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Spreadsheet Analysis of Harvesting Systems

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SUMMARY

Harvesting systems can be modeled and analyzed on microcomputers using commercially available "spreadsheet" software. The effect of system or external variables on the production rate or system cost can be evaluated and alternative systems can be easily examined. The tedious calculations associated with such analyses are performed by the computer. For users familiar with harvesting cost analysis, a minimum amount of training is necessary to use the methodology described. This paper presents the basic procedure for implementing system analysis with a spreadsheet program.

INTRODUCTION

The repetitive calculations involved in determining an optimum mix of harvesting equipment, predicting system costs and production rates, or evaluating alternative systems can be a tedious chore for a logging manager or forest engineer. Simply because of the time required, optimization of harvesting systems "by hand" is difficult and expensive. Microcomputers, with their speed and relatively low cost, can inexpensively perform the same calculations in a fraction of the time. Using an electronic spreadsheet program as a calculation tool, a person with no previous programming experience can successfully formulate and solve many harvesting system problems. VisiCalc, SuperCalc, and Lotus 1-2-3[1] are examples of commercially available spreadsheet software widely used in business and accounting applications. Many logging managers may already be familiar with the mechanics of spreadsheet operation.

[1]The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

SPREADSHEET SOFTWARE

An electronic spreadsheet is a grid of rows and columns stored in computer memory and displayed on the computer screen. The intersection of a row and a column is called a cell. For example, cell Al is the intersection of column A with row 1. The user can put words, numbers, or formulas into any cell of the spreadsheet. The computer automatically performs all the calculations indicated by the formulas placed in the cells.

The power of spreadsheets derives from the use of cell addresses, or references, in formulas. Cell B3, for example, could contain the formula "B1 +B2". The computer would add the value in B1 to the value in B2 and display the result in B3. The actual contents of cell B1 and B2 could be numbers or formulas that generate a number. Using cell references in formulas establishes an interrelationship between the cells of a spreadsheet. Changing any formula or number is a simple matter and the entire spreadsheet is automatically recalculated showing the effect of the change. The ease of recalculation makes the spreadsheet a valuable tool, providing the ability to answer "what if" questions.

HARVESTING SYSTEM ANALYSIS

Traditionally, harvesting system analysis is done by hand using an iterative, what-if approach. Starting with some basic assumptions-average d.b.h., acres in the tract, machine rate, etc.-production rates for each element in the harvesting system are estimated with appropriate regression equations. The production rates for all of the elements in the system are examined to determine the element with the minimum production rate. This limiting element determines the actual utilization of every other element in the system and fixes the system production rate and cost. After calculating an initial system production rate and cost, the logging manager adjusts the system, altering the balance of equipment for exam

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ple, and recalculates the system production rate and cost. It is possible to arrive at a practical optimum system balance or to determine the effect of changing stand and system variables with this approach, but it can be tedious and time consuming.

The procedure outlined above is easily incorporated into a spreadsheet. A simple spreadsheet model of a harvesting system will have two sections-a section of basic assumptions about the stand and system, and a section to calculate a production rate for each element in the system. A spreadsheet function that determines the minimum value in a specified range of cells is used to find the element with the lowest productivity. Given the basic system configuration and the limiting production rate, the spreadsheet can calculate system production rate, system cost, and actual utilization rates for each of the system elements. A simple example will serve to illustrate the mechanics of calculating a production rate with a spreadsheet.

SHORTWOOD SYSTEM EXAMPLE

An analysis of a shortwood harvesting system might require the determination of a production rate for manually felling, limbing, and bucking the wood. A regression equation that estimates a volume production rate for this system element might be:

$$\text{Cords/Productive MachineHour} = -0.6035 + 0.2536^*\text{DBH} - 0.0052^*(\text{DBH}^2)$$

Given an average d.b.h. for the stand and a utilization rate (productive hours/scheduled hour), the production rate for this element can be determined.

$$\text{Cords/Scheduled Hour} = \frac{\text{Cords}}{\text{PMH}} \times \frac{\text{PMH}}{\text{SMH}}$$

where: PMH = Productive Machine Hours
SMH = Scheduled Machine Hours

Production costs can then be calculated using appropriate fixed and variable costs.

This example, entered in a spreadsheet program and displayed on the computer screen, might look like figure 1. Cell Al contains the title “Av. DBH”. Cell B1 contains the value of the average d.b.h., 10 inches. The regression equation, entered in cell B3, calculates a production rate based on the average d.b.h. value in B1. Production per SMH is calculated by the equation in cell B4. The assumed fixed and variable costs are applied to the calculated production rate to arrive at a cost for this element (cell B5).

Once the spreadsheet has been laid out, it is a simple matter to change numbers and recalculate. For example, to determine the effect of larger timber on production cost, change the d.b.h. in cell B1. The spreadsheet automatically recalculates all the formulas and displays the new values.

An entire harvesting system can be set up in a similar fashion. Figure 2 illustrates a section of a spreadsheet model for a shortwood system that includes manual felling, limbing, bucking, handpiling, forwarding to set-out trailers, and hauling to a wood yard or mill. This spreadsheet calculates a production rate (column E) for each element of the system using the maximum utilization for the element, a regression equation, and the number of production units (i.e., men or machines) assigned to the element. The minimum production rate of all the elements is the limiting factor that determines the system production rate. In figure 2, the system production rate is the minimum value of cells El9 through E22 and is calculated in E23.

The system production rate is used to calculate the actual utilization of each element. The actual utilization is, in turn, used to calculate element costs based on a cost equation and the number of production units. Woods labor costs, in this example, are calculated as a separate item based on production. Cell H24 simply multiplies the number of workers times the system production rate by the labor cost per man per cord. Total system cost is the sum of all the previously calculated costs.

Starting with a system description like figure 2, the spreadsheet can be expanded to the required level of detail. If, for example, the user wanted to evaluate the effect of haul distance on system costs, more data might be included to determine the hauling production rate. An additional section could be added to the spreadsheet to calculate the hauling production rate as a function of haul distance and average travel speed. Similarly, when the effect of stand composition is a concern, the value of d.b.h. used in the regression equations can be developed from a stand table included in the spreadsheet.

APPLICATIONS

A spreadsheet can be used to help solve many system analysis problems. Depending on the complexity and configuration of the spreadsheet model, the user can evaluate the effects of system balance or external variables on production rate and system costs. With a spreadsheet, the system configuration can be altered to

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	A	B	C	D
1	'Av. DBH	10	'DBH SQ	B1**2
2	'Fixed $	4.94	"Variable $	3.00
3	"Cds/PMH	-.6035+.2536 B1-.0052*D1	'Utiliz'n	.5
4	"Cds/SMH	B3*D3		
5	"$/SMH	B2+D2*D3		
6	'$/Cd	B5/B4		

Figure 1 .-*Sample spreadsheet showing the formula content of the cells.*

	A	B	C	D	E	F	G	H
18	"Element	'Units	"Cds/PMH	'Max Util	"Cds/SMH	"Act. Util	"$/SMH	"$/Cd
19	• Feil,L6B	5	B19*Eq'n	.5	C19*D19	E23/C19	B19*Cost	G19/E23
20	'Handpile	5	B20*Eq'n	.5	C20*D20	E23/C20	B20*Cost	G20/E23
21	"Forward	1	B21*Eq'n	.69	C21*D21	E23/C21	B21*Cost	G21/E23
22	"Haul	2	B22*Eq'n	.9	C22*D22	E23/C22	B22*Cost	G22/E23
23	'No. men	SUM(B19:B22)			MIN(E19:E22)		SUM(G19:G22)	SUM(H19:H22)
24					'System cds/SMH	E23	"Labor $/cd	B23*E23*Cost
25							'Total S/cd	H23+H24

Figure 2.-*Spreadsheet model of a hypothetical shortwood harvesting system.*

determine the performance of alternative systems. Because of the ease of manipulation and speed of calculation, many alternatives can be examined and an optimum configuration identified.

LIMITATIONS

While spreadsheet analysis has many possibilities, some limitations and cautions should be noted. As with any computer application, the results of the spreadsheet analysis are only as good as the information used to calculate them. The user must insure that the formulas and numbers used in the spreadsheet are appropriate for his application. For example, a regression equation for skidder production based on studies conducted in steep terrain may not accurately predict production rates in a swampy setting. Likewise, data from sparsely stocked, natural stands may generate misleading results in an analysis of a system for evenly spaced, planted stands. Cubbage (1983) discusses the various kinds of production data available and notes some of the limitations associated with using each type.

Finally, users should understand that a spreadsheet model, developed with the methodology presented here, is a static model. There is no provision for dynamic interaction between system elements or the occurrence of random events. The interference between skidders and feller-bunchers might, for example, cause significant delays that would not be accounted for in a spreadsheet. Mill shutdowns could cause system delays that are not included in the model. Additionally, there is always variation in production rates that cannot be explained by the regression equations. While the spreadsheet may give a reasonable approximation of system performance, actual production rates will vary due to random events and the effect of factors not included in the model.

CONCLUSION

The prudent application of the methodology presented here can provide a useful tool for forest engineers and logging managers. There is a large body of formulas and data that can be used in this type of analysis. Cubbage (1983) summarizes some of the available material relating to the harvest of southern pines. Requiring only a moderate amount of effort and investment, spreadsheet analysis offers an alternative to costly simulation programs and allows the user to concentrate on decision-making rather than calculating.

LITERATURE CITED

Cubbage, F.W. 1983. Harvesting productivity information for southern pines. Southern Journal of Applied Forestry. 7(3):128–134.

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