Appendix 1-c

ESTIMATES OF BIAS AND IMPROVEMENTS IN SHORT-RUN PROGRAMMING MODELS FOR CROPPING SYSTEM ANALYSIS[1]

by

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Abstract

Benefits of rotational cropping involve reduced machinery-labor requirements as well as yield interactions. The latter are commonly included in crop budgets of rotations but the former are not. Thus, using crop budgets for cropping decision analysis is largely confined to short-run analysis. In this analysis, long-run machinery-crop benefits are estimated for a grid of alternative cropping systems from a large model, and these are imposed in short-run programming models. The purpose is to estimate biases in long-run solutions which arise from this procedure. The results demonstrate that bias is small when the grid of crop combinations are large.

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Introduction

Crop budgets are commonly developed to aid in the understanding of cropping system economics. Crop budgets are developed in various formats but almost always involve some degree of assumed input fixity. In that sense crop budgets act as a partial budget in which some factors are assumed to change but others remain constant.

Currently there is high interest in diversified agriculture and the benefits accruing to it. Often these benefits are described in a somewhat general manner. The focus of cropping system decision analysis is generally derived from single-crop budgets rather than a system oriented basis. Thus, it is difficult to quantify cropping system benefits and make optimum decisions for crop mixes where system benefits are involved. Fitting a single output and single input framework into a multi output multi input environment creates hazards. Yet the multi output and multi input environment with its interactions currently is receiving much interest.

Cost budgets for crops sometimes include a charge for machinery in terms of a rental charge. This is usually done for infrequently used machines. Generally, however, ownership costs of machinery is excluded. Labor costs are sometimes included, however the basis for its estimate is not well documented. Rarely, as with machinery, are its costs endogenously determined. Given the complexities for estimating costs of labor and machinery (hence also machine operating costs) these items are sometimes excluded from cost budgets.

There are various system benefits of rotational (as well as diversified) cropping. A commonly suggested benefit is reduced risk. Focusing only on profit maximization, three major factors cause rotational mixes of crops have advantages over single crop systems. These include 1) yield interactions among crops of a system, 2) reduced inputs, and 3) reduced machinery-labor costs. The latter occurs because under weather timeliness constraints, multiple cropping generally requires less machinery-labor compared to single crop agriculture. Yet most crop budgets ignore this aspect because they are single crop oriented with costs usually confined to operating costs. In either simplified partial budgeting analysis or programming analysis, ignoring the latter interaction can lead to erroneous solutions from a longer-run perspective. This is because the benefits of reduced machinery-labor arising from combining crops can only be secured by a model which endogenizes both the machine-labor choice and cropping system choice simultaneously. While benefits of yield interactions and input reductions can be included in crop budgets for specified crop mixes in the form of rotations, benefits from reduced machinery-labor costs have not been commonly credited.

One time-intensive procedure to achieving optimum solutions where system benefits are present is to construct large integer programming matrices involving ownership costs of various machines as well as their field time capacities in the face of detailed "windows" of field time availabilities. This also requires a proper method of incorporating long-run costs of machinery assets without biasing the solution (not using predetermined assumptions of use while solving for optimum use).

Even though long-run costs of machine ownership and labor are difficult to estimate, this does not mean that such costs are unimportant. Where there are significant long-run cost advantages of one cropping system over another it is expected that this will be evidenced in cropping system choices by producers. Again, of course, other cost factors as well as gross income differences between systems will also be important to those choices.

It is unclear how inaccurate short-run programming models and partial budgeting models using only a return over operating cost objective function are relative to the above norm. Only when compared in identical "solution space" can a comparison be made. A second issue is if the predetermined longer-run benefits to cropping systems can be estimated and then such benefits placed in simple return over operating cost models, can approximately close solutions be obtained to those from full models? When expectations of prices or costs change, it may be convenient to use simple programming models to examine optimum crop acreage change than large models. System benefits cannot technically be placed on a per acre basis because the benefits arise from a specified acreage assumption. Hence, when including system benefits in short-run models, only specified systems using all acres (integer) can be examined. Thus, this issue becomes one of how inaccurate a "scaled down" model using only gross returns over operating costs plus previously estimated system benefits is compared to a complete model which includes other inputs. If accurate, the reduced-cost benefits of alternative cropping systems and combinations of systems can be placed in crop budgets allowing a more complete perspective of the overall economics of crop choice. The second issue is if accurate programming solutions can be achieved with short-run models using combinations of systems.

Objectives

The objective of this analysis is to determine the feasibility of using predetermined long-run cropping system benefits in short-run models when comparing the overall economics of alternative cropping systems. A second objective is to assess the feasibility of using such benefits in programming models of cropping systems.

General Procedure

The analysis proceeded in three steps.

1. An Integer Programming model optimizing gross returns over operating inputs, machinery, labor, and machine operating cost was constructed for an eastern Nebraska setting. This model is hereafter referred to as long-run. In particular eleven timeliness periods were incorporated into the model with a number of machine sizes and types available. Three crops along with combinations of these

crops were analyzed: corn, soybeans, and oats. Seven systems were examined: corn, soybeans, oats, corn-soybeans, corn-oats, soybeans-oats, and corn-soybeans-oats.

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 included as a part of the longer run items.

3. For a given acreage (640 acres), the machine ownership, labor, and machine operating cost, hereafter termed MOLMO, was found for each of the seven systems.

4. For each system the reduced MOLMO costs (compared to corn) were entered in the objective function for each system into an identical short-run model except the objective function was maximization of returns over operating inputs.

5. Comparisons were made between the modified short-run model and the long-run model.

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 within and between crops.

Costing For Depreciable Assets

The economics of machine size, machine numbers, and machine-labor substitution hinge on an accurate costing of the various machines by hours of use. Otherwise, model results may vary considerably from use assumptions made in constructing costs. Estimating ownership costs of depreciable assets involves a number of complex issues particularly when those ownership costs are developed without an assumed life in years. Here that is done with two assumptions. One is that remaining value functions are linear and the second is that repair functions are linear.

Remaining value functions for machinery decline with use because of wear-out (reduced remaining service), increasing probability of down time and repairs, and preferences for newer machines. Thus, remaining value functions are frequently observed to be convex whether observed in a use or time context.

Costing depreciation and interest on investment for a convex remaining value function by time can be accurately accomplished by using present values and amortization. In fact, where convexity exists, the amortization process is the only process which can yield fully accurate estimates. The traditional method of estimating depreciation and interest separately becomes increasingly inaccurate as convexity increases. However, the amortization process involves assumptions of use per year which would eliminate the previously described economic forces important to a study of this nature. Thus a linear remaining value function is assumed here which results in a linear interest on investment cost function.

Depreciation

Wear-out is assumed to be directly related to machine use. Thus, original cost less salvage value is divided by lifetime hours of use. For example, the cost per hour of machine use of a machine with an original cost of $80,000, a salvage value of $5,000, and 2,000 lifetime hours is $75,000 ÷ 2,000 hr. or $37.50 per hour.

Interest on Investment

It is often suggested that interest on investment for a depreciable asset is fixed and invariant with respect to use. A simple example will demonstrate that this is not the case.

Suppose the above example again. Assuming a 10-year machine life results in a per hour interest on investment charge of $9.23 per hour. The mid-value (and using a beginning-of-year machine value basis) is $46,250. With a 4 percent real interest rate, this results in an annual average cost of $1,850.00. For 200 hours of use per year the opportunity interest cost is $9.25 per hour. Assuming 1,000 hours of use for two years would result in an annual interest charge of $2,450.00 or $2.45 per hour (based on a mid value of $61,250). Thus, considerable savings are derived from a smaller machine used for more hours as opposed to a large machine used fewer hours per year (assuming other factors constant). Thus, smaller machines used at a higher rate have an advantage over large machines. The challenge, however, is to incorporate this principle in an annual period programming model.

Assuming machine life (H) in hours and initial machine cost (V_o), depreciation (d) on an hourly basis is

1) $$d = \frac{(V_o - SV)}{H}$$ where SV represents salvage value

The depreciation cost per year is

2) $$D = dX$$ where X is the hours of use per year

In capital budgeting the annualized interest charge can be shown to be approximated by

3) $$I = \frac{(V_o + SV + D)}{2}\, i$$

where i is the annual interest rate. Substituting (2) into (3) one obtains

4) $$I = i\,\frac{(V_o + SV)}{2} + \frac{id}{2} X$$

The annual interest on investment cost consists of a fixed component (the first term) which is independent of the intensity of use and a variable component which increases with use (X). In Equation 4 per unit interest costs decrease with greater intensity of use while total annual interest costs increase as the useful life of the asset is shortened. Thus, the economic pressure for greater intensity of machine use due to the resultant reduction of average interest costs is properly modeled if a linear approximation (as a function of use) to the remaining value function is satisfactory.

Repairs

Cumulative repair function estimates are published for various machine classes (ASAE). While these are not linear, a linear assumption is not unrealistic because only an average is desired in annual-based models. Thus, cumulative repair costs are divided by hours of use.

Setting and Model Detail

Eastern Nebraska is the setting for the analysis. Three dryland crops were considered, corn, soybeans, and oats. For each crop, machinery operations were specified in eleven or less critical time periods. These time periods included two spring tillage and planting periods, weed tillage 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, 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.

In both the long and short-run model identical yield interactions (Friesen) were involved with some systems (corn-soybeans, corn-oats, soybeans-oats, and corn-soybeans-oats). Also, with these rotations, inputs such as insecticides change compared to continuous cropping. Fertilizer production functions for corn were also included with the functions different depending upon whether continuous or rotation corn. These aspects are important to crop system choice but are common to the two models. Crop budgets were based on Selley et al.

The overall model involves choice between herbicides/tillage/hand weeding. The herbicide tillage system here was restricted to a reduced-herbicide system for all crops to reduce interpretation complexity. Base prices for corn, soybeans, and oats in both models was $2.20, $5.50, and $1.25 per bu. respectively.

Results

Using the complete programming model which includes machine ownership, labor, and machine operating costs the reduced cost advantages for six cropping systems were secured. These were developed for 640 acres with corn as the base (zero reduced cost) crop. The alternative systems were soybeans, oats, corn-soybeans, corn-oats, soybeans-oats, and corn-soybeans-oats. These reduced-cost advantages are machinery ownership, labor, and machine operating cost differences for each system relative to corn. These cost differences are presented in table 1. They range (on a per acre basis) from $36.36 per acre for a corn-oats system to $88.64 per acre for a soybean-oat system. These cost differences among systems only present part of the system economic difference because the "partial budget" side would need to be considered for overall economic comparisons. That is, gross returns and input cost differences among systems may well override the differences of Table 1. Clearly such is the case even when machinery ownership, labor, and machine operating costs are totally excluded from budgets.

Use in Cropping System Comparisons

As indicated above partial budgeting components can override the cost advantages (in this case in comparison to corn all systems have advantages) of Table 1. This is easily tested by taking the short-run model with imposed system advantages attributed to the objective function for each system and examine the change in the price of corn for 640 acres of continuous corn necessary to give the same objective function. Similarly the long-run model could be used. These were found to be identical in both models. Thus, a short-run budget analysis which includes system advantages is a mirror of the overall long and short-run economics of systems if systems are confined to total farm acreage (not divisible).

Short-Run Programming

The inclusion of the previously described system economics are useful for comparing overall economics of alternative systems used fully for all acres. Placed on a per acre basis and used in a divisible basis for programming purposes, however, is another matter. To examine the extent of bias from this the short-run programmed objective functions (including system advantages) are compared for seven cropping systems to the long run solutions. These are presented in Figure 1 with the estimated objective functions included in Table 2.

In Figure 1 the seven system objective functions are graphed simultaneously. The long-run objective functions are fully costed hence except for the optimal long-run solution all objective functions are negative. Such is not the case with the short-run matrix because only gross returns less input costs are included.

Clearly, it can be expected that solutions are generally upward-right dominant. Such is obviously the case as is shown in Figure 1. The slight lack of correspondence of continuous beans and corn-beans is due to a labor selection reason. In the long run model hired labor was required but operator labor was "free" in the short-run model. The difficulty of the approach attempted here lies in the optimal solution. The long run solution is achieved by optimizing the long-run model. This solution, however, cannot be secured using the short-run model. The long run solution involves 144 acres of continuous soybeans and 248 units of corn-soybeans. When this solution is forced into short run space it is located as indicated.

Conclusions

For comparing the overall economics of various cropping systems it has been seen that imposing long-run cost differences among systems to short-run budgets allows accurate performance using modified short-run budgets. At the same time, placing such cost differences on a per acre basis and incorporating these into short-run programming models will not necessarily result in accurate estimates of optimal long-run solutions.

Detailed integer programming models involving machinery and labor choices allow these long-run cost differences to be estimated. It is recommended that greater emphasis be placed on estimating such benefits and validation of producer behavior be studied to determine how important long-run cost differences among systems are in practice.

Table 1. Estimated Reduced Costs By Cropping System for Machine Ownership, Labor, and Machine Operation Using Continuous Corn as the Reference.

System	Benefit[1]
Corn	0
Soybeans	79.39
Oats	74.48
Corn-Soybeans	51.49
Corn-Oats	36.36
Soybeans-Oats	88.64
Corn-Soybeans-Oats	58.20

[1] Per acre for all acres.

Table 2. Objective Functions for the Two Models for Seven Systems and Optimal Solution.

System	Long-Run Model	Short-Run Model
Corn	-93,417	75,904
Soybeans	-25,106	146,169
Oats	-78,454	90,867
Corn-Soybeans	-24,978	144,342
Corn-Oats	-70,339	98,982
Soybeans-Oats	-28,909	140,413
Corn-Soybeans-Oats	-41,811	127,509
Optimal	12,655	144,753[1]

[1] From forcing in long-run optimal solution.

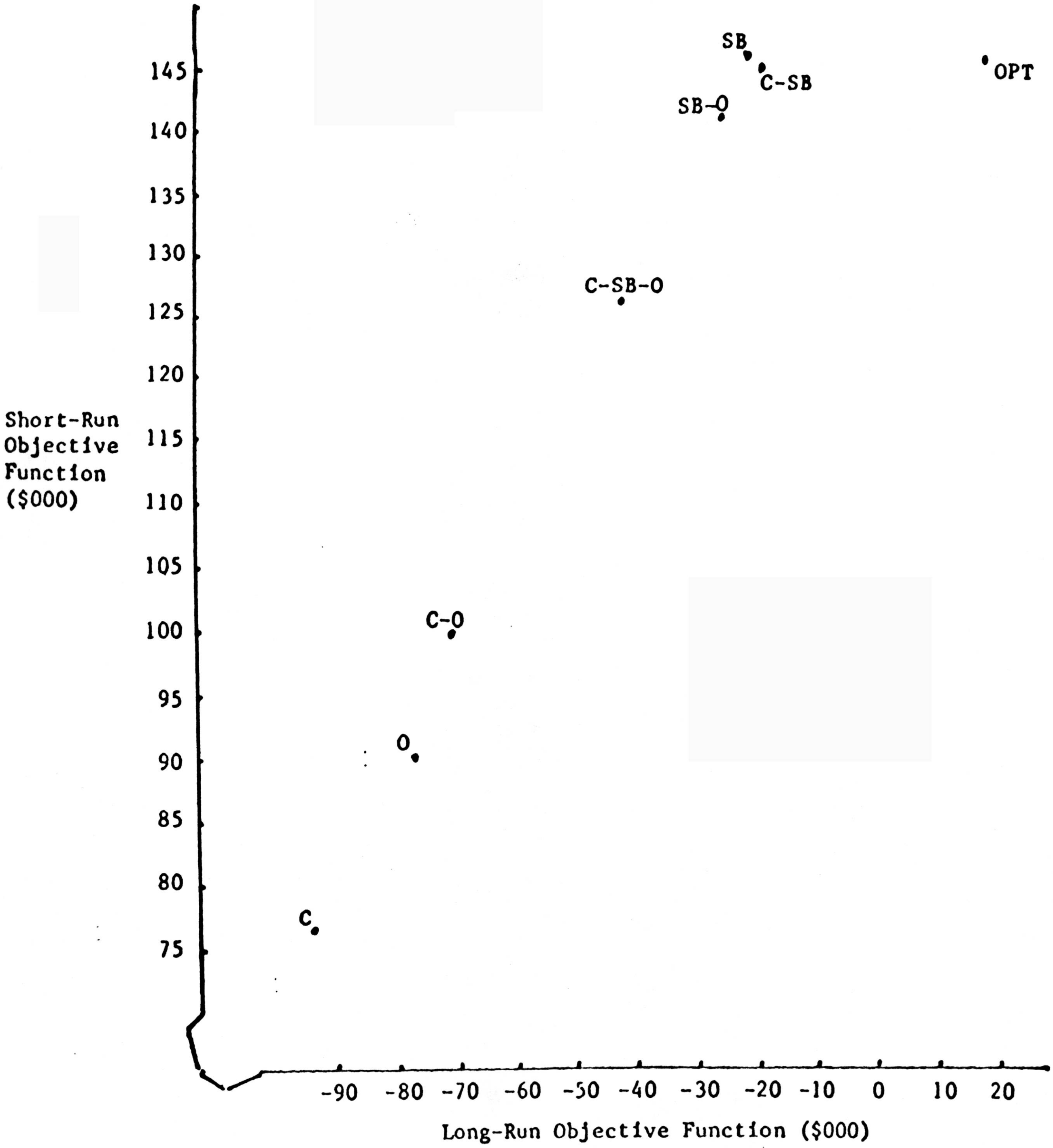

Figure 1. Solutions to Modified Short-Run Model Vs. Long-Run Model for Corn (C), Soybeans (SB), Oats (O), Corn-Soybeans (C-SB), Corn-Oats (C-O), Soybeans-Oats (SB-O), Corn-Soybeans-Oats (C-SB-O), and Optimal Long Run Solution.

References

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