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Paper

Appendix 1-d

ESTIMATES OF LONG-RUN MULTI CROPPING EFFICIENCIES FOR ALTERNATIVE CROPS[1]

by

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Abstract

Machine ownership, labor, and machine operating costs were minimized for four crops (corn, soybeans, oats, and alfalfa) in various crop proportions. These longer-run costs which are omitted in short-run studies add a perspective of the nature of cropping system economies. The results demonstrate considerable difference among crops and their proportions in systems in terms of cost reduction potential.

ESTIMATES OF LONG-RUN MULTI CROPPING EFFICIENCIES FOR ALTERNATIVE CROPS

Introduction

In cropping agriculture a number of potential economic benefits arise from growing multiple crops. If multiple cropping involves rotations, positive yield interactions among crops can increase gross returns compared to crops grown singly. Also, with rotations, fewer inputs are sometimes required (such as fertilizer and insecticides), weed control costs may be reduced, and machine operating costs may be reduced because of better soil tilth. Whether in rotation or not, two other economic benefits can result from multiple crop systems. One is risk reduction resulting from diversification. The other is reduced labor and machinery ownership costs because with multiple crops reduced labor and machine timeliness pressure allows smaller machinery-labor sets to complete field operations. This last factor and its quantification are the focus of this paper.

Currently there is much interest in whole-farm analysis. This interest is generally predicated on the proposition that growing crops in combination results in consequences which cannot be demonstrated by simply aggregating single crops. In this study, one aspect of this interaction is quantified, that being labor and machinery advantages of multi cropping.

Ignoring risk the overall long-run profit maximizing decision process made by producers of what crops to grow depends on two general components. The first is expected yields, prices, and operating costs (fertilizer, seed, etc.) for each crop. The second is the machinery-labor requirements and respective costs for various crops and cropping systems. Often the second component is omitted and a partial budget used to analyze how, in the short run, cropping systems should change as yields, prices, and operating costs change. Ignoring machinery and labor (assuming adequate capacity exists for any crop mix) is not only unrealistic, but may result in inaccurate short-run analysis. Assuming a given machinery-labor set is better for analyzing short-run change but one cannot be confident that any assumed machinery-labor set is optimal. The ideal approach is the simultaneous optimization of both 1) the shorter-run aspects of yields, prices, and operating costs for each cropping system as well as 2) the longer-run machinery-labor differences among systems. The former can be termed "partial budgeting" aspects while the latter is termed "backside" costs.

The quantification of the general economic incentives related to multi cropping arising from machinery-labor does not, in itself, result in direct conclusions about multi cropping for a specific firm. Were that the objective the machinery-labor component would simply be combined with the first component (yields, prices, and annual costs) and optimized. Were this done, however, it would be difficult to isolate which component was instrumental to the differences in returns among cropping systems, the longer run component or the short-run component.

Objectives

There are two objectives of this analysis:

1. to estimate the reduced (increased) long-run costs resulting from the inclusion of a crop in various proportions and sequences in a specific cropping system and

2. to estimate the general reduced (increased) long-run costs for a crop when included in a large number of cropping systems.

In the first case the costs or benefits of adding a crop are dependent upon the exact proportion and sequence of the crop relative to others. In the second case an attempt is made to generalize the impact across a large number of cropping systems.

General Procedure

The analysis proceeded in three steps.

1. An Integer Programming model optimizing returns above all costs (including machinery, labor, and machine operating cost) was constructed for an eastern Nebraska setting. In particular eleven timeliness periods were incorporated into the model with a number of machine sizes and types available. Four crops along with combinations of these crops were analyzed; corn, soybeans, oats, and alfalfa.

2. Machine ownership costs for depreciation and repairs were constructed on a per hour of use basis. For interest on invested capital a procedure was developed to accurately reflect interest cost decreases per hour of use as use increases per year. Labor costs were included in one-half person integers. Because machine operating costs are inseparable from machine choice, these costs were endogenized.

3. For a given acreage (640 acres), the machine ownership, labor, and machine operating cost, hereafter termed MOLMO, was found for each crop grown singly and proportional combinations of each crop (one-half, one-third, and one-fourth).

4. For different combinations of four crops the MOLMO costs were averaged to find the impact on costs of different crop proportions.

Machine-Labor Economics

Two factors are important in considering machinery cost impacts in multiple crop systems compared to single crop systems. When one crop is added to another, more machines may be required simply because the additional crop may require different machines. For example, in midwestern agriculture a grain harvesting head is required if soybeans are added to a corn system. Countering this, however, is that because each crop requires field operations in unique time periods or "windows," growing multiple crops may reduce timeliness pressure and thus a smaller machinery set may not only complete all field operations but do at a reduced cost compared to single-crop systems. A similar phenomenon holds for labor. Under complete specialization, labor may need to be significantly higher than where labor is "spread" over the growing and harvesting seasons using multiple crops.

To analyze the nature of this force for different crops the economics of labor and machinery must be incorporated into comparisons of alternative cropping systems. To do this requires a process of assuring that for any specified or potential cropping system, the optimum machinery-labor set can be determined. Here that is done with Integer Programming where machinery and labor costs were minimized for a specific crop mix (including associated machine operating costs).

This process requires a model to accurately express the costs of machinery and labor. Here an "average-year" programming model is used rather than a multi-period model. A multi-period model provides a simple framework for providing for the ownership costs of machinery by the purchase of machines and selling these when worn out. However if done in a proper manner, a one-period model can very closely approximate the expression of those ownership costs and avoid the enormous matrix size and computational problems of a multi-period Integer Programming model. Here machinery and labor can substitute, machines of various sizes of the same machine can substitute, machines of different sizes can substitute for different machines of different sizes, and substitution of herbicide-tillage methods can occur.

Costing For Depreciable Assets

Space limitations do not permit discussion related to the ownership costing of machinery beyond that described in the procedure section. A procedure was developed to linearize the nature of ownership cost relationships (author reference omitted).

Setting and Model Detail

Eastern Nebraska is the setting for the analysis. Four dryland crops were considered, corn, soybeans, oats, and alfalfa. For each crop, machinery operations were specified in eleven or less critical time periods. Limited space does not allow a listing of these. These time periods included two spring tillage and planting periods, weed tillage periods, alfalfa harvesting periods, an oat harvesting period, and early, medium, and late fall harvesting periods for soybeans and corn. All crops involved time conflicts in one or more periods with other crops. Historical weather records were used to estimate the average number of 10-hour days available for field work for each period. For this analysis it was assumed that because of weather risk, only 75 percent of those days would be available providing more confidence that machine capacity will be adequate.

A machinery dealer provided new costs and estimates of field performance for three tractors, three disks, three field cultivators, six planters, two grain drills, one rotary hoe, three cultivators, windrower and baler, and three combines - each with corn and grain head alternatives. These were included in the model as integer choices. Model costs were estimated for these as previously described with interest charged at 4 percent (real). An integer variable was included for labor in one-half person units. A $14,000 charge for each unit was included.

Because the focus of this analysis is directed to machine ownership, labor, and machine operating costs, costs of land and operating inputs as well as prices and yields for output are irrelevant. These would obviously be important to an overall optimization problem where the short-run partial budget economies are included with the longer-run economies estimated in this analysis.

Results

Specific

In this analysis crops are added to other crops in a proportional way. Further the sequencing of the inclusion of the crop is important. Thus, "branches" resembling a decision tree occur. The results of those branches for each of three initial crops are presented in Table 1.

The three basic crops (corn, soybeans, and oats) are each analyzed as initial crops and other crops added in different sequences. Alfalfa cannot be used as an initial crop because it requires a "nurse" crop oats for establishment.

When replacing 320 of the 640 acres of corn with soybeans, for example, a benefit of $57.42 per acre is achieved for all 640 acres. Thus, for the 640 acres, MOLMO costs are $36,751 less for 320 corn - 320 soybeans compared to 640 acres of corn. When oats is then added to corn-soybeans resulting in 213.3 acres of each, another $3.15 per acre benefit for all 640 acres is secured. Finally, when alfalfa is added resulting in 160 acres of all four crops, a $33.06 loss per acre occurs. Another view of this is that compared to 640 acres of corn, an equal mix of corn, soybeans, oats and alfalfa result in a decreased cost of $27.51 per acre (57.42 + 3.15 - 33.06). The addition of soybeans to corn generalizing across all additions has mixed (positive and negative) results. Oats is always positive and alfalfa is always negative.

When soybeans is the initial crop, the addition of corn results in mixed effects. Oats has positive benefits, and alfalfa is always negative. Starting with oats, the impact resulting from the addition of corn is mixed, soybean impacts are always positive and alfalfa impacts always negative.

Summarizing across all initial crops, the addition of oats always results in positive benefits with alfalfa having negative benefits. For corn and soybeans the results are mixed depending on particular settings. These results it must be noted are for specific initial crops and for specific proportional changes.

<u>General</u>

Sixty five combinations of corn, soybeans, oats, and alfalfa were constructed to examine the general effect on MOLMO costs for various cropping systems. The 65 systems are shown in Table 2. Because alfalfa can't be grown without the presence of oats, the 65 systems do not involve equal proportions of all crops. The proportions of crops covered includes zero, 20, 33.3, 40, 50, 60, 66.7, 75, 80, and 100.

All 65 systems were analyzed related to alfalfa. Alfalfa has had a long history associated with crop diversification. However, the results in Figure 1 demonstrate that while estimated MOLMO costs for alfalfa at 20 percent are not dramatically higher compared to other crops, these costs increase very dramatically thereafter.

For accurate estimates of other crops only the 37 systems not involving alfalfa were examined. This is because oats is tied to alfalfa establishment hence its estimate is biased relative to corn and soybeans using 65 systems because alfalfa has such high costs. For corn, costs increase as the proportion of corn increases. The opposite occurs for soybeans. Hence, combinations of corn and soybeans of one-third and two-thirds respectively would be predicted to be quite efficient relative to the opposite mix. For oats, a small decrease occurs over the 20-50 percent range but generally oat costs are generally stable and relatively low.

The results for the specific analysis previously discussed can be interpreted from the results shown in Figure 1. For example, a corn, soybean, oats, alfalfa system would involve the average of the costs for each crop in Figure 1 at 25 percent. That could be compared to the average of corn, soybeans, and oats at 33.3 percent to determine the impact of adding alfalfa as a last crop (-33.06 per acre from Table 1).

Conclusions

The impact of four crops on machine ownership-labor-machine operating costs were estimated for specific crop mixes as well as for general tendencies. The capacity for reduced cost as one crop is added to a mix depends on its costs relative to what is displaced. Corn, soybeans, oats, and alfalfa exhibit different costs depending upon the proportion of acres they occupy. From only the machine ownership-labor-machine operation cost standpoint, alfalfa is moderately costly to add to a crop mix in small proportions and increases rapidly for larger proportions. Soybean costs are high in small proportions but decrease for a large range. Corn cost is low in small proportions but then dramatically increases for higher proportions. Oats tends to be a relatively low cost enterprise across all proportions of acreages.

The costs estimated here only represent the longer-run backside" economies of mixing four crops. These costs are not included in partial budgeting short-run studies. The costs estimated here add a perspective to the understanding of the economic forces affecting cropping systems in terms of what crops in what proportions achieve system economies.

Table 1. Per Acre Benefits (Reduced Costs) and Losses (Increased Costs) from the Addition of Crops into Particular Sequences.[1]

Initial Crop	Second Crop	Third Crop	Fourth Crop
C	B (57.42)	0 (3.15)	A (-33.06)
C	O (37.13)	B (-23.44)	A (-33.06)
C	O (37.13)	A (-32.59)	B (22.98)
B	C (-.93)	O (3.15)	A (-33.06)
B	O (34.34)	C (-32.12)	A (-33.06)
B	O (34.34)	A (-85.94)	C (20.76)
O	C (-14.17)	B (23.44)	A (-33.06)
O	C (-14.17)	A (-32.59)	B (22.98)
O	B (41.39)	C (-32.12)	A (-33.06)
O	B (41.39)	A (-85.94)	C (20.76)
O	A (-113.75)	B (69.20)	C (20.76)
O	A (-113.75)	C (90.84)	B (22.98)

[1] The benefits or losses are additive. Benefits and costs are expressed based on 640 acres.

Table 2. Description of the 65 Crop Combinations Unsed for the General Analysis.[1]

1. C	23. CCBOA	45. COOOA
2. B	24. CBBOA	46. CCCOA
3. O	25. CBOOA	47. BBBOA
4. A	26. CBB	48. COAAA
5. CB	27. CCB	49. BOAAA
6. CO	28. COO	50. CCCO
7. BO	29. BOO	51. CCCB
8. OA	30. CCO	52. BBBC
9. CBO	31. OOA	53. BBBO
10. BOA	32. OAA	54. COOO
11. COA	33. BBO	55. BOOO
12. CBOA	34. OOAAA	56. OAAAA
13. CBOO	35. CCBBB	57. OOOA
14. CBBO	36. CCCBB	58. CCCCO
15. CCBO	37. CCOOO	59. CCCCB
16. BOOA	38. BBOOO	60. CBBBB
17. COOA	39. CCCOO	61. BBBBO
18. COOA	40. BBBOO	62. COOOO
19. BOAA	41. OOOAA	63. BOOOO
20. CCOA	42. CBBBO	64. OAAAA
21. BBOA	43. CCCBO	65. OOOOA
22. CBOAA	44. BOOOA	

[1] C, B, O, and A refer to corn, soybeans, oats, and alfalfa respectively. For this analysis the sequencing of crops is irrelevant except in practice A must follow O or A.

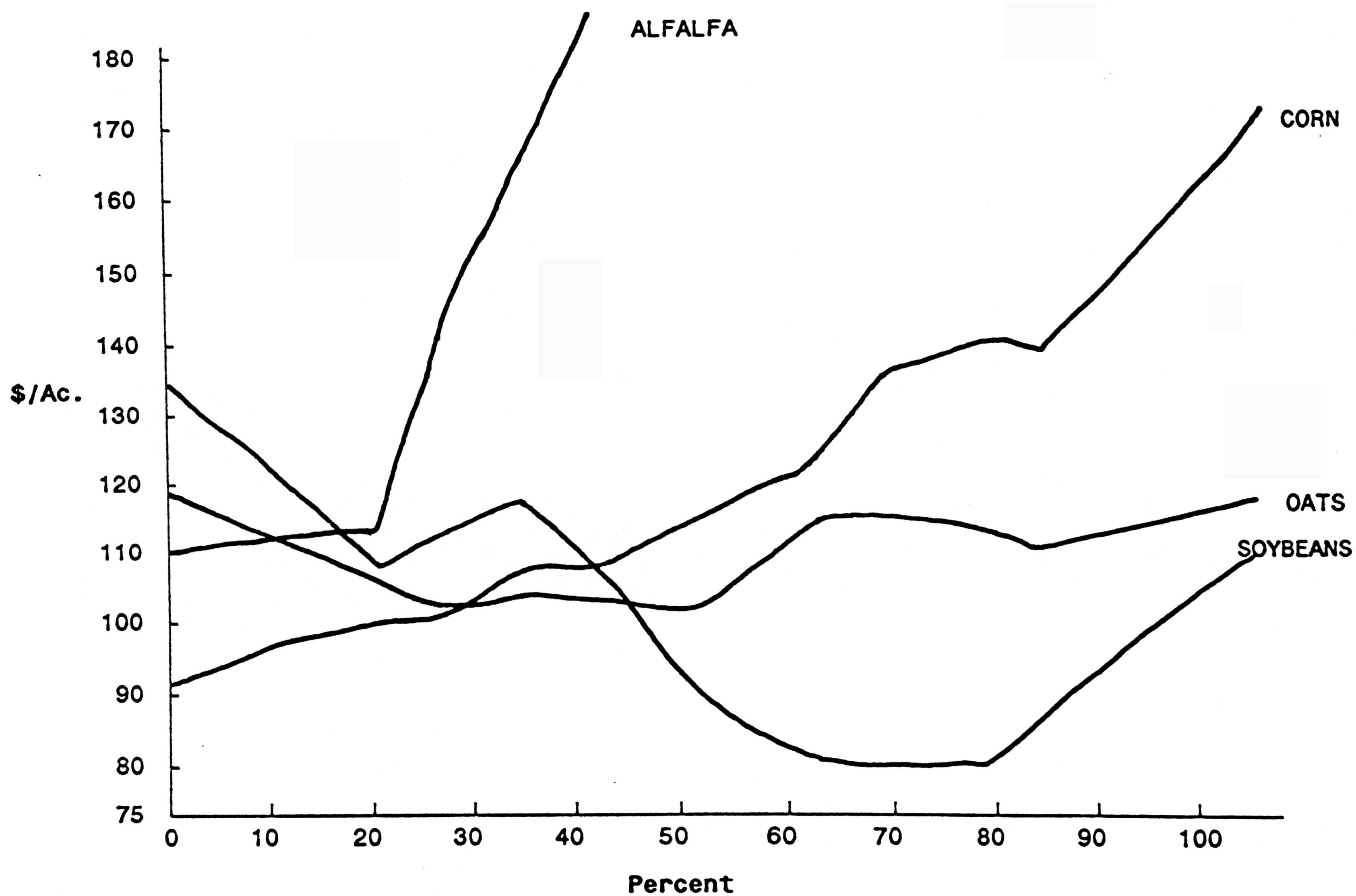

Figure 1. Machine Ownership-Labor-Machine Operating Cost By Crop at Alternative Percentages of 640 Acres of Cropland (Alfalfa Not Included Above 40 Percent).