to minimize costs.

A rather simple method of incorporating risk reduction into the machinery selection decision is to then choose the least-cost set with the smallest standard deviation in cases where more than one set is identified as least-cost. This criterion results in a reduction in the degree of risk with no significant increase in expected costs; thus it is assumed that cost minimization is the primary goal of the producer and risk reduction is a secondary consideration.

Figure 3 compares the sizes of the optimal machinery sets using this criterion to the average size of the least-cost-sets at each acreage level. The size of the machinery sets is measured by the total number of acres over which all machinery operations could be completed in one hour, using each set. Where more than one machinery set was least cost (700, 800 and 900 acres) the average size of the least-cost sets was slightly smaller than the size of the optimal set under the cost-variance criterion (i.e. the largest least-cost set).

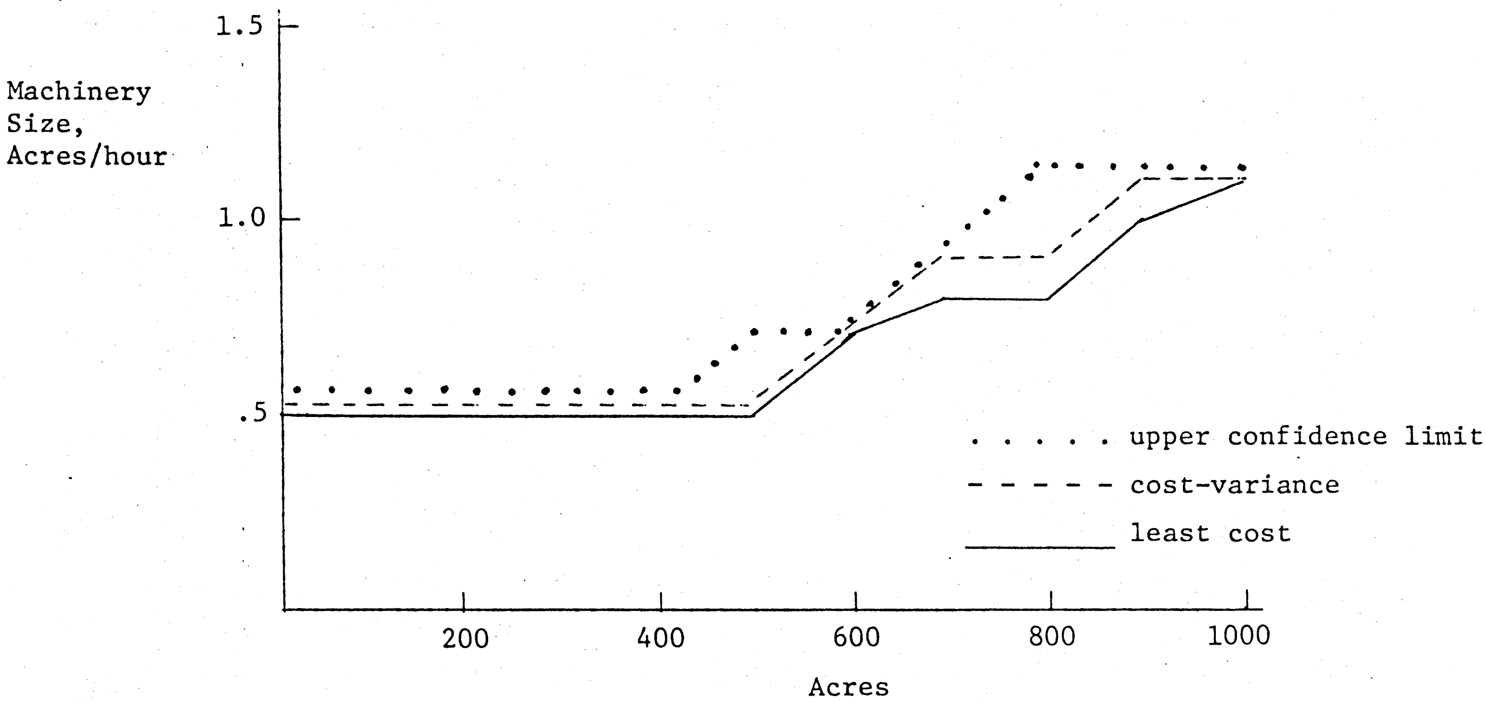

Figure 3. Size of optimal machinery sets under least cost, cost-variance and upper confidence limit criteria.

This strategy of selecting the least-cost sets and choosing the one with the lowest variability is relatively simple to apply since it merely requires estimating the expected costs and standard deviation for each machinery set. The only selection parameter which must be specified is the level of statistical significance used for identifying the least-cost sets. For lower significance levels, more machinery sets tend to be least-cost, since differences in long-run average costs have to be larger in order to be statistically significant.

<u>Upper confidence limit</u>

The upper confidence limit (minimax) criterion is equivalent to the lower confidence level criterion utilized in a profit maximization context (Baumol; McInerney). It involves calculating the maximum total cost expected for each machinery set at a designated level of statistical significance or confidence. The set with the lowest upper confidence limit or expected maximum cost is then chosen as the optimal set. The goal is to maximize the chances of survival of the business rather than minimize total machinery costs.

For example, if a farmer wants to know the maximum total cost he can expect from a machinery set nine years out of ten, he computes an upper confidence limit for that set which corresponds to the .90 level of confidence. When the sample size is twenty (years of weather data) the .90 upper confidence limit is 1.73 standard deviations above the mean. The more stress the farmer places on avoiding large losses, i.e., very high total machinery costs, the larger the value he must choose for the level of confidence for the maximum expected cost. At a higher confidence level, the values for the upper limits for total costs depend more on the standard deviations and less on the means, causing the upper limits for the smaller machinery sets to increase faster than those for the larger sets. This occurs because the standard deviations for total machinery costs vary inversely with machinery size. Hence, the more risk-averse the decision maker is, the larger his optimal set of machinery will be for a given acreage.

Figure 3 shows the sizes of the optimal machinery sets using this criterion and a .90 confidence level. At each acreage level the standard deviation decreased as machinery size increased. However, at the smaller acreage levels, particularly from 100 to 400 acres, the mean increased enough to offset the decreasing standard deviation so that the smallest machinery set, the four-row small equipment, had the lowest upper limit on total costs. At the higher acreage levels (500 and above), the timeliness costs for the smaller machinery sets increased, causing both the mean and standard deviation to increase, thus making the upper confidence limits for the small machinery sets much greater than for the large sets. The overall effect was for the size of the optimal machinery set to increase as the number of acres increased, just as when only total costs were considered.

At each level except 500 and 800 acres the optimal set under the upper confidence limit criterion was also one of the least-cost sets, so that the difference in average total costs or "risk premium" (difference between the cost of the least-cost and the optimal set) was not statistically significant. At the 500 acre level the risk premium was $1.12 per acre and at 800 acres it was $.58 per acre. When the confidence level was raised to .99 slightly larger machinery sets were found to be optimal at the 300, 600 and 700 acre levels. The risk premiums were greater at this confidence level, but still ranged only from $.00 to $2.41 per acre.

Choosing a machinery set by minimizing the worst possible result protects the farm business against a disastrous year. This procedure requires only an estimate of the mean and standard deviation for each machinery set, plus a designated level of confidence for estimating the upper limits for total machinery costs.

Maximum affordable cost

The upper confidence level criterion can be restructured so as to fix the maximum total machinery cost affordable and estimate the probability of exceeding it for each machinery set. At each acreage level the set with the lowest probability is then chosen as the optimum.

Using the mean costs and standard deviations from tables 1 and 2 it was found that unless the maximum affordable cost is assumed to be close to the mean cost for a particular machinery set (within $5 to $10 per acre under the conditions assumed), the probability of exceeding it approaches zero or one. Where this is true for a majority of the machinery sets at a particular acreage level the information provided by calculating the probabilities is of little use. Most or all of the sets will be equally acceptable or unacceptable, and will either exceed the maximum affordable cost in most years or not at all.

Conclusions

The variability of total machinery costs as estimated in this study was small enough that the probable range of costs for a particular machinery set over the years can be expected to be narrow except when the smallest machinery sets are used at the highest acreage levels. This result was due partly to the effects of the progressive marginal tax rates, and partly to assumptions of some flexibility in the scheduling of field operations in years with fewer than average suitable field days. Since the primary source of high mean costs, timeliness cost, was also the main source of variation in total costs, the lowest cost sets in many cases also had the least variability. This was especially true at the higher acreage levels. This means that although it may be possible to include consideration of variability as well as level of costs in selecting machinery, choosing machinery sets on a least-cost basis will typically not result in a machinery set that presents a high degree of risk.

If the standard deviation of the total cost distribution can be estimated, the most practical way of incorporating this information into the machinery selection decision is probably to determine which machinery sets have total average costs not significantly higher than those of the least-cost set, and to choose the largest of these sets. Another workable method is to rank the sets according to their maximum expected cost (upper confidence limit). Both of these criteria require only one item of information related to individual risk preference - the degree of confidence to be used in comparing the average costs or in estimating the maximum costs. Other criteria require information regarding marginal substitution rates between risk and returns, or a maximum affordable cost both of which may be difficult to elicit from the typical producer.