Estimating Field Machinery Cost: A Whole Farm Approach

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ABSTRACT

A Lotus 1-2-3 spreadsheet program has been developed to calculate machinery costs on a whole farm level. The Whole Farm Machinery Cost Program estimates machinery costs for multiple enterprises or crops, allows flexibility in field operation parameters to accurately reflect machinery field requirements under various conditions, and summarizes results for a whole farm analysis. The program is designed to provide machinery costs on a per-hour and per-acre basis. Field operations are summarized by crop enterprise to obtain cumulative ownership, repair, labor, and fuel costs per acre. Results from the program may be transferred to other decision aid or budgeting applications. This program has been useful for: (i) teaching fundamentals of machinery cost analysis to producers and within the traditional classroom; and (ii) applied multidisciplinary research projects.

FIELD MACHINERY is a major component of farm production expenses. Producers make decisions concerning the replacement of individual machines, changing of tillage practices, and whether to own specialized equipment or custom hire. For crops that require specialized equipment on a relatively small number of acres, there is concern about the economic aspects of owning and operating these specialized equipment items versus leasing or having field operations custom hired.

A whole-farm basis for evaluating field machinery costs is important when: (i) the use of machinery is shared between several enterprises; (ii) machinery is used under a range of conditions (e.g., speed, field efficiency, fuel use); and (iii) machinery costs are compared for different situations such as farm size or production practices. Machinery costs are often difficult to estimate for applied research, extension programs, or teaching. However, microcomputers present an opportunity to incorporate a whole farm perspective for machinery cost estimation and management decisions.

Computer programs have used various techniques and assumptions for budgeting and economic analysis of field machinery costs (Cawich and Slocumbe, 1991; Huhnke et al., 1990; McGrann et al., 1986; McGrann and Ellis, 1987; Siemens and Gui, 1986; Siemens et al., 1988; Sowell et al., 1988). These approaches have been based on individual enterprises or at most have limited whole farm machinery linkages.

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Machinery costs are classified as either operating or ownership (ASAE Standard S495; ASAE, 1996a). Operating costs include labor, fuel, and lubricants. Ownership costs of machinery are often referred to as DIRTIS, which represents depreciation, interest, repairs, taxes, insurance, and shelter (Forster and Ervin, 1981). DIRTIS costs have often been described as *fixed annual* costs; however, in the case of machinery, repair costs are generally a function of usage. Depreciation of machinery represents the decline in value between the initial capital outlay and ending salvage value. Depreciation is often described as comprised of the components: (i) loss in value as a function of usage, and (ii) loss in value due to technological obsolescence. Consequently, depreciation may include both a use dimension and obsolescence or age dimension (time).

Depreciation is a critical element in estimating machinery ownership costs and the calculation method can be important (Robb et al., 1990). Traditionally, economists assumed depreciation is based only on TIME (e.g., years), which results in a fixed annual depreciation charge, but the per unit charge will vary as annual use changes. As stated in the ASAE Standard EP496.2 (ASAE, 1996b), "depreciation for crop accounting may be spread evenly over the accumulated 'USE' of the equipment." The ASAE standard implies a constant depreciation charge per unit of use, resulting in a variable annual depreciation charge. In applied analysis, it is often useful to calculate depreciation as implied in the ASAE standard.

Maintenance and repair costs are difficult estimations. Factors affecting repair costs include machine life, preventive maintenance and care, field conditions, and operating speed. Estimates of maintenance and repair costs used within the model described here are based on a wide range of operating conditions discussed by Rotz and Bowers (1991) and Rotz (1987).

Applied analyses often require machinery cost programs to have the ability to vary field efficiencies and field speed parameters for the same machine operating in different field operations. For example, a disk is often used in the spring for heavy tillage, whereas in the fall the same implement may be used at a shallow depth to cut and lightly incorporate residue for erosion control purposes. Obviously, the two field operations have different fuel requirements, labor requirements, and operating speeds. Another example of field operating variations is the speed for sugarbeet (*Beta vulgaris* L.) planting and early row cultivations, which is much slower than for most other field crops. However, the authors recognize that as additional data are required, and as more flexibility is incorporated into any software package, the potential for data problems (availability and entry errors) also increases.

The objectives of this paper are to:

1. Describe a unique machinery cost program that calculates machinery costs on a whole farm level
2. Provide examples of applications

SPREADSHEET DESCRIPTION

A microcomputer spreadsheet program, WFMACH$ (Whole Farm Machinery Cost Estimation Program) has been developed and documented (Robb and Ellis, 1991) to calculate the economic costs and budgeting of field machinery operations. Version 2.2 of the WFMACH$ spreadsheet program totals 256K and is designed to operate by using the macro programming features of Lotus 1-2-3 (release 2.01 or later) on an IBM-PC or compatible computer. Required hardware includes a minimum of 640K RAM, a printer, and either a color or monochrome monitor. The software is available on a 3.5-inch high density disk and includes a 61-page user's manual. The software and user's manual can be purchased for $15 from the University of Nebraska Panhandle Research and Extension Center, 4502 Ave. I, Scottsbluff, NE 69361. Request "CP 8 WFMACH$—Whole Farm Machine Cost Estimator."

WFMACH$ was developed with the flexibility to meet the requirements and concerns in applied research and educational activities. Interest, depreciation, repairs, and fuel costs can be calculated by field operation, accumulated by enterprise, and then totaled for a whole farm analysis. The unique features of the WFMACH$ program are fivefold. Although several of these features are available in other machinery cost software, not all these features are known to have been incorporated into a single program. The five features are discussed below.

Two Depreciation Methods. WFMACH$ offers the user the flexibility to decide whether to base depreciation on either TIME or USE. However, several input parameters must be modified for each equipment item when the method of depreciation is changed.

Annual Use Calculated. As previously described, an estimate of annual use is a required input of most machine costing programs. Incorrect estimates of annual use can lead to significant errors in estimating field machinery costs. The influence of annual use is very crucial in calculating ownership and repair costs. Estimating annual hours of use is challenging, especially as analyses are performed for different tillage systems or different size of farms. One of the most advantageous features of WFMACH$ is the computation of annual use based on individual field operations, then aggregation to a whole farm level. Field capacity is based on agricultural engineering practices defined in ASAE Standard EP496.2 (ASAE, 1996b), and user-defined speed, width, and field efficiency. The user is able to evaluate machine cost differences for varying crop acres and different equipment complement sizes.

Average Cost Period. The capability of calculating repair and ownership costs for the next budgeting period (one production period, e.g., year) or the average cost over the remaining life for each machine is a feature incorporated in WFMACH$. Questions often arise as to the length of period or number of units (hours or acres) over which the estimated repair and depreciation costs have been or may be accumulated. Machine costs may be based on an average cost over the remaining life of the machine or over the next budgeting period. This latter feature is useful when comparing costs of newer and older equipment.

Calculated vs. Predefined Costs. The fourth feature is the ability to input user-defined costs for individual machines. The user can specify for each machine whether calculated or user-defined costs should be used. Substituting previously calculated machinery costs in the section for actual costs sometimes helps maintain consistency for comparative purposes. By using simple spreadsheet formulas, the user may mix user-defined costs into the analysis without modifying the underlying formulas within WFMACH$. For example, user-defined repair costs may be used along with the calculated ownership costs for individual machines.

Three Machinery Classifications. WFMACH$ is designed to accommodate three types of machinery. The classifications are based on productivity units that the user determines most appropriate for each individual machine. The three different machine classes and associated units of use are as follows:

1. Tractor/self-propelled machinery use measured in hours
2. Implement use measured in acres
3. Equipment use measured in bu, ton, etc.

The equipment component of WFMACH$ (item 3) is designed to incorporate those equipment items for which productivity is not based on hourly or acre units. This module calculates hourly costs and facilitates, using prompts, the conversion process to a per-acre basis. The conversion process occurs during the entry of field operations for equipment items. After identifying the measurement units (bu, ton, etc.), WFMACH$ will prompt the user for two responses, which facilitate the conversion process. For illustration purposes, assume a grain cart, generally measured in terms of bushels (in the USA), is the selected equipment item. The first prompt "What is the capacity in bushels/h for the grain cart" and the second prompt "What is the capacity in bushels/acre for the grain cart" will be displayed for the user to respond. Further, assume the cart can handle 300 bushels/h and the corn crop is averaging 150 bushels/acre. The calculated capacity would be 2 acres/h (300 bushels/h ÷ 150 bushels/acre). When used with caution, this feature allows the user great flexibility in calculating costs for many types of machinery items.

INPUT PARAMETERS AND CALCULATED VALUES

The WFMACH$ program consists of three major input areas. Tables 1, 2, and 3 illustrate the required inputs and cost calculations for each of the three areas. Global parameters that influence machinery and field operating costs are presented in Table 1. The user inputs values used in the calculation of those costs associated with interest or opportunity costs, labor, fuel, taxes, and insurance. The options of basing depreciation on TIME or USE and the budgeting period on expected ownership life or anticipated annual use are also entered in the General Parameters section.

The second area of input requirements consists of three sections: power unit, implement, and equipment parameters. Table 2 illustrates parameters required to estimate power unit repair and ownership costs. Input requirements for implements and equipment items are similar. The primary parameters are current, salvage, and list price values, remaining ownership period, and engineering repair cost factors. The program allows a maximum of 12 power units, 18 implements, and 10 equipment items.

Estimating current and future salvage values is a challenge. The values may be estimated by the user or calculated based on agricultural engineering depreciation coefficients (ASAE D497.2; ASAE, 1996c). A Lotus 1-2-3 macro may be invoked to provide a format to estimate values for each machine item.

For each machinery item, the user has an option of identifying either calculated or user-defined costs. The user-defined option should only be used if actual records are available, or if the user is not comfortable with the calculated costs.

The third set of parameters are factors associated with field operations (Table 3). The power unit, implement or equipment item, operating speed, fuel and labor requirements, and other miscellaneous cost items are primary inputs for estimating field operating costs. Actual values, if known, or estimated values may be used. Examples of sources for this information include ASAE Machinery Management Data Standard EP496.2 (ASAE, 1996b) and Parsons (1980). Machinery selected for an individual field operation may include one power unit and one or two implements. The ability to include two implements creates the opportunity to model field operations in which implements are pulled in tandem. The design of the WFMACH$ program allows for varying field operating parameters for similar field operations. Calculated values include field capacity, labor and fuel costs/acre, and estimated repair and ownership costs for the combined machinery complement. The program has the capability to allocate machinery costs to seven different enterprises with each enterprise consisting of up to 18 field operations.

Eight reports are generated from the Whole Farm Machinery Cost Program. The reports include a listing of general parameters (Table 1), parameter and machine cost calculations for the three machine classifications (Table 2), identification of field operations and costs associated with each operation (Table 3), machinery ownership and repair costs on a per-hour or per-acre basis, and summary of cumulative enterprise and annual machine costs. Graphical com-

Table 1. General input parameters for WFMACH$ program that apply to all power units.†

Interest costs (%)	11.00%		
Operating labor ($/h)	$5.50	Depreciation based on	
Tax/housing/ins. (%)	1.00%	(T)ime (yr) or (U)se	T
Diesel ($/gal)	$1.00		
Gasoline ($/gal)	$1.00	Budget period based on	
Electricity ($/kwh)	$0.06	(O)wnership life or (B)udget year	O
Propane ($/gal)	$0.40		

† Input data is required for the underlined values. Default values are provided but may be changed. Tax/housing/ins. value is a percentage of purchase price per year.

Table 2. WFMACH$ program input parameters and calculated values for specific power units.†

Power unit	180 hp	150 hp	Combine
Current value	$75 000	$52 000	$90 000
Salvage value	$7 500	$5 200	$9 000
Hours of ownership left	12 000	12 000	3 000
Annual hours specified	**642**	**603**	**157**
Additional hours used	0	0	0
Current no. of hours	0	0	0
Equiv. list price	$75 000	$49 000	$90 000
Repair Factor 1	0.007	0.007	0.04
Repair Factor 2	2	2	2.1
Eng. estimated life (h)	12 000	12 000	3 000
Calculated costs (based on ownership period)			
Interest cost ($/h)	**$7.07**	**$5.22**	**$34.65**
Depreciation ($/h)	**$5.63**	**$3.90**	**$27.00**
Tax/housing/ins. ($/h)	**$1.17**	**$0.86**	**$5.73**
Repair cost ($/h)	**$6.30**	**$4.12**	**$12.05**
Actual costs			
Interest cost ($/h)			
Depreciation ($/h)			
Tax/cousing/ins.			
Repair cost ($/h)			
Annual costs			
Interest cost	**$4 537.50**	**$3 146.00**	**$5 445.00**
Depreciation	**$3 610.18**	**$2 349.89**	**$4 242.86**
Tax/housing/ins.	**$750.00**	**$520.00**	**$900.00**
Repair cost	**$4 043.40**	**$2 480.03**	**$1 894.22**

† Bold face values represent calculated data. Single underlined values require input data. Default values are provided by the program for the single underlined input data but these default values should be replaced with known values, if available, to address the specific application. Actual costs should be provided as input in the "Actual costs" section, if known.

Table 3. WFMACH$ program field operation input parameters and calculations for implements assigned to specific power units.†

Field operation	Power unit	Machine 1	Machine 2	Width	Speed	Field Eff.	Capacity	Acres/trip
				ft	mph	%	acres/h	
Disk	180 hp	Disk 24 ft		24	4	85	**9.89**	300
Plow and pack	180 hp	Plow 6-18″	Packer 9 ft	9	4	90	**3.93**	300
R. Harrow-1	180 hp	R. Harrow 21 ft		21	4	85	**8.65**	300
Plant	150 hp	Plant 8-30″-1		20	3	90	**6.55**	300
Cult-1	150 hp	Cult 8-30″1		20	2.5	85	**5.15**	300

Field operation	Hours of use	Labor mult.	Labor	Fuel	Fuel/lube	Misc.	Repair cost	Ownership cost	Total costs
		%	$/acre	gal/h	$/acre				
Disk	**30.3**	120	**0.79**	9	**0.85**	0.00	**1.14**	**3.02**	**5.80**
Plow and pack	**76.4**	120	**1.99**	10	**2.38**	0.00	**2.88**	**5.50**	**12.74**
R. Harrow-1	**34.7**	120	**0.90**	9	**0.97**	0.00	**1.04**	**3.29**	**6.20**
Plant	**45.8**	130	**1.29**	7	**1.00**	0.00	**1.52**	**9.23**	**13.03**
Cult-1	**58.2**	130	**1.64**	7	**1.27**	0.00	**1.19**	**2.59**	**6.69**

† Single underlined values represent input values. Bold face indicate calculated values.

parisons of enterprise costs as illustrated in Fig. 1 may also be displayed. The format of the figures and reports within the Lotus 1-2-3 framework provides the user the capability of linking or combining results into other spreadsheet budgeting or decision aid tools.

APPLICATIONS

The WFMACH$ program has been utilized to evaluate the machinery cost component of several applied economic analyses. Primary comparisons have involved machinery costs for varying row spacings and cropping rotation changes. Other applications have focused on generating field machinery ownership and operating costs for enterprise budgets based on a *typical* farm.

Sugarbeet Equipment Sizes

One analysis compared 6-22 (6 row, 22 inch row spacings) row and 12-22 row equipment costs for a sugarbeet enterprise. Typical field operations were used for a western Nebraska gravity irrigated farm. Depreciation and repairs per unit (hours for power units and acres for implements) were assumed equal for both machinery complement sizes. The only ownership cost differences were in the interest and taxes/housing/insurance components. The reduced labor and fuel costs for operating the larger equipment complement offset the increased interest and taxes/housing/insurance costs associated with the higher valued machinery. The analyses calculated the advantage of 12-row over 6-row equipment to range from $8.97/acre at 100 acres of annual use to more than $18.00/acre at 300 acres of annual use. Assuming depreciation and repairs remain constant per acre for different size machinery, larger equipment was more economical than smaller equipment for larger size farms.

Comparison of Calculated vs. Custom Rate Costs

Another application evaluation was made by comparing field operating costs calculated by the WFMACH$ program to typical western Nebraska custom rates (survey summary data reported by Massey, 1990a,b) for a corn (*Zea mays* L.), dry edible bean (*Phaseolus vulgaris* L.), and sugarbeet farm. Farm diesel fuel costs were set at $0.85/gallon, labor costs at $6.50/h, and interest on machinery investment at 10%. Two case farms with 450 and 900 acres, respectively, equal acreage for each crop, 30-inch rows, and identical equipment complements were modeled in the WFMACH$ program. As shown in Table 4, calculated machinery costs for sugarbeet exceeded custom rates by approximately $16.00/acre for the smaller farm. Conversely, for the larger farm custom rates were $15.00/acre higher than the calculated machinery costs. The largest field operation difference was with the plow and packer combination. This was due to the relatively small plow (four-18 inch bottom size used in WFMACH$) with an estimated capacity of 2.33 acres/h. The difference in cultivation cost is because WFMACH$ used the low field speed for early season cultivations. The lower field speed increased the per-acre cost of the power unit and labor.

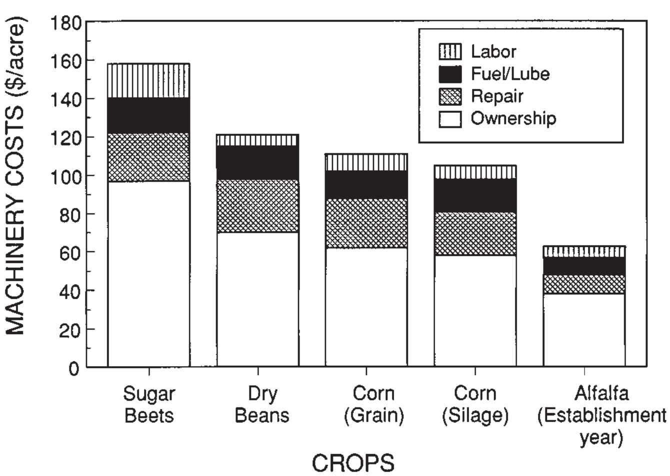

Fig. 1. Total machinery costs generated by the WFMACH$ program, for an example farm, allocated to specific crops (alfalfa, *Medicago sativa* L.).

Crop Rotation Changes

Variations in cropping patterns or rotations were also modeled in the WFMACH$ program. In the dryland wheat [*Triticum aestivum* (L.) em Thell]–fallow (one crop every 2 yr) regions of the Central Great Plains, 3-yr rotations (two crops every 3 yr) are being considered because of increased weed pressures and government farm program provision changes. The inclusion of a proso millet (*Panicum miliaceum* L.) or sunflower (*Helianthus annuus* L.) crop in a 3-yr rotation requires additional machinery investment, changes in annual machinery use, and modifications in tillage systems. On a representative 2000-acre dryland farm, machinery ownership costs for the wheat enterprise in a 3-yr wheat–fallow–sunflower rotation decreased $4.00/acre compared with the wheat–fallow system. On a whole-farm basis, a 3-yr rotation with sunflower increased costs of repairs, labor, and fuel by 27% over the conventional wheat–fallow system.

Table 4. Sugarbeet field operation costs calculated by WFMACH$ program compared with custom rates established by a grower survey.

Sugarbeet enterprise	WFMACH$ estimated costs ($/acre)		Western Nebraska custom rates
Field operation	450-acre farm	900-acre farm	($/acre)
Disk	8.39	6.99	5.09
Plow and pack	21.01	18.57	9.37
Roller harrow-1	8.00	6.78	No survey data‡
Roller harrow-2	8.09	6.86	No survey data
Plant	13.53	11.15	8.75
Rotary hoe	4.46	3.70	3.19
Spray (boom)	2.93	2.67	3.34
Spray (boom)	2.93	2.67	3.34
Cult-1	9.88	8.44	No survey data
Cult-2	6.49	5.53	4.20
Cult-3	5.11	4.36	4.20
Cult/ditch-1	6.63	5.67	4.20
Ditch-2	5.33	4.45	3.63
Defoliate	26.27	20.81	96.14§
Lift (23 tons/acre)	56.96	44.02	
Subsoil	9.13	7.90	7.82
Difference from custom rates†	−15.90	14.78	

† These values do not include cost differences from operations that have no custom rates established by the grower survey.

‡ Sufficient data was not available from grower survey to establish a reliable custom rate for these operations.

§ The custom rate value includes both defoliating and lifting.

SUMMARY

Machinery management is an integral component of a farming business. The proper decision, when evaluating cropping or management system changes is crucial for the continued profitability of a farming operation. Understanding the effects of machinery costs is vital when considering an alternative management option. The Whole Farm Machine Cost Program was designed to assist producers, consultants, and extension personnel in calculating machinery costs on an hourly, acre, and whole-farm basis. The ability to vary field capacity, fuel and labor requirements, and to calculate annual hours of use have proved very beneficial for applied analysis.

A limitation of WFMACH$ is the increased quantity and refinement of the machinery cost inputs to achieve the desired output. An understanding of field operation parameters, realistic machinery capacities, labor and fuel requirements, etc. is required to successfully utilize the program. Evaluating depreciation in either a TIME vs. USE dichotomy can be helpful in applied studies. However, improved depreciation calculations could be made if parameters reflecting the relative contributions of the time and usage components were available. The spreadsheet should not be considered an optimizing machinery selection program and does not incorporate timeliness penalties.

This paper has introduced WFMACH$, discussed the program's unique features, and provided a brief overview of several applied machinery cost analyses. The program has proven useful in developing components of educational programs that help integrate applied economics, engineering, and agronomy.

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