Estimating and Benchmarking Farm Machinery Costs

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Presented at 2003 K-State Risk and Profit Conference
August 14-15, 2003 – Ramada Inn, Manhattan, KS

Introduction

- Machinery costs are those associated with machinery services, usually ownership and operating costs
- To make good management decisions, we want to the reduce decisions to numbers
  - Custom hire
  - Own vs. rent
  - Lease vs. purchase
  - Trading strategies
- … targeting the decision tools:
  - *KSU-MachCost.xls*
  - *OwnSpray.xls*
  - *OwnTractor.xls*

Machinery cost categories

- Repair and maintenance
- Labor
- Depreciation (market, not tax depreciation)
- Interest (opportunity interest)
- Fuel and lubrication
- Taxes insurance and shelter
- Custom hire

How important are farm machinery costs for Kansas farmers?

Kansas Farm Management Association Enterprise Analysis
Nonirrigated Crops -- State Averages, 1999-2001

	Corn	Sorghum	Wheat	Soybean	Alfalfa	Weighted Average
Number of Farms	102	246	391	187	81	
Average Acres	277	293	544	344	142	1,600
Costs, $ per Acre						
Seed	$25.38	$8.04	$5.11	$19.42	$6.57	$12.36
Fertilizer	30.12	20.36	15.32	3.28	8.56	15.62
Herb-Ins	21.85	17.72	4.47	18.45	10.77	13.47
Crop Ins	3.27	2.63	3.02	2.86	0.23	2.71
Machinery	**79.27**	**61.37**	**58.97**	**65.59**	**75.62**	**65.83**
Other	21.99	17.78	16.51	18.85	22.26	18.70
Land	30.00	18.13	16.35	20.26	37.00	21.72
Interest	19.17	14.18	12.42	15.85	16.58	15.02
Total Cost	$231.06	$160.22	$132.16	$164.56	$177.59	$165.42
Machinery, %	**34.3%**	**38.3%**	**44.6%**	**39.9%**	**42.6%**	**39.8%**

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Note – a portion of interest cost should also be allocated to machinery costs

Why Producers Need to Know

- Benchmarking
- Selecting Profit-maximizing Crop Mix
  – must prorate to crops
- Dealing with Technological Change (no-till)
  – alternative systems use machinery less intensively
- Banking (tracking market value & deprec.)
- Minimizing Costs of Production
  – owning vs. leasing vs. custom hire
  – optimal trade decisions

Cost benchmarking is an important task when targeting improvement

Internal benchmarking

vs.

External benchmarking

Machinery costs are highly variable across farms …

Kansas Farm Management Association Enterprise Analysis Nonirrigated Crops -- State Averages, 1999-2001						
	Corn	Sorghum	Wheat	Soybean	Alfalfa	Weighted Average
Number of Farms	102	246	391	187	81	
Average Acres						
High profit farms	309	365	683	404	106	449
Mid profit farms	306	299	589	344	182	398
Low profit farms	216	214	360	283	139	272
Machinery Costs, $/acre						
High profit farms	$66.02	$49.55	$46.30	$55.50	$61.10	$53.60
Mid profit farms	$75.12	$55.07	$54.95	$60.90	$63.24	$60.48
Low profit farms	$96.68	$79.49	$75.75	$80.54	$102.51	$83.47
High less low, $	**$30.65**	**$29.94**	**$29.46**	**$25.03**	**$41.41**	**$29.86**
High less low, %	**-31.7%**	**-37.7%**	**-38.9%**	**-31.1%**	**-40.4%**	**-35.9%**

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Machinery costs are important in explaining profitability differences across farms …

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Differences between high profit farms and low profit farms in …						
Total costs	-$81.11	-$73.39	-$64.08	-$56.30	-$65.53	-$67.19
Net returns	$100.49	$87.24	$69.79	$75.81	$145.05	$86.29
Cost/net returns	80.7%	84.1%	91.8%	74.3%	45.2%	80.6%
Mach/total costs	-37.8%	-40.8%	-46.0%	-44.5%	-63.2%	-44.8%

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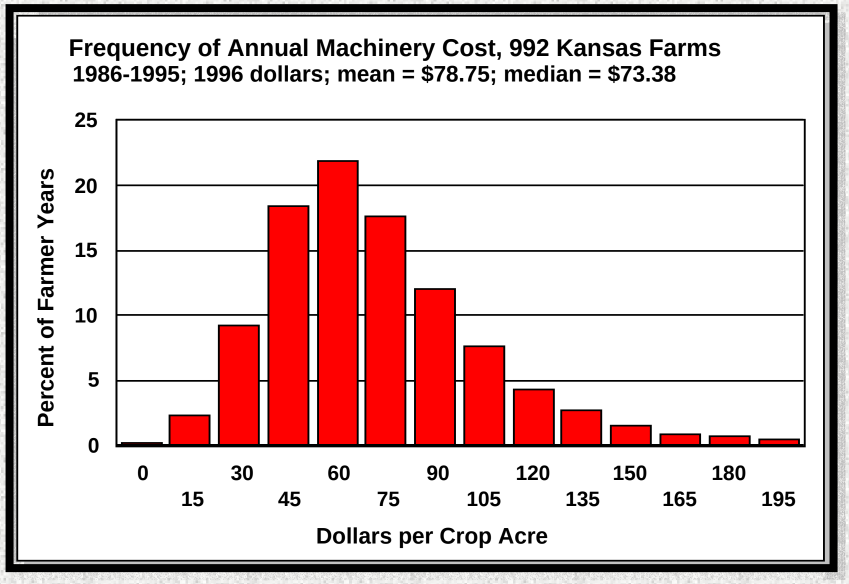
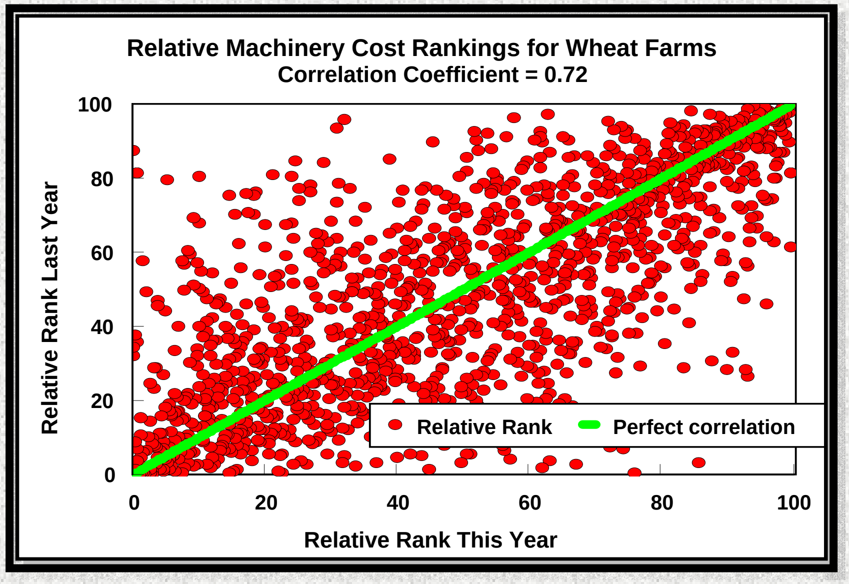
Machinery costs are highly variable across farms …



Relative machinery costs are somewhat repeatable …



Machinery Costs NW KS Wheat Enterprises

	Farm A	vs.	Farm B
Labor (hired & unpaid)	$17.23		$27.00
Gas/Fuel/Oil	$ 6.03		$ 7.57
Repair & Maintenance	$11.43		$ 9.19
Personal Property Tax	$ 0.53		$ 0.49
General Insurance	$ 1.97		$ 1.89
Utilities	$ 1.69		$ 1.48
Auto Expense	$ 0.72		$ 0.00
Economic Depreciation	$ 8.71		$12.91
Net Machine Hire	$11.93		$ 0.82
Interest (9% assign)	$ 8.97		$11.40
Total	$69.21		$72.75

Machine hire makes it hard to compare

Machinery Costs NW KS Wheat Enterprises
combine tax, insurance, utilities; prorate auto expense and machine hire

	Farm A	vs.	Farm B
Labor (hired & unpaid)	$21.08		$27.31
Gas/Fuel/Oil	$ 7.38		$ 7.66
Repair & Maintenance	$13.99		$ 9.29
Tax, Insurance, Shelter	$ 5.13		$ 3.90
Economic Depreciation	$10.66		$13.06
Interest (9% assign)	$10.97		$11.53
Total	$69.21		$72.75

Machinery Costs NW KS Wheat Enterprises
using custom rates approach

	# operations	$/operation
Undercutter (V-Blade)	4	$ 4.68
Offset Disk	1	$ 4.38
NH3 Application	1	$ 6.16
Drill	1	$ 5.61
Harvest 40 bu.	1	$19.87
Total		$54.74

Where's the rest of the costs?

Benchmarking will become harder over time …

- Some farms do more custom hire
- Some farms rent machines
- Some farms do less tillage
- Some farms raise specialty crops

KSU-MachCost.xls

- Excel spreadsheet to estimate and benchmark machinery costs
- Master's thesis – Aaron Beaton
- Based on KFMA database and cooperator surveys for the year 2001

Data

- Field operations performed
  - Survey of Kansas Farm Management Association Members
    - Collected number of units (acres, tons, miles)
- Financial data
  - Kansas Farm Management Association database.
    - Total Crop Machinery Costs = crop share of machinery repairs, gas-fuel-oil, farm auto expense, motor vehicle depreciation, machinery-equipment depreciation, machine hire expense, opportunity interest on crop machinery investment, machinery shelter costs, machinery insurance cost and crop machinery labor.
  - Modified variables
    - Depreciation, shelter, insurance, and labor

Summary Statistics

	Average	Low Quartile[1]	High Quartile[1]
Machinery costs			
Total crop machinery cost/acre (dollars)	$83.29	$53.92	$121.74
Acres			
Harvested acres (acres)	1,188	1,405	982
Machinery cost components			
Machinery labor cost	22.5%	27.7%	21.1%
Insurance	0.9%	0.8%	0.8%
Shelter	1.7%	1.2%	2.1%
Repair	15.7%	14.3%	16.2%
Fuel, gas and oil	10.4%	10.6%	9.8%
Auto	0.8%	0.9%	0.7%
Depreciation (percent)	23.2%	16.2%	26.8%
Machine hire expense	11.9%	16.0%	9.8%
Opportunity interest	12.9%	12.3%	12.7%

[1] Quartiles when sorted by Total crop machinery costs per acre.

Expected costs …

- Benchmarking means to compare actual costs with what they might be expected to be
- Given that KFMA data are whole-farm costs, across farm comparisons are not appropriate. Thus, what costs do we benchmark against?
- Where do “expectations” come from?

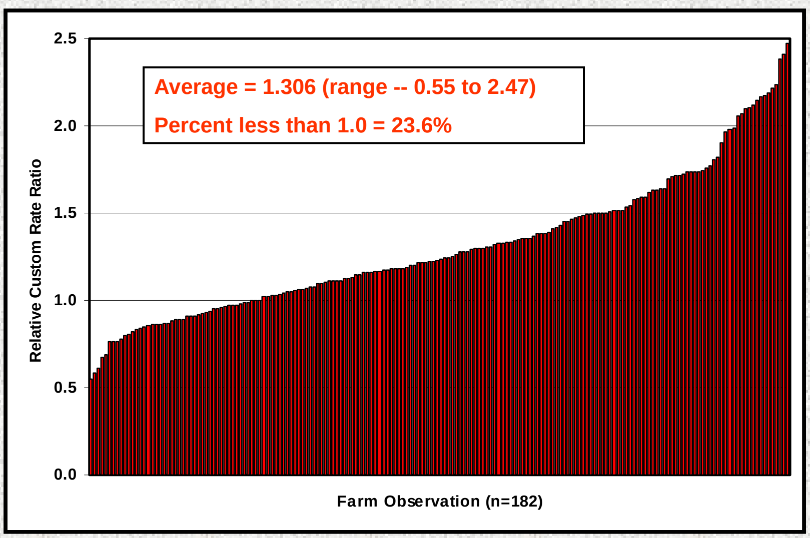
Farm costs vs. custom rates

Expected crop machinery cost at custom rates

– Sum of all operations performed on the farm multiplied by their respective custom rates

– Relative custom rate ratio developed
  - If > 1, then per unit costs are greater than custom rates
  - If = 1, then per unit costs are equal to custom rates
  - If < 1, then per unit costs are less than custom rates

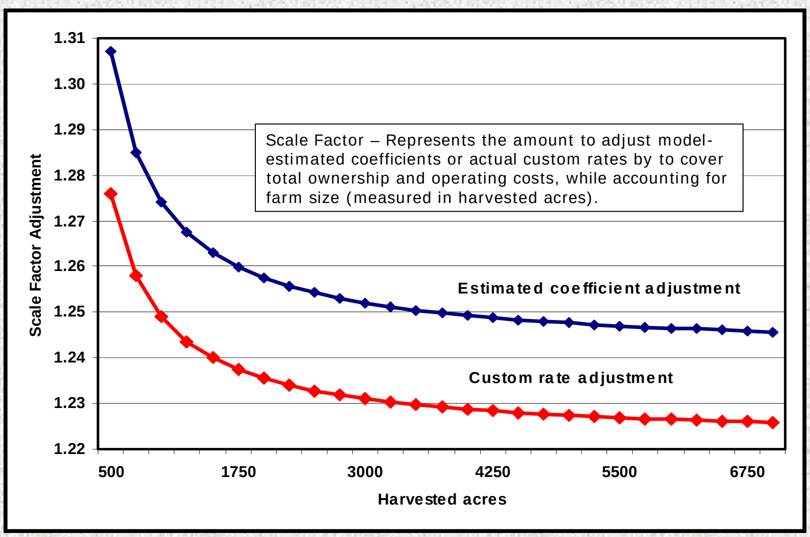
Relative custom rate ratio



Conceptual model

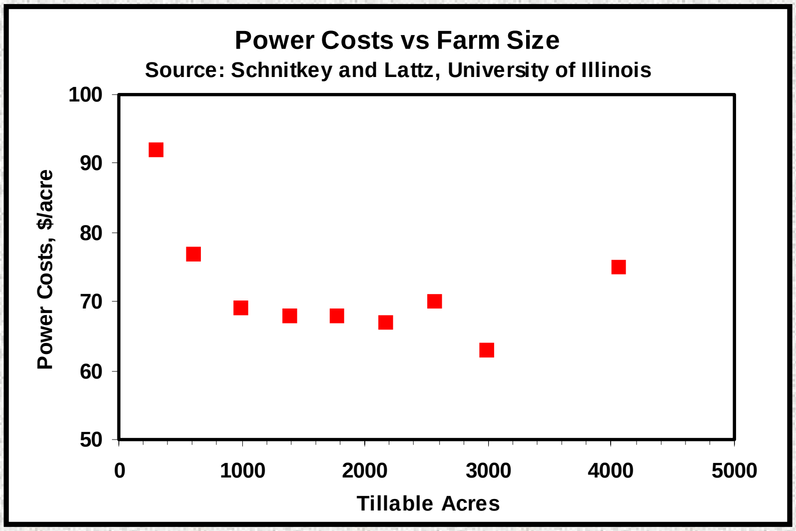
- **TCMC = *f* (field operations, farm size)**
- **Expected value of field operation coefficients are custom rates published by Kansas Agricultural Statistics**
- **Farm size represents a scale factor to adjust model-estimated coefficients by to account for economies of size**

Estimated Scale Factor



Note – Estimated coefficient adjustment is "larger" because estimated coefficients are slightly lower than custom rates (-1.4% on average).

Machinery cost economies of size …



Conclusions

- Published custom rates need to be increased by approximately 25% (for a farm with 1,000 harvested acres)
- Economies of size exist (i.e., scale factor adjustment decreases as farm size increases)
- Procedure developed to find farm specific, per unit machinery costs
- Results useful for benchmarking costs

For more information see:

- ***Custom Rates and the Total Cost To Own and Operate Farm Machinery In Kansas (MF-2583)***
- ***KSU-MachCost.xls***
- **Available at www.AgManager.info**
  (Farm Management Machinery Section)

OwnSpray.xls and *OwnTractor.xls*

- **Excel spreadsheets developed to help producers calculate the cost of owning and operating self-propelled sprayers and tractors.**
- **Sprayer – costs per year, per hour, and per acre**
- **Tractor – costs per year and per hour**
- **Analysis is based on after-tax net present value of costs but summary costs are converted back to pre-tax for rent/hire comparison purposes.**
- **OwnSpray.pdf and OwnTractor.pdf – supporting papers available on the web.**

Machinery ownership decisions especially depend on …

- Time value of money issues
  - Interest rates
  - Income tax rates
- Market value of machines over time
- Market value of machines over usage rates
- Repairs
  - Because older machines have greater repairs and farmers trade off repairs and depreciation according to their perceived comparative advantage

A very big issue is MARKET VALUE and DEPRECIATION

Machinery Market Valuation Methods

- KSU – use industry values from "Blue Book" and values from High Plains Journal ads to estimate depreciation for different classes/brands
  - Calculated against advertised / "Resale Cash" price for new
  - $RVP_{age} = 100*\exp[B_1(age)+B_2(accumulated\ hrs/100)]$
  - Used in *OwnSpray.xls* and *OwnTractor.xls* spreadsheets

Example KSU market depreciation parameters:

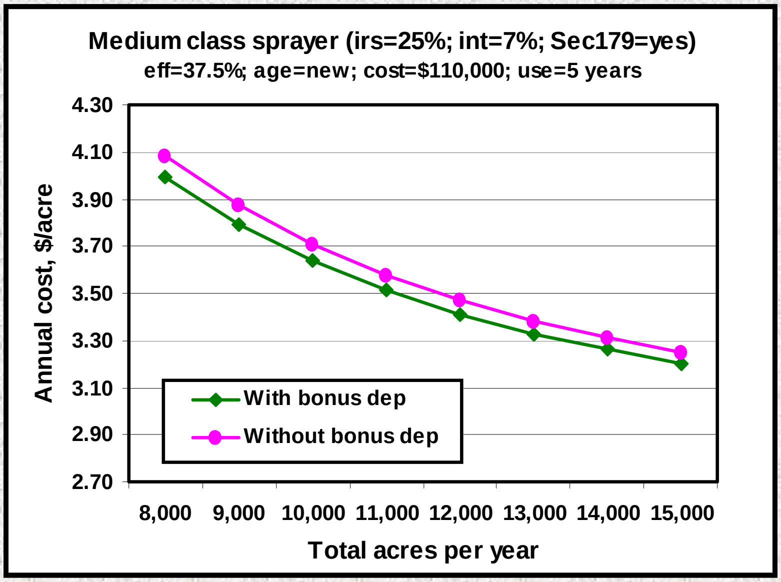
	B_1	B_2	
Sprayer	-0.146484	-0.011786	(*OwnSpray*)
JD 2wd/MFWD	-0.050218	-0.005255	(*OwnTractor*)
AGCO 2wd/MFWD	-0.060674	-0.007274	(*OwnTractor*)
Case-IH 4wd	-0.043420	-0.007285	(*OwnTractor*)

OwnSpray.xls -- Input assumptions

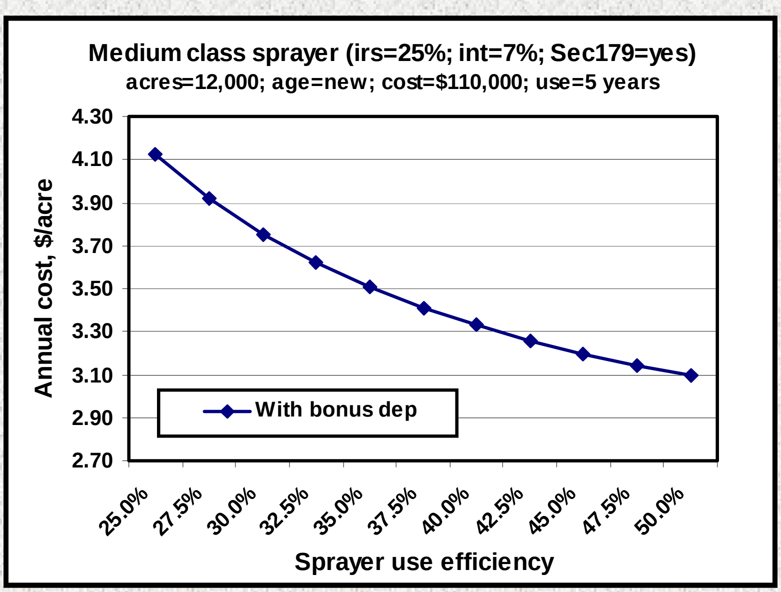
- Sprayer information (Class 2 – medium)
  - Sprayer cost = $110,000
  - Use for 5 years
  - 80 foot boom, 11.5 mph travel speed
  - Expected efficiency = 37.5%
  - Repairs based on ASAE
  - Fuel consumption = 10 gph
  - Oil and lubrication = 10% of fuel costs

OwnSpray.xls -- Input assumptions

- Financial information
  - Fuel cost = $1.00/gal
  - Sprayer labor cost = $10/hour
  - Taxes, insurance, & shelter = 1.5% of value
  - Marginal tax rate = 40.3% (25% + 15.3%)
  - Section-179 deduction = $24,000
  - Bonus depreciation = 30% (new only)
  - Tendering cost = $10/hr + $1/ac


Medium class sprayer (irs=25%; int=7%; Sec179=yes)
eff=37.5%; age=new; cost=$110,000; use=5 years
Annual cost, $/acre
4.30
4.10
3.90
3.70
3.50
3.30
3.10
2.90
2.70
With bonus dep
Without bonus dep
8,000
9,000
10,000
11,000
12,000
13,000
14,000
15,000
Total acres per year

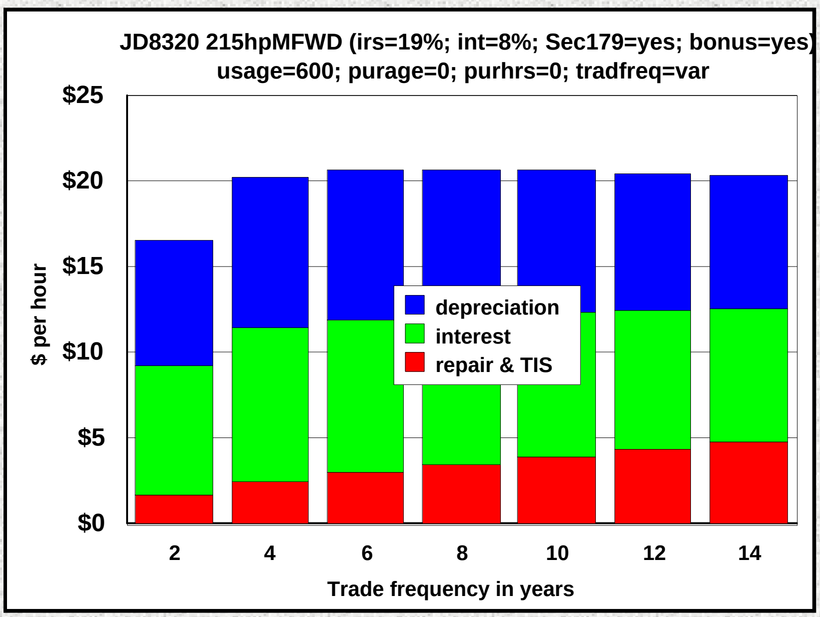
31


Medium class sprayer (irs=25%; int=7%; Sec179=yes)
acres=12,000; age=new; cost=$110,000; use=5 years
Annual cost, $/acre
4.30
4.10
3.90
3.70
3.50
3.30
3.10
2.90
2.70
With bonus dep
25.0%
27.5%
30.0%
32.5%
35.0%
37.5%
40.0%
42.5%
45.0%
47.5%
50.0%
Sprayer use efficiency

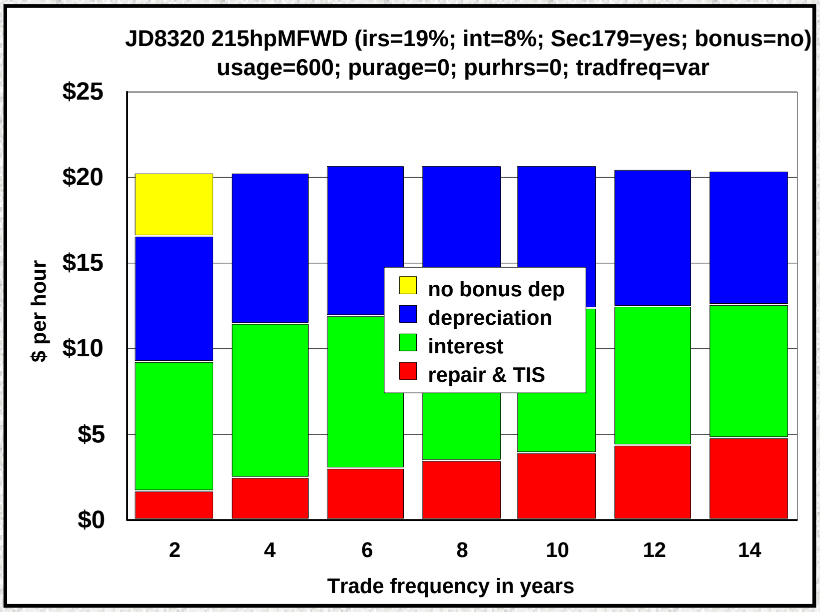
32

OwnTractor.xls -- Input assumptions

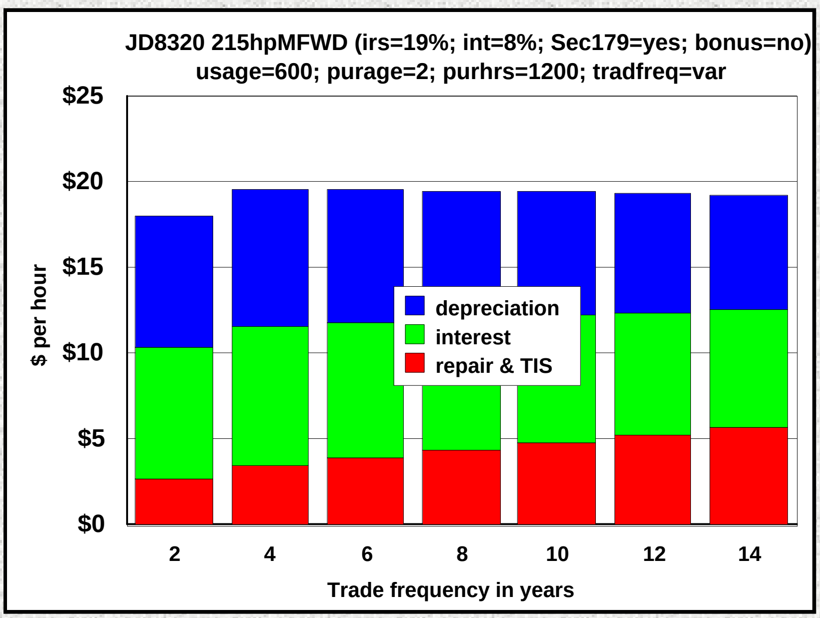
- **Tractor information**
  - **- Tractor is "like" a JD 8320 MFWD 215 hp**
  - **- Tractor cost = $102,448**
  - **- Valuation from Blue Book based model**
  - **- Based on Resale Cash Price (not trade premium)**
  - **- Buy and sell at market price**
  - **- 15.3% SE tax is on top of the stated IRS/state rate**



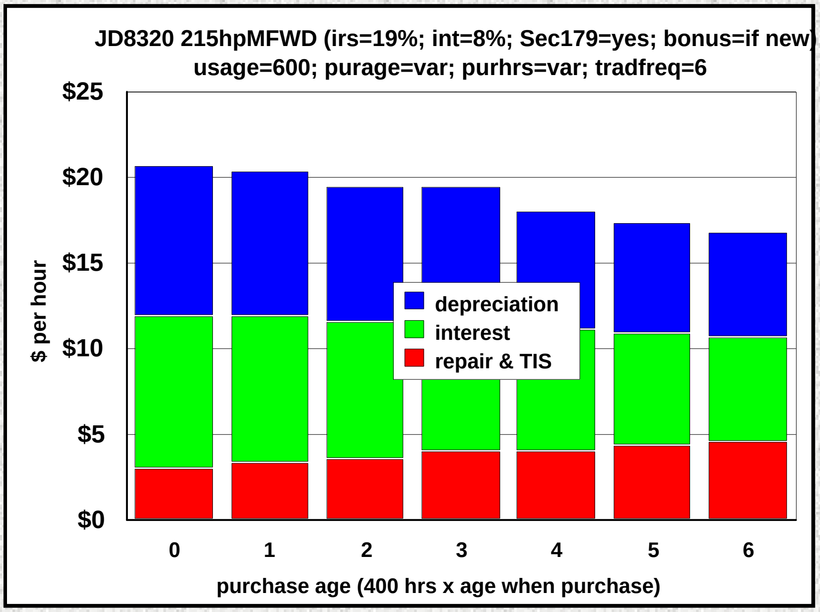
Except for frequent trading the market is fairly efficient



Without the bonus depreciation, frequent trading would be like less frequent

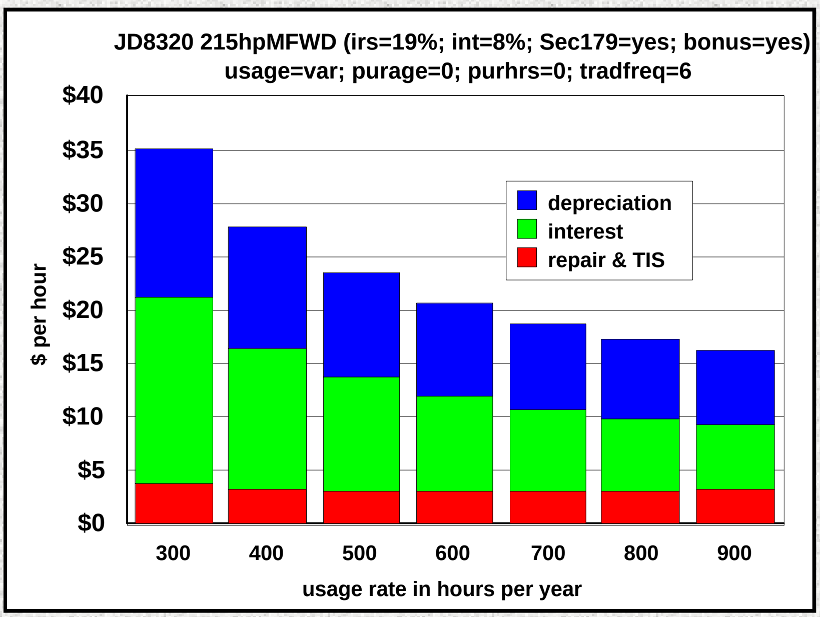


Market is also efficient for used tractors (only slightly lower cost than new)



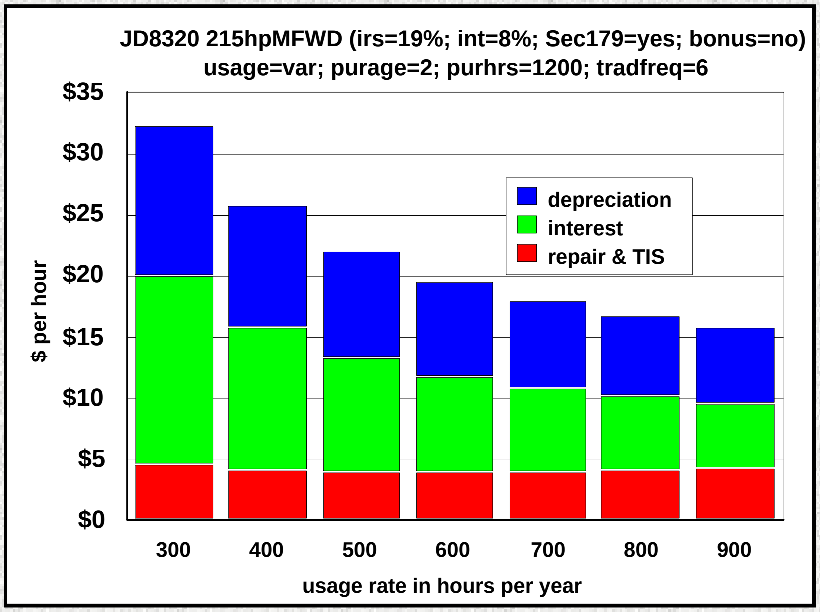
Buying older tractors can be advantageous if it fits your management style

37

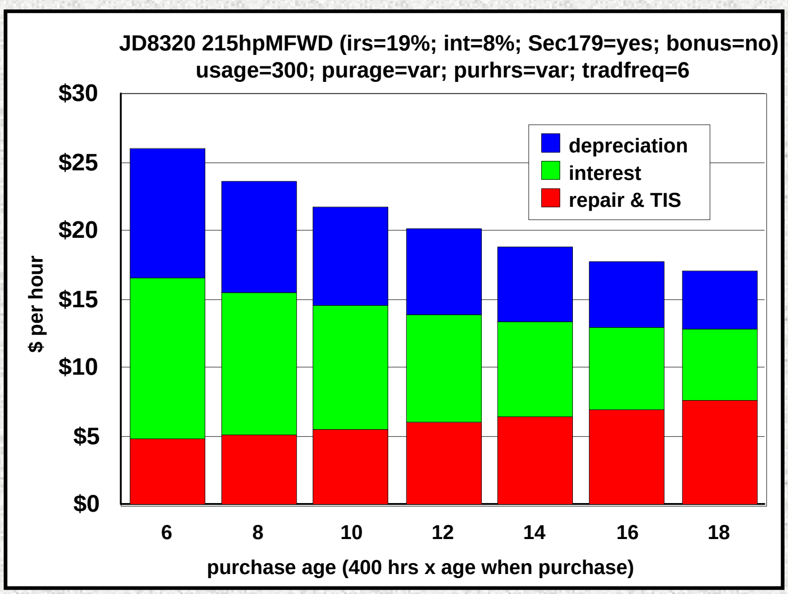


Not a trading strategy, but putting more hours on per year really pays off

38



Buying used won’t compensate for not putting on enough hours



Less intensive users can hold down costs by buying older tractors,
but must be able to handle high repairs and do without newer technologies

Summary . . .

- Machinery costs represent a major cost category
  - Large differences between producers
  - Tend to be persistent from year-to-year
- Economies of size generally exist
- Benchmarking is critical for improvement
  - Internal and external benchmarking are important
  - Custom hire complicates benchmarking
  - Individual categories are becoming less meaningful
- Quantifying costs is important in order to make machinery management decisions

Custom Rates and the Total Cost to Own and Operate Farm Machinery In Kansas

Kansas State University

Department of Agricultural Economics

MF-2583

Farm Management

Farm machinery is a vital part of most farming operations, from the physical work it performs in the production process to the enjoyment provided from its operation. For producers, landowners, or farm managers who do not have the capital, time, or desire to perform machinery operations themselves, hiring a custom operator to perform machinery operations is an alternative method of obtaining machinery services. For others, custom farming may be a method to spread fixed costs of machinery over more acres, reducing per unit costs and increasing cash flow. Regardless, whether a business is a user or provider of machinery services, determining a rate to charge for machinery services can be difficult due to the various costs of farm machinery.

One alternative to calculating ownership and operation costs to help determine charges for machinery services is to simply use custom rates, for example, those published annually in *Kansas Custom Rates* (Kansas Agricultural Statistics). However, research of farms in Illinois indicates published custom rates do not represent the full cost to own and operate machinery (Schnitkey).

This publication discusses the following issues regarding machinery costs and custom rates: (1) to what degree do custom rates cover all ownership and operating costs of farm machinery? (2) why don't custom rates cover the total cost to own and operate machinery? (3) what are the total costs to own and operate machinery on average? (4) how can a farmer apply these results to his or her operation? and (5) how can a producer benchmark machinery costs?

This research does not question that the Kansas Agricultural Statistics (KAS) custom rates published in *Kansas Custom Rates* are truly what are charged and paid for custom-provided machinery services. Rather, it questions whether the published custom rates cover all costs an individual or entity incurs to own and operate farm machinery. The competitive market of custom machinery operations will ultimately determine the price of custom rates. However, discussion of the issues surrounding custom farming, and determining average rates that cover all ownership and operating costs will aid custom operators and individuals hiring the service of custom operators.

Do published custom rates cover all costs?

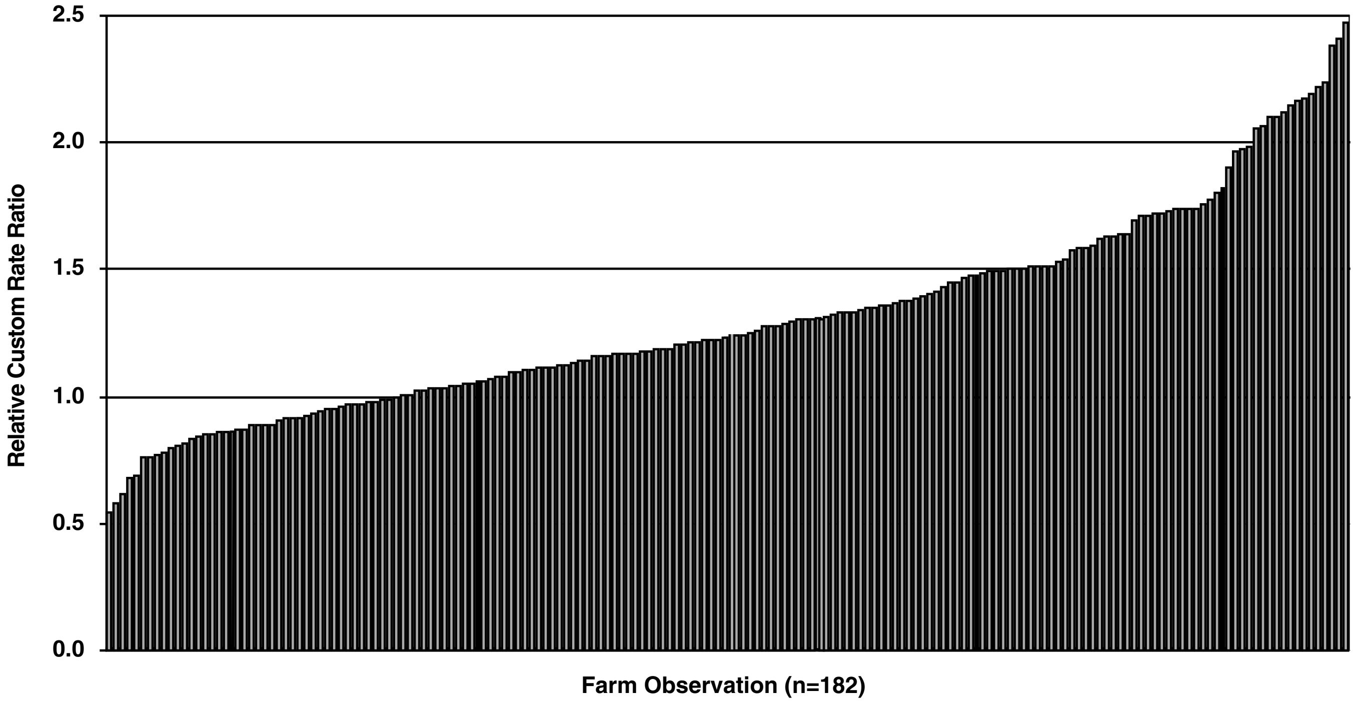
Based on Illinois data, Schnitkey concluded that, on average, it costs Illinois farmers $90.60 per acre annually to perform machinery operations. Alternatively, if the operations would have been hired at the state average custom rate, he estimated that it would cost approximately $70 per acre annually. Thus, he estimated that actual costs are almost 30 percent higher than custom rates.

Using KAS-reported custom rates along with financial and field-operation data from the Kansas Farm Management Association (KFMA), a "Relative Custom Rate Ratio" was developed. This ratio measures what it actually costs Kansas farmers to perform machinery operations relative to the statewide average published custom rates. If a particular farm has a ratio less than, equal to, or greater than 1.0, then the farm can perform machinery operations for less than, equal to, or greater than the published custom rates, respectively. Figure 1 displays the Relative Custom Rate Ratio (vertical axis) for 182 KFMA member farms (horizontal axis) that participated in a survey pertaining to the number of field operations they performed in 2001. Each bar represents a farm in this data set.

From Figure 1, the wide variability of machinery costs between farms can be seen. One farm performed machinery operations at 55 percent of the cost of published custom rates while another farm incurred costs of almost 247 percent of the published custom rates. The average (across farms) of the relative custom rate ratio is 1.31. This initial estimate indicates that 31 percent needs to be added to custom rates to cover the full costs of ownership and operation across farms. However, it is important to note that almost a fourth of the farms (23.6 percent) performed machinery operations for less than custom rates.

This publication accompanies the spreadsheet KSU-MachCost.xls located at *www.agmanager.info* (in the *machinery* section of the *farm management* area) that can be used to calculate farm-specific custom hire rates for machinery and benchmark a farm's machinery costs. The Excel® spreadsheet performs the calculations that may be performed manually as demonstrated in the worksheet at the end of this publication.

Figure 1. Relative Custom Rate Ratio.



Possible reasons why custom rates do not cover all ownership and operating costs

A reasonable question to ask is, Why do published custom rates not cover all costs? There are numerous possible answers to this question. One is that the ownership costs for the machinery a farmer owns are sunk costs. In short, the ownership costs of the machinery (already owned) are incurred whether or not the farm performs additional operations. Thus, if a farmer performs custom operations for others (without purchasing additional equipment), the fixed costs are spread over more acres, reducing per unit costs and generating cash flow. An important issue with this reason is how timely the operations are performed. That is, a farm might "have time" to perform custom activities only before or after the optimal time for such operations, meaning that such activities likely would be valued lower than optimally timed operations. This means that a farm considering the purchase of such activities as a less expensive alternative to machinery ownership may not necessarily enhance its profits. If such ill-timed activities dominate, then finding custom rates to be lower than full machinery costs for the average farm should not be surprising. Thus, there are rational economic reasons why neighbor-to-neighbor custom work is often performed below the full cost of owning and operating machinery.

It might be that operations that perform operations for others (and report their charges to KAS) are more efficient operators (than the "average" farm) and actually are covering all of their costs by charging the current published custom rates. That is, it may be that these farms have a relative custom rate ratio of less than or equal to 1.0. Other possible reasons why custom rates tend to be less than the total cost to own and operate the machinery are related to less control of the quality of work (planter or harvesting settings that directly affect quality or yield of the crop) and management of the activities performed. Custom hire activities must be managed, as to say, someone must determine when to perform the operation and how to set the machinery for those operations (depth of planting, tillage, etc.). If the individual hiring the operation makes these decisions, then less labor and management is provided by the custom operator. That is, the actual machinery costs calculated for Figure 1 might incorporate more labor and management than that provided by custom operators. Finally, in some instances, a producer might not charge friends, family, and neighbors the full cost to perform an operation to avoid upsetting friends or family.

Another reason why custom rates may be lower than actual farm machinery costs is because businesses specializing in custom operations (e.g., custom harvesters) likely have lower costs on a per unit basis. This is because they use the equipment – often specialized for a specific operation – more intensively (i.e., cover more acres per year) than most farmers, thus reducing the fixed costs per acre. Additionally, custom operators may be able to purchase machinery at a lower cost than most farmers due to volume discounts (i.e., a custom harvester purchasing multiple combines on a regular basis can likely negotiate a better purchase price than a farmer that purchases only one combine every several years).

In determining custom hire rates, one must consider the technology and maintenance of the machinery being used. Does the machinery perform the operations in a desirable manner, that is, does the planter plant an even stand at the desired population; does the combine separate the crop adequately without excess damage; does the sprayer have plugged nozzles; are skips left in the field; etc.? Although this does not necessarily explain why rates are lower than the true cost of ownership and operation, these factors affect costs and therefore should be considered when determining custom rates.

Based on total ownership and operating costs, what should custom rates be?

Equation 1

   Machinery repairs
\+ Gas, fuel, oil
\+ Farm automobile (pickup) expense
\+ Machinery and equipment depreciation
\+ Machine (custom) hire
\+ Machinery insurance
\+ Machinery shelter
\+ Opportunity interest on crop machinery investment
\+ Crop machinery labor
= Actual whole-farm crop machinery cost.

The first step in determining appropriate custom charges from total ownership (fixed) and operating (variable) costs is to define actual whole-farm crop machinery cost. Actual whole-farm crop machinery cost is defined as the crop share of Equation 1.

The crop share of each of these expenses should be included in these calculations (as compared to the total machinery costs which might include livestock-related machinery costs). That is, if a farm has livestock enterprises, or uses farm machinery for personal use (e.g., pickups, cars), only the crop share (portion) of the total expense should be included in the actual whole-farm crop machinery cost. Many farms do not keep detailed records of the amount each asset is used in each enterprise, but a subjective decision (by the producer) of how to prorate the costs among crop and livestock enterprises, as well as between business and personal use, is often adequate.

The following is a brief discussion of each of the costs. Machinery repairs consist of the expenses for replacement parts due to age, wear, or accident. Gas, fuel and oil expenses are simply the fuel and lubrication expenditures prorated to crop enterprises. Farm automobile (pickup) expenses are all of the pickup, car and other light vehicle expenses allocated to crop production. This should include all depreciation, taxes, gas, fuel, oil, insurance, and repairs on these vehicles that have not been included in other categories. Machinery and equipment depreciation is the market (as compared to tax) depreciation of all farm machinery. Market depreciation can be determined by looking through local classified ads, area auction results, or various Web site classified ads (e.g., Case IH, John Deere, New Holland). Mathematical depreciation formulas are also available to estimate market depreciation (Kastens; Williams and Kastens).

Machine (custom) hire expenses include what is paid to others to have machinery operations performed. Machinery insurance and shelter costs are the cost to insure and store machinery, respectively. Opportunity interest on the crop machinery investment is the revenue foregone had the capital invested in the crop machinery been invested in the next best investment. This is usually calculated as a percentage of the machinery (market) value. Currently, the Kansas Farm Management Association uses an opportunity cost charge of 8 percent of the machinery investment per year (Langemeier). Crop machinery labor cost includes only crop machinery labor (time dedicated to machinery operation, maintenance, repairs, and management), as compared to total crop labor cost that would also include time spent managing the crop enterprises (i.e., marketing, crop scouting, complying with government programs, etc.). For irrigated farms with newer machinery, this percentage would be expected to be lower than a dryland farm with older machinery. For more details on each of the costs or how to estimate these costs see *Farm Machinery Operation Cost Calculations,* MF-2244 (Kastens), or *Lease, Custom Hire, Rent or Purchase Farm Machinery: Evaluating the Options* (Williams and Kastens).

Actual whole-farm crop machinery costs (i.e., those shown in Equation 1) along with reported acres of various field operations for 182 farms participating in the KFMA were used to estimate the per-acre costs of owning and operating machinery for the different field operations. In addition to the specific field operations performed, the estimation procedure included a "scale factor" to account for farm size. This was done to capture the economies of size effect, if indeed it is present in the observed data. For more details of the data, methods, and estimation procedure, see *Per*

Table 1. *Estimated Rates and Published Rates.*[a]

Operation	Unit	Estimated Coefficients	Published Rates
Field cultivate without fertilizer	$/acre	5.55	5.92
Sweep/undercut without fertilizer	$/acre	5.39	5.38
Disk	$/acre	6.33	6.48
Chisel less than 12 inches deep	$/acre	7.88	7.79
Chisel greater than 12 inches deep	$/acre	9.42	9.54
Disk-chisel/disk deep-chisel	$/acre	9.27	9.54 [c]
Moldboard plow	$/acre	8.96	8.98
Row crop cultivate	$/acre	6.40	6.25
Drill/air-seed no-till without fertilizer	$/acre	10.03	9.89 [b]
Drill/air-seed conventional till without fertilizer	$/acre	5.88	6.49 [b]
Plant no-till without fertilizer	$/acre	9.79	10.02 [b]
Plant conventional till without fertilizer	$/acre	8.11	8.03 [b]
Spray chemical	$/acre	3.63	3.75
Spray fertilizer	$/acre	3.73	3.75 [c]
Spray chemical and fertilizer	$/acre	3.74	3.75 [c]
Anhydrous ammonia application	$/acre	5.50	5.61
Broadcast dry fertilizer	$/acre	3.41	3.53
Inject liquid fertilizer	$/acre	3.51	3.57
Harvest wheat	$/acre	13.64	13.77
Wheat yield above 20 bu/ac (bushels)	$/bushel	0.130	0.131
Harvest corn	$/acre	20.08	19.43
Corn yield above 48 bu/ac (bushels)	$/bushel	0.126	0.119
Harvest grain sorghum	$/acre	14.14	14.58
Grain sorghum yield above 35 bu/ac (bushels)	$/bushel	0.128	0.129
Harvest soybeans	$/acre	18.99	19.48
Soybean yield above 24 bu/ac (bushels)	$/bushel	0.127	0.127
Harvest sunflowers	$/acre	17.99	17.93
Swath	$/acre	8.36	8.20
Rake hay	$/acre	2.93	2.88
Round bales less than 1,500 lbs	$/bale	7.36	7.46 [b]
Round bales greater than 1,500 lbs	$/bale	7.99	8.15 [b]
Large square bales	$/bale	12.08	11.70
Small square bales	$/bale	0.533	0.535 [b]
Chop silage (no hauling or ensiling)	$/ton	3.07	3.09
Rotary mow	$/acre	7.83	7.90
Miles on farm pickups	$/mile	0.336	0.345 [c]
Miles on grain/hay trucks	$/mile	1.80	2.07 [c]
Fertilizer adjustment percentage	percent	1.124	1.134 [c]
Field cultivate with fertilizer	$/acre	6.24	6.72 [c]
Sweep/undercut with fertilizer	$/acre	6.06	6.10 [c]
Drill/air-seed no-till with fertilizer	$/acre	11.28	11.22 [c]
Drill/air-seed conventional till with fertilizer	$/acre	6.61	7.36 [c]
Plant no-till with fertilizer	$/acre	11.00	11.37 [c]
Plant conventional till with fertilizer	$/acre	9.11	9.11 [c]
Scale Factor[d]			
Constant		1.241	
1 ÷ harvested acres		33.026	

[a] *Estimated Rates = Estimated coefficient multiplied by the scale factor*
[b] *Indicates published custom rates had to be combined to arrive at these rates*
[c] *Indicates an estimated rate (based on related cost information)*
[d] *Scale Factor = 1.241 + 33.026 × (1 ÷ harvested acres)*

Unit Costs To Own and Operate Farm Machinery on Kansas Farms (Beaton).

The "Estimated Coefficients" reported in Table 1, along with the scale factor adjustment, represent the custom rates estimated to cover total ownership and operating costs. The operation column lists each operation, and the unit column identifies the units for each rate. The "Estimated Coefficients" column identifies the rates that cover total ownership and operating costs when adjusted by the scale factor. That is, the "Actual Rates" are the "Estimated Coefficients" multiplied by the "Scale Factor." The "Published Rate" column includes the 2001 published custom rates (KAS).

For clarification purposes, the four operations reported in Table 1 dealing with wheat, corn, grain sorghum, and soybean harvesting account for the extra harvesting charges associated with high yields. When making calculations (as defined in this paper), the total number of bushels (for the whole farm) that each of the crops exceeds the base yield must be included. If these production numbers are difficult to identify, \$3.47, \$7.88, \$4.77, and \$1.41 may be added to the per-acre cost to harvest wheat, corn, grain sorghum, and soybeans, respectively. These additional charges are based on the average additional per-acre cost for farms in the underlying research, due to high yields for the respective crops.[1]

Application of these results

Two methods are available to estimate a farm's expected per-unit machinery costs. The methods available require different amounts of time, effort, and information, with an inverse relationship to the specificity of the results to an individual operation (i.e., the more time spent finding farm-specific information, the more accurate the results will be).

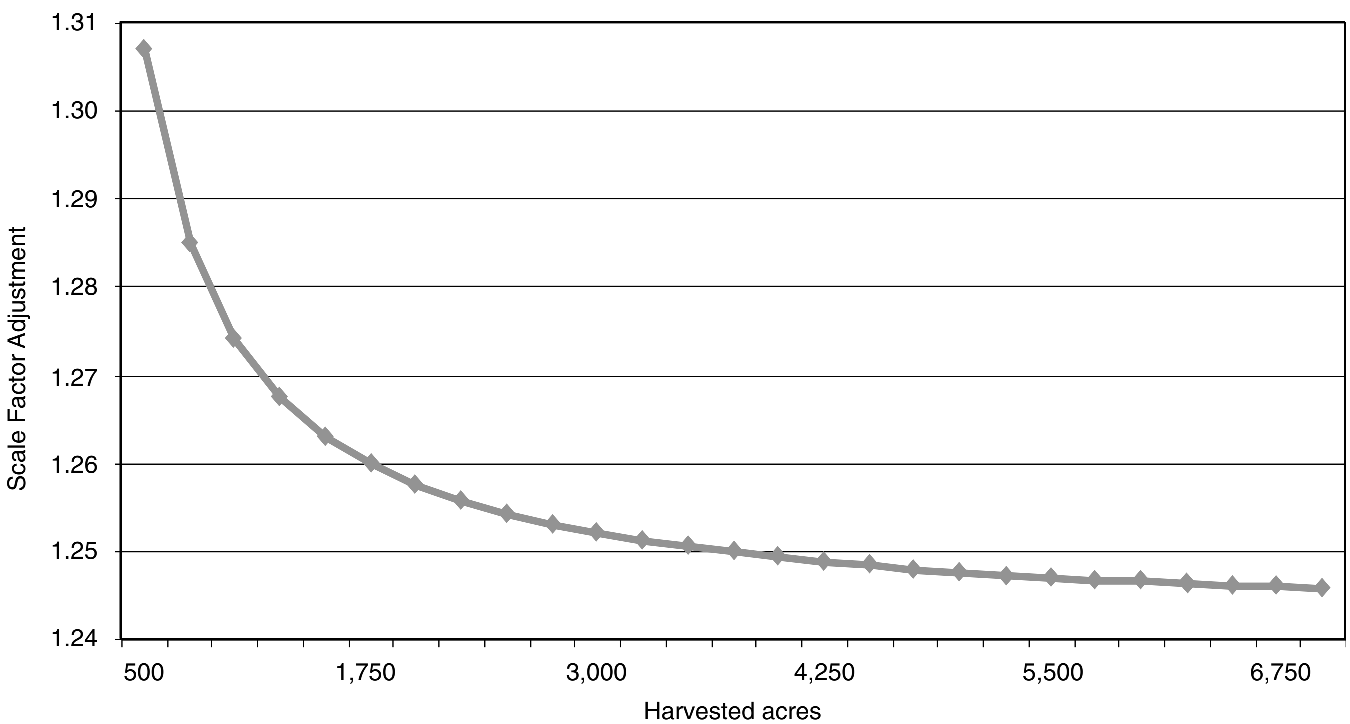
The first option would be to multiply the "Estimated Coefficient" for the operation of interest and the "Scale Factor" adjustment for the farm, taking into account the number of harvested acres of the farm. The "Scale Factor" adjustment takes into account the understatement of published custom rates relative to farm-level costs as well as the differences in farm size, and is calculated as follows:

$$\text{Scale Factor} = 1.241 + 33.026 \times (\, 1 \div \text{harvested acres}),$$

where harvested acres is the number of acres the farm harvested during the year. This results in the expected per unit cost for that farm to perform the desired operation. However, this method does not take into account farm-specific cost information and is therefore not unique to an individual farm operation. Figure 2 plots the scale factor at various farm sizes (measured in harvested acres). Due to the mathematical form of the

[1] *In the KSU-MachCost.xls spreadsheet this generalization can be captured automatically by entering a negative one (-1) as the bushels for each of the respective crops.*

Figure 2. *Estimated Scale Factor Adjustment versus Harvested Acres.*



scale factor, as harvested acres increases, the scale factor will approach 1.241 asymptotically (i.e., the scale factor will approach 1.241, but never equal 1.241).

Consider the following example of how the scale factor is used to adjust the estimated rate for a specific field operation. A farm with 1,000 harvested acres wants to know its expected per-acre cost to disk. This farm's scale factor would be 1.274 (1.274 = 1.241 + 33.026 × (1 ÷ 1,000 harvested acres)), which is then multiplied by the Estimated Coefficient to disk ($6.33/ac), resulting in $8.06 per acre (1.274 × $6.33/ac). Thus, for a farm harvesting 1,000 acres, the estimated rates need to be adjusted up by 27.4 percent to arrive at an expected cost per unit (acre, ton, bale, mile) that covers total costs.

It is important to note that the "Scale Factor" reported in Table 1 should be used to adjust the "Estimated Coefficients" and not the "Published Rates," as they are not identical. On average, across all operations, the "Estimated Coefficients" were 1.4 percent lower than the "Published Rates." Therefore, if custom rates are used to estimate total machinery costs, as opposed to the estimated coefficients in Table 1, the 27.4 percent increase in the preceding example would be approximately 25.6 percent [1.274 × (1.0 – 0.014) – 1.0].

The second option to estimate costs can be used if a farm-specific operation cost is desired. It takes into account farm-specific information about the number of units of each operation performed during a time period (e.g., one year), and the aggregate crop machinery costs during the same time period. The following seven-step process outlines the procedure.

1. Calculate expected per unit machinery costs.
2. Calculate expected crop machinery costs for each field operation.
3. Calculate expected whole-farm crop machinery costs.
4. Calculate the field operation percentages.
5. Find actual whole-farm crop machinery costs.
6. Prorate actual whole-farm crop machinery costs to various field operations using the field operation percentages.
7. Calculate actual per unit machinery costs.

Step one, calculating expected per unit machinery costs, is the same as described in the first option of estimating per unit machinery costs. This provides the producer with the expected cost per unit to perform a specific operation.

Step two, calculate the expected crop machinery costs for each field operation by taking the product of the expected per unit machinery costs, step one, and the number of units (acres, tons, bales, miles) on which that operation was performed. This represents the expected cost for the farm to perform the operation of interest over the number of units that operation was performed.

Step three, calculate the expected whole-farm crop machinery costs by taking the sum of the expected machinery costs for each operation (step two) across all operations. This represents the farm's total expected crop machinery cost, based on farm size, as well as the type and number of operations performed.

Step four, calculating the field operation percentages is the division of the expected crop machinery cost per operation (step two) by the expected whole-farm crop machinery costs for the farm (step three), to determine the percentage of estimated costs each individual operation makes up of the total costs.

Step five, finding actual whole-farm crop machinery costs, is where the individual farm's management abilities and cost characteristics are taken into account. In this step, the farm would sum together the crop portion of market depreciation, farm automobile expense, opportunity charge on the machinery investment, machinery insurance, machinery shelter, repairs, fuel, lubrication, labor, machinery rent, and machinery leasing as well as custom farming performed for the farm (i.e., the farm-specific costs outlined in Equation 1). All of these costs are relatively easy to determine if a moderate amount of effort is put into farm financial tracking or record keeping for tax purposes. See pages 2 and 3 (Based on total ownership and operating costs, what should custom rates be?) for aid in calculating actual whole-farm crop machinery costs.

Step six, prorate actual whole-farm crop machinery costs to various field operations by multiplying the field operation percentages (step four) times the actual whole-farm crop machinery costs (step five). This represents the farm's prorated actual cost to perform the respective operation, as compared to the expected cost to perform the operation, as found in step two.

Step seven, calculate actual per unit machinery costs by dividing the prorated actual field operation costs (step six) by the number of units that particular operation was performed over. This is the farm-specific cost to perform that particular field operation on a per-unit basis. Because it includes the farm's own machinery costs it is not based on averages or assumptions that do not reflect the farm's individual management.

To further illustrate how option two would be calculated, consider the following example farm (Table 2). This table is divided into various parts and columns (denoted by capital letters) to display how to proceed through the steps. Part A, Part B, Part C, Column D, Column E, Column F, and Part K of this table are the "Estimated Coefficients" and other relevant cost and operation data needed to perform the necessary calculations. Part A of the table identifies the scale factor coefficients. Part B is the harvested acres of the example farm. This is used to calculate the farm-specific scale factor in Part C. Column D contains the labels for the operations the farm performed and appropriate units for each operation. In Column E, the Estimated Coefficients are displayed (values taken directly from Table 1). Column F shows the units of each operation for the example farm (in acres, bushels, tons, bales, miles) performed.

Column G represents step one of the seven-step process — the product of the scale factor (Part C) and the estimated coefficients (Column E). Column H represents step 2 and is the product of the units of the operation performed (Column F) and the expected per unit cost (Column G). Part I (the sum of Column H) is step three of the seven-step process, and is the expected whole-farm crop machinery cost. Column J is the percent each type of operation makes up of the expected whole-farm machinery costs (Column H divided by Part I). Part K (step five) is the actual whole-farm crop machinery cost for the farm. This is the step where the farm's individual management and costs enter into the calculations. Column L (step six) is the product of the actual whole-farm crop machinery costs (Part K) and the percent each type of operation makes up of the whole-farm crop machinery costs (Column J). Column M (step seven) is the final calculation of this process. This step divides the prorated actual crop machinery costs for each field operation (Column L) by the units over which the operations were performed (Column F) to arrive at a farm-specific actual cost of each operation.

Benchmarking machinery operations

For a farm to determine its relative standing to other farms with respect to machinery ownership and operating costs, it needs to benchmark its machinery costs. Benchmarking simply refers to comparing the costs for an individual farm with the average of other similar farms (i.e., compare actual costs to expected costs). To do this, the farm would calculate its relative crop machinery cost coefficient. If this relative crop machinery cost coefficient is one, then the farm can perform the operations at the average cost of other producers. If it is greater than one, the farm has relatively high machinery costs, and if it is lower than one, the farm has relatively low machinery costs.

In practice, the farm can benchmark its costs at the whole-farm level by comparing Part K to Part I or operation-specific costs by comparing Column M to Column G. The relative crop machinery cost coefficient for the example farm (Part N in Table 2) was calculated to be 0.954, indicating that this farm has machinery costs equal to 95.4 percent of what is expected of typical producers of the same size performing the same type of operations. The relative crop machinery cost coefficient, which compares farm-specific costs to average costs of other farms, should not be compared to the relative custom rate ratio shown in Figure 1, which compares to average custom rates, as the two ratios compare costs against different standards.

Although benchmarking machinery is important, one must remember that having the lowest whole-farm machinery cost is not necessarily the best management objective. If whole-farm machinery cost is minimized, losses in production may result from non-uniform fertilizer application, uneven plant stands, harvesting losses, or untimely field operations, just to name a few. Rather, the lowest cost per unit of production (bushel, ton, etc.) is more desirable in that it takes into account the effect machinery has on yields, but analyzing this is outside the scope of this publication. However, benchmarking whole-farm or per acre machinery costs can still be valuable to give the farm an idea of what it should aim for with regard to machinery costs.

These calculations may be performed manually in the worksheet provided at the end of this publication or performed automatically with the spreadsheet KSU-MachCost.xls located at *www.agmanager.info.*

Conclusions

This research found that, on average, custom rates for a Kansas farm harvesting 1,000 acres are 20.4 percent lower than the true cost to own and operate machinery. Therefore, "total" custom rates (i.e., ones that include total ownership and operating costs) were estimated. These estimated rates may be used to prorate a farm's actual machinery costs to different field operations to find a farm-specific custom rate. A farm's machinery costs can then be used to benchmark the farm's actual costs against its expected costs, allowing a farm manager to see the farm's strengths or weaknesses with regards to total machinery costs.

Even though this research found that custom rates need to be increased by 25.6 percent, on average, to cover all ownership and operating costs, the market place will still determine what is charged and paid for custom machinery services. As previously

Table 2. *Estimating Farm-Specific per Unit Machinery Costs.*

A. Scale Factor Coefficients	
Constant	1.241
1 ÷ harvested acres	33.026
Scale Factor = 1.241 + 33.026 × (1 ÷ harvested acres)	
B. Harvested Acres	1,218
C. Scale Factor	1.268
I. Step 3 – Expected whole-farm machinery costs (Sum of Column H)	$133,670
K. Step 5 – Actual whole-farm machinery costs (Calculated from farm records)	$127,563
N. Relative Crop Machinery Cost Coefficient (K ÷ I)	0.954

D Operations	**E Estimated Coefficients**	**F Units**	**G Step 1[a] (C×E)**	**H Step 2[b] (F×G)**	**J Step 4[c] (H÷I)**	**L Step 6[d] (J×K)**	**M Step 7[e] (L÷F)**
Field cultivate without fertilizer (acres)	$5.55	1,254	$7.04	$8,825.70	6.60%	$8,422.48	$6.72
Disk (acres)	$6.33	3,263	$8.03	$26,192.65	19.60%	$24,995.98	$7.66
Chisel less than 12 inches deep (acres)	$7.88	962	$9.99	$9,613.02	7.19%	$9,173.83	$9.54
Drill/air-seed conventional till without fertilizer (acres)	$5.88	1,005	$7.46	$7,493.80	5.61%	$7,151.43	$7.12
Plant conventional till without fertilizer (acres)	$8.11	563	$10.28	$5,790.12	4.33%	$5,525.59	$9.81
Spray chemical (acres)	$3.63	1,625	$4.60	$7,480.29	5.60%	$7,138.54	$4.39
Spray chemical and fertilizer (acres)	$3.74	563	$4.74	$2,670.17	2.00%	$2,548.18	$4.53
Broadcast dry fertilizer (acres)	$3.41	1,440	$4.32	$6,226.95	4.66%	$5,942.46	$4.13
Harvest wheat (acres)	$13.64	1,007	$17.30	$17,418.17	13.03%	$16,622.38	$16.51
Wheat yield above 20 bu/ac (bushels)	$0.130	25,842	$0.16	$4,260.18	3.19%	$4,065.55	$0.16
Harvest grain sorghum (acres)	$14.14	113	$17.93	$2,026.22	1.52%	$1,933.65	$17.11
Grain sorghum yield above 35 bu/ac (bushels)	$0.128	8,438	$0.16	$1,369.65	1.02%	$1,307.07	$0.15
Harvest soybeans (acres)	$18.99	450	$24.08	$10,836.68	8.11%	$10,341.58	$22.98
Soybean yield above 24 bu/ac (bushels)	$0.127	1,521	$0.16	$244.96	0.18%	$233.77	$0.15
Swath (acres)	$8.36	376	$10.60	$3,986.14	2.98%	$3,804.03	$10.12
Round bales greater than 1,500 lbs (bales)	$7.99	525	$10.13	$5,319.43	3.98%	$5,076.40	$9.67
Small square bales (bales)	$0.533	1,222	$0.67	$821.31	0.61%	$783.78	$0.64
Miles on farm pickups (miles)	$0.336	16,000	$0.43	$6,817.39	5.10%	$6,505.92	$0.41
Miles on grain/hay trucks (miles)	$1.80	2,750	$2.28	$6,277.17	4.70%	$5,990.38	$2.18

[a] *Expected per unit machinery cost*
[b] *Expected crop machinery cost for each operation*
[c] *Field operation percentages*
[d] *Prorated actual whole-farm machinery costs to each operation*
[e] *Actual per unit machinery cost*

mentioned, there are rational economic reasons that producers choose to perform operations for less than their true cost to own and operate that machinery, or why producers hiring these services do not pay the full cost. However, if a farm is going to perform custom operations as an enterprise, it should consider the long term consequences of not covering all ownership and operating costs.

References

Beaton, A.J. "Per Unit Costs To Own and Operate Farm Machinery on Kansas Farms." M.S. Thesis, Department of Agricultural Economics, Kansas State University, Manhattan, KS. May 2003.

Case IH: http://www.equipment-locator.com

John Deere (Machinery Finder®): http://www.machinefinder.com/

Kansas Agricultural Statistics Service. Kansas Custom Rates. 632 SW Van Buren Street, Topeka, KS 66603. http://www.nass.usda.gov/ks/custom/crsel.htm

Kansas Farm Management Association. http://www.agecon.ksu.edu/kfma/

Kastens, T.L. Farm Machinery Operation Cost Calculations. Farm Management Guide MF-2244. Agricultural Experiment Station and Cooperative Extension Service, Kansas State University, Manhattan, Kansas. May 1997. http://www.agmanager.info/farmmgt/machinery/#Farm%20Machinery%20Papers

Langemeier, L.N. Kansas Farm Management Data Bank Documentation. Staff Paper No. 01-05 Kansas Agricultural Experiment Station, Kansas State University, Manhattan, Kansas. August 2000.

New Holland: http://www.equipment-locator.com

Schnitkey, G. Per Acre Machinery Costs on Illinois Grain Farms. Farm Economics Facts and Opinions, FEFO 01-06. University of Illinois, Urbana-Champaign, Illinois. April 2001. http://www.farmdoc.uiuc.edu/manage/

Williams, J. and T. Kastens. Lease, Custom Hire, Rent or Purchase Farm Machinery: Evaluating the Options. Risk and Profit Conference, Department of Agricultural Economics, Kansas State University, Manhattan, Kansas. September 1998. http://www.agmanager.info/farmmgt/machinery/#Farm%20Machinery%20Papers

Worksheet for estimating farm machinery costs

A. Scale Factor Coefficients	
Constant	1.241
1 ÷ harvested acres	33.026
B. Harvested Acres	
C. Scale Factor = 1.241 + 33.026 × (1 ÷ harvested acres)	
I. Step 3 – Expected whole-farm crop machinery costs (Sum of Column H)	
K. Step 5 – Actual whole-farm crop machinery costs	
N. Relative crop machinery cost coefficient (K ÷ I)	

Worksheet for estimating farm machinery costs (continued)

D Operations (required units)	E Estimated Coefficients	F Units	G Step 1 (C × E)	H Step 2 (F × G)	J Step 4 (H ÷ I)	L Step 6 (J × K)	M Step 7 (L ÷ F)
Field cultivate without fertilizer (acres)	$5.55						
Field cultivate with fertilizer (acres)	$6.24						
Sweep/undercut without fertilizer (acres)	$5.39						
Sweep/undercut with fertilizer (acres)	$6.06						
Disk (acres)	$6.33						
Chisel less than 12 inches deep (acres)	$7.88						
Chisel greater than 12 inches deep (acres)	$9.42						
Disk-chisel/disk deep-chisel (acres)	$9.27						
Moldboard plow (acres)	$8.96						
Row crop cultivate (acres)	$6.30						
Drill/air-seed no-till without fertilizer (acres)	$10.03						
Drill/air-seed no-till with fertilizer (acres)	$11.28						
Drill/air-seed conventional till without fertilizer (acres)	$5.88						
Drill/air-seed conventional till with fertilizer (acres)	$6.61						
Plant no-till without fertilizer (acres)	$9.79						
Plant no-till with fertilizer (acres)	$11.00						
Plant conventional till without fertilizer (acres)	$8.11						
Plant conventional till with fertilizer (acres)	$9.11						
Spray chemical (acres)	$3.63						
Spray fertilizer (acres)	$3.73						
Spray chemical and fertilizer (acres)	$3.74						
Anhydrous ammonia application (acres)	$5.50						
Broadcast dry fertilizer (acres)	$3.41						
Inject liquid fertilizer (acres)	$3.51						
Harvest wheat (acres)	$13.64						
Wheat yield above 20 bu/ac (bushels)	$0.130						
Harvest corn (acres)	$20.08						
Corn yield above 48 bu/ac (bushels)	$0.126						
Harvest grain sorghum (acres)	$14.14						
Grain sorghum yield above 35 bu/ac (bushels)	$0.128						
Harvest soybeans (acres)	$18.99						
Soybean yield above 24 bu/ac (bushels)	$0.127						
Harvest sunflowers (acres)	$17.99						
Swath (acres)	$8.36						
Rake hay (acres)	$2.93						
Round bales less than 1,500 lbs (bales)	$7.36						
Round bales greater than 1,500 lbs (bales)	$7.99						
Large square bales (bales)	$12.08						
Small square bales (bales)	$0.533						
Chop silage (no hauling or ensiling) tons	$3.07						
Rotary mow (acres)	$7.83						
Miles on farm pickups (miles)	$0.336						
Miles on grain/hay trucks (miles)	$1.80						

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Helpful comments of Martin Albright are greatly appreciated.

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

MF-2583 April 2003

Evaluating Self-propelled Crop Sprayer Ownership with the OwnSpray Spreadsheet

October, 2002

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Background

The recent trend towards less tillage brought about by advances in farm chemicals, especially herbicides, has sharply increased the availability and interest in self-propelled crop sprayers that can be used for both pre- and post-plant treatments. This paper accompanies the *OwnSpray* computer spreadsheet, which was developed as a "quick and dirty" aid to help individuals think through the sprayer ownership decision. Thus, most of the underlying assumptions and formulas are simply asserted rather than developed here. For a more comprehensive treatment of machinery costs, and for development of the mathematical formulas underlying *OwnSpray*, the reader is directed to *Farm Machinery Operation Cost Calculations, MF-2244* (referred to here as *MF2244*) and *Lease, Custom Hire, Rent or Purchase Farm Machinery: Evaluating the Options*. Supporting research references are contained therein. Both publications can be found at the Dhuyvetter/Kastens home webpage, www.agecon.ksu.edu/kdhuyvetter. It should be noted that *OwnSpray* arose from an urgent demand for such information. The current version should not be considered as definitive or comprehensive, as many of the calculations could benefit substantially from additional research.

Machinery investment decisions are inherently complex because they involve time, and a dollar today is worth more than a dollar tomorrow – because it can earn interest. A few examples of time issues regarding machinery are a) machinery depreciates over time; b) tax depreciation and market depreciation typically occur at different rates; c) repairs tend to increase as a machine ages; and d) as machines age they become less dependable (more prone to breakdowns), leading to owner concerns about timeliness. Although *OwnSpray* accommodates most relevant time-dimensioned issues related to sprayer ownership, it does not explicitly deal with timeliness issues. That is, quantifying loss of business for custom applicators or reduced crop yields for farm operators due to excessive breakdowns is not handled by *OwnSpray*. Such potentially important considerations are left to the user to assess. Further, although *OwnSpray* does consider tendering (i.e., keeping the sprayer supplied with water and chemicals) costs, that part of the spreadsheet is not fully developed.

In an economic analysis, machinery ownership and operating costs are often classified into the following categories: 1) interest; 2) depreciation; 3) repair and maintenance; 4) labor; 5) fuel and lubrication; and 6) property taxes, insurance, and shelter (TIS). Although the timing of tax depreciation does impact overall costs and profitability, the depreciation ultimately of interest here is market depreciation. Market depreciation is the change in machine market value over time, which represents a real loss in asset value over time. Although based on prevailing lender interest rates, the interest cost considered most important here is opportunity interest, rather than the interest associated with an actual loan arising from an owner's financing decision. That is, because equity could be invested elsewhere, it is considered to bear interest just as does debt (and at the same rate – see *MF2244*). Because a machine could have been sold at the end of last year, with the proceeds invested elsewhere, this year's opportunity interest cost is calculated by multiplying last year's machine market value by the prevailing lender interest rate. In its sprayer analysis, *OwnSpray* follows the same machinery ownership and operating cost categories as described above.

The goal of machinery investors is assumed to be maximizing after-tax (i.e., income tax) profits. Thus, wherever necessary, *OwnSpray* computes after-tax values. However, because decision makers are used to comparing observed costs, which are intrinsically pre-tax (e.g., the price of fuel or reported custom rates), *OwnSpray* converts after-tax to pre-tax values in the final analysis.

Following a discussion around sprayer valuation, this paper proceeds directly into a description of using the *OwnSpray* spreadsheet. A brief discussion of underlying concepts and assumptions, on an issue-by-issue basis, is provided in that section.

Market Valuation (Depreciation)

A key requirement of the sprayer investment decision is a reasonable expectation of market valuation (depreciation) over time. That is, how much will a new or used sprayer purchased for *X* dollars today be worth *Y* years from now, after being used on *Z* acres each year? Typically, market valuation formulas are based on many years of observed market data or engineering estimates. Unfortunately, because self-propelled crop sprayers are quite new, market valuation formulas are not readily available. Consequently, to derive the market valuation formulas in *OwnSpray*, we examined data from dealer offerings of self-propelled sprayers in the classified ads section of the *High Plains Journal*, considering one issue each month from January 2000 through January 2001. Because the data set was limited, we focused on the following sprayer features: a) brand, b) model year, and c) engine hours. A more detailed analysis using more comprehensive data would undoubtedly allow finer market valuation distinctions, such as those related to model, tank size, boom width, or type of controlling equipment. However, the distinctions provided here go a long ways towards making informed sprayer investment decisions. A brief discussion of our sprayer valuation analysis follows.

In the sprayer valuation analysis, our first assumption was that both age and hours of use impact machine value, thus depreciation. Second, to accommodate sprayers whose market value varies widely across age, hourmeter hours, and brand, we considered depreciation to be a constant proportional change for each year or for each hour of use. Thus, for example, a sprayer's expected worth one year was assumed to be its worth in the prior year, multiplied by some constant percentage. Likewise, each additional 100 hours on the engine hourmeter was assumed to devalue the sprayer by a constant percentage. The *High Plains Journal* data were used to determine the values for these percentages. Second, in order to test whether different sprayer classes might depreciate at different rates, we categorized sprayers as low-end (*Low*), medium (*Med*), or high-end (*High*). Spra-Coupe® and Apache® are examples of *Low* sprayers. Example *Med* sprayers are Hagie® and Wilmar®, and example *High* sprayers are Deere 4700/4710®, RoGator®, and Walker®.

In our analysis, we did not observe depreciation rates to be statistically different across *Low*, *Med*, and *High* sprayers. That is, the depreciation as a percent of market value was similar for *Low*, *Med*, and *High* sprayers. Nor did we find usage rate (i.e., hours/age) to statistically contribute to a model of sprayer price whenever each of age and hours was already included as a separate explanatory variable. The statistical sprayer price model selected for use in *OwnSpray* explained over 90% of the sprayer price variation observed in the data set, and was specified as:

Sprayer Price = exp(11.2414 + 0.3046**Med* + 0.6133**High* - 0.1465**Age* - 0.0118**100hrs*) ,

where *Med* is a binary variable valued at 1 if the price observation pertains to a *Med*-classed sprayer, else 0; *High* is a binary variable valued at 1 if the price observation if from a *High*-classed sprayer, else 0; *Age* is the valuation year (here, 2001) less the model year for the sprayer; *100hrs* is the sprayer's hourmeter hours divided by 100; and exp denotes the exponential function (i.e., the inverse natural log, or e^x). Thus, a 3-year old low-end sprayer with 650 hours would be expected to be priced at exp(11.2414 + 0.3046*0 + 0.6133*0 - 0.1465*3 - 0.0118*6.5) = $45,488. That same sprayer, after being used for another 250 hours during the course of one more year would be expected to have a value of exp(11.2414 - 0.1465*4 - 0.0118*9) = $38,147.

For very small changes in age or hours, the price model suggests roughly a 15% (0.1465) drop in price for each additional year of age and roughly a 1% (0.0118) drop in price for each additional 100 hours. The model is largely dominated by age rather than hours, which contrasts sharply with published models for other machines such as tractors or combines. Likely that is because, compared to tractors and combines, sprayer technology is still changing rapidly, leading to more rapid obsolescence with age.

Using the *OwnSpray* Spreadsheet

The *OwnSpray* spreadsheet calculates operating costs for self-propelled crop sprayers using internal calculations based on inputs provided by the user. Blue numbers in the spreadsheet are user inputs and black numbers are calculated from the blue numbers. Simply put, if the user wants a black number to change, he must change a blue number. The spreadsheet accounts for both time-dimensioned variables as well as those that are fixed over time. This section of the paper describes each of the spreadsheet inputs, assumptions, and related calculations. The end result is an annually amortized pre-tax cost per acre that can be compared across alternative sprayer ownership strategies as well as directly with custom rates.

In *OwnSpray*, the time a purchase decision is made is considered year 0. The first year a sprayer is actually used is considered to be year 1, and so on. Although income taxes are typically not paid until early in the year after they are accrued, for simplicity, we assume taxes are paid in the same year as accrued. This should result in little distortion overall, and potentially none for those paying income tax estimates quarterly. Thus, with these assumptions, because the sprayer is considered purchased in year 0, that is also the first year that tax depreciation is taken. Conceptually, for a sprayer that is to be used for 3 years, it is probably easiest to think of purchasing it on December 31 in year 0, using the machine for spraying throughout the year-1, year-2, and year-3 seasons, and subsequently selling the machine on December 31 in year 3.

Notice that *OwnSpray* assumes the sprayer is explicitly sold following the last year of use rather than traded in. Because trading a machine results in a change in tax basis rather than in depreciation recapture, results would be different than those calculated in the spreadsheet. However, as long as treatment of exiting machines is consistent (as it is here, where exiting machines are always considered sold), then using *OwnSpray* to evaluate different sprayers is still appropriate – whether or not a sprayer is in fact sold or traded.

The *OwnSpray* spreadsheet has three main sections: 1) user input and related calculations section, 2) time and tax (TT) section, and 3) sprayer analysis summary section. User inputs are entered in the user input section. This section also shows related calculations for use elsewhere or otherwise of interest to the user. The time and tax section displays the time-dimensioned variable values over time, ultimately leading to a computation of after-tax net present value of costs. The sprayer analysis summary section condenses the results of the analysis into a breakdown of pre-tax sprayer ownership and operating costs by category, providing costs that can easily be compared across alternative ownership strategies and directly with custom rates.

Step 1. Select the sprayer's class, age, and hours

Based on a sprayer's class, age, and hours, an expected sprayer price is calculated using the price model discussed earlier. Because depreciation percentages do not change with sprayer class, knowing the sprayer class is not strictly necessary for using this spreadsheet. However, it does provide one check against which the Step 2 sprayer cost might be compared.

Step 2. Select the sprayer's expected purchase price

This is the dollar amount expected to be paid for a sprayer in question (without a trade-in). All depreciation calculations will be keyed off of this value. Given the user-supplied purchase price, the spreadsheet uses the price model to calculate a new equivalent price, which will be used in repair calculations.

Step 3. Select the number of seasons (years) the sprayer will be used before it is sold

Step 4. Select boom width and travel speed

Based on boom width and travel speed, the spreadsheet calculates theoretical acres per hour at 100% efficiency.

Step 5. Select the operating efficiency

Relative to many field operations, and partly due to fast travel speeds, crop sprayers are generally not very efficient. That is, substantial time is spent moving from field to field, slowing down for turnarounds, and tendering the sprayer. *MF2244* suggests a field efficiency range of 50% to 80% for pull type sprayers operating at 3 to 7 mph. Likely, self-propelled sprayers are less efficient. Unless the user has better information, we suggest values in the 30% to 60% range. Based on the field efficiency selected, the actual acres covered per hour is calculated.

Step 6. Select the expected number of acres covered annually by the sprayer

Using the user-supplied annual number of acres covered, along with actual acres per hour, the spreadsheet calculates the number of hours expected to be put on the sprayer each year – a key variable for determining repairs, market depreciation, and labor costs. Based on casual evidence from farm and commercial applicators, covering much more than 25,000 acres/year with a single sprayer is often unrealistic. For some farm operators a practical upper limit may be only 10,000 to 15,000 acres. As a reminder, spraying the same 100 acre field three times counts as 300 acres.

Step 7. Select labor cost per hour

Hourly labor charges are assigned to actual hours of sprayer use described in Steps 5 and 6. As used here, the user-supplied constant hourly labor charge must accommodate overtime pay if applicable, fringe benefits, as well as any inefficiencies not captured in the field efficiency value described earlier. Labor associated with sprayer tendering is not considered here, but included in tendering costs discussed later.

Step 8. Select fuel per hour and price per gallon

Fuel per hour should be the expected gallons per hour consumed by the sprayer. Fuel price is typically the expected price of non-taxable (farm-use) diesel. Besides fuel consumption and price, the user is asked to select the percentage that oil and lubrication cost is of fuel cost. *MF2244* suggests this value to be 10%; others suggest values as low as 5%.

Step 9. Select inputs for repair calculations

Information from private sources suggests that sprayer repair and maintenance costs for custom applicators are around 9% to 10% of total revenue, or perhaps $0.30 to $0.40 per acre. Thus, *OwnSpray* allows for calculating repairs based on a constant per acre or per hour charge, which is referred to as the CPAH method (an hourly rate and a per-acre rate can be included simultaneously). However, considering per-acre or per-hour repairs to be constant across time is probably inappropriate. Certainly, older higher-houred sprayers would be expected to require more repairs than newer lower-houred sprayers.

To allow for repairs that increase as sprayers age with use, *OwnSpray* allows for repairs to be calculated with an alternative method, referred to as the ASAE method – because it is based on a formula used by the American Society of Agricultural Engineers. Because it allows for analyzing a wider range of sprayer ownership strategies, the ASAE method is preferred to the CPAH method for most situations. As described in *MF2244*, the ASAE method estimates repairs according to the formula:

$$\text{accumulated repairs} = NEP * RF1 * (\text{accumulated hours}/1000)^{RF2},$$

where *NEP* is the new equivalent price of the sprayer, and *RF1* and *RF2* are repair factors. Then, annual repairs is calculated by subtracting last year's accumulated repairs from this year's accumulated repairs. *MF2244* provides ASAE-suggested *RF1* and *RF2* factors for a variety of equipment, but not for self-propelled sprayers. After considering various simulations using *OwnSpray*, we believe that *MF2244*'s repair factors for self-propelled windrowers may be reasonable for self-propelled sprayers, namely *RF1* = 0.06 and *RF2* = 2.0. Based on the user's assessment, repairs could be proportionately adjusted up or down by changing *RF1*. Thus, setting *RF1* = 0.066 would boost all repairs by 10%. Also, if a user believes repairs should grow faster (slower) with increased hours, *RF2* would need to be adjusted up (down).

It should be noted that, in *OwnSpray*, the user can select either the ASAE method or the CPAH method for repair calculations, but not both. If the ASAE method is selected, CPAH calculations are ignored, and vice versa.

Step 10. Select the property tax, insurance, and shelter (TIS) percentage

The cost associated with property taxes, insurance, and shelter is considered to be a fixed percent of sprayer market value. Assuming no property taxes, *MF2244* suggests a value of 1.5%.

Step 11. Select a bank interest rate, income and self-employment tax rates
The selected bank interest rate should be the typical borrowing rate expected from lenders. The combined state and federal income tax rate should be the rate expected on the next taxable dollar earned. Typically, federal income tax rates for sole proprietors are either 15% or 28%, with state rates around 4% to 5%. For many users, a dollar of expense saves both income tax and self-employment tax. Thus, *OwnSpray* allows for including self-employment tax (currently 15.3%). Further, because tax depreciation saves income and self-employment tax, yet depreciation recapture when a used sprayer is sold garners only income tax, *OwnSpray* distinguishes income tax from self-employment tax rates.

Step 12. Enter tax depreciation information
OwnSpray allows for the Section 179 expensing deduction for depreciable assets. The Section 179 deduction reduces taxable income by that amount in the year of purchase. This deduction is taken before any IRS formula-based tax depreciation schedule is applied. The maximum allowed in 2002 is $24,000 and goes to $25,000 in 2003.

Beginning in 2001, a bonus first-year depreciation of 30% is allowed on only new machines. *OwnSpray* allows a user to use this tax deduction by inserting a 1 in the appropriate spreadsheet cell. The 30% bonus depreciation is taken *after* any Section 179 deduction. Like the Section 179 deduction, it reduces taxable income by that amount in the year of purchase. Also like the Section 179 deduction, it directly reduces the dollar amount to which any IRS formula-based tax depreciation schedule is applied. When a 1 is used to signal use of the 30% bonus depreciation, the spreadsheet double checks that the sprayer is actually 0 years old at the time of purchase.

After accounting for the Section 179 and 30% bonus depreciation deductions, *OwnSpray* uses the MACRS tax depreciation percentages for 7-year property to play out tax depreciation across the years that a sprayer is considered owned. As the spreadsheet is currently structured, faster depreciation (if applicable) can be accommodated by changing the cell values appropriately, with some cells perhaps set to 0. When changing, care should be taken that the values sum to 100%.

Step 13. Select a cash downpayment
As already discussed, there is an opportunity interest cost associated with an investment whether or not money is actually borrowed – because equity funds could just as well be invested elsewhere to earn a return. Thus, for a sprayer investment, the choice of financing does not impact profitability or cost. However, to aid understanding, *OwnSpray* allows for a user-selected downpayment. Then, *OwnSpray* shows (in the TT section) the cash flows associated with an interest-only loan, followed by a balloon principal payment at the end of the last year of use for the sprayer. Other loan structures, such as an annually amortized loan, are not considered in *OwnSpray*. Of course, such alternative structures would not impact profitability or cost. Users might select different downpayment amounts to see that sprayer costs do not change.

Step 14. Tendering costs
Although tendering is an important cost associated with crop spraying, *OwnSpray* is not designed to provide and extensive breakdown of such costs. Thus, tendering costs must be entered as a constant cost per acre or a constant cost per hour or both. Based on information from one private source, a tendering cost between $1.00 and $1.50 per acre seems reasonable. However, tendering costs likely will vary

considerably for different situations (e.g., due to different application rates or field sizes). Thus, users are encouraged to estimate tendering costs appropriate for their situations.

Cash flows and economic variable calculations over time (understanding the TT section)

The time and tax (TT) section of the *OwnSpray* spreadsheet calculates the expected values for those variables that change over time. Some columns are not strictly needed, but are included to aid understanding (e.g., loan interest and loan principal, as discussed in Step 12, or the annual breakdown of per acre repairs). Most columns are self-explanatory, while others can be understood by examining the formulas they contain. Essentially, this section tracks all cash flows over time, with future cash flows appropriately discounted to year 0 (the present). Tax savings due to business expenses and tax depreciation is considered a cash flow because it would reduce taxes paid.

After discounting for time, all cash flows in this section are summed to provide the after-tax net present value of costs (NPVc). Since the only time-dimensioned variables considered in *OwnSpray* are interest, depreciation, repairs, and TIS, the NPVc value must be prorated among these four cost categories. Because opportunity interest and market depreciation are ultimately the relevant interest and depreciation cost categories, prorating NPVc is not immediately straightforward. *OwnSpray* handles this as follows. First, market depreciation and opportunity interest columns are included in the TT section. Then, the after-tax discounted NPV for each of these two columns, along with that of the repairs and TIS columns, is calculated. Finally, the relative share that each of the four values is of the total of all four, determines the NPVc proration portions.

Sprayer analysis and summary section

First, this section repeats a few of the underlying user inputs to facilitate printing a report. Second, based on after-tax amortization of values from the TT section, followed by conversions to pre-tax values, this section reports the ownership and operating costs associated with the sprayer analyzed. To facilitate cost and custom rate comparisons, categorical costs are reported as annual costs, per hour costs, and per acre costs.

Evaluating Tractor Ownership with the OwnTractor Spreadsheet

October, 2002
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Background

The trend towards larger, more sophisticated, more productive, and higher cost tractors makes the tractor purchase decision especially important. This paper accompanies the *OwnTractor* computer spreadsheet, which was developed as a "quick and dirty" aid to help individuals think through the tractor ownership decision. Thus, most of the underlying assumptions and formulas are simply asserted rather than developed here. For a more comprehensive treatment of machinery costs, and for development of the mathematical formulas underlying *OwnTractor*, the reader is directed to *Farm Machinery Operation Cost Calculations, MF-2244* (referred to here as *MF2244*) and *Lease, Custom Hire, Rent or Purchase Farm Machinery: Evaluating the Options*. Supporting research references are contained therein. Both publications can be found at the Dhuyvetter/Kastens webpage, www.agecon.ksu.edu/kdhuyvetter. The reader is pointed also to the *OwnSpray* spreadsheet available at the same website. That spreadsheet helps the user analyze the self-propelled crop sprayer ownership decision.

Machinery investment decisions are inherently complex because they involve time, and a dollar today is worth more than a dollar tomorrow – because it can earn interest. A few examples of time issues regarding machinery are a) machinery depreciates over time; b) tax depreciation and market depreciation typically occur at different rates; c) repairs tend to increase as a machine ages; and d) as machines age they become less dependable (more prone to breakdowns), leading to owner concerns about timeliness. Although *OwnTractor* accommodates most relevant time-dimensioned issues related to tractor ownership, it does not explicitly deal with timeliness issues. For example, quantifying lost profit from reduced crop yields due to excessive breakdowns is not handled by *OwnTractor*. Such potentially important considerations are left to the user to assess.

In an economic analysis, machinery ownership and operating costs are often classified into the following categories: 1) interest; 2) depreciation; 3) repair and maintenance; 4) labor; 5) fuel and lubrication; and 6) property taxes, insurance, and shelter (TIS). Although the timing of tax depreciation does impact overall costs and profitability, the depreciation ultimately of interest here is market depreciation. Market depreciation is the change in machine market value over time, which represents a real loss in asset value. Although based on prevailing lender interest rates, the interest cost considered most important here is opportunity interest, rather than the interest associated with an actual loan arising from an owner's financing decision. That is, because equity could be invested elsewhere, it is considered to bear interest just as does debt (and at the same rate – see *MF2244*). Because a machine could have been sold at the end of last year, with the proceeds invested elsewhere, this year's opportunity interest cost is calculated by multiplying last year's machine market value by the prevailing lender interest rate.

OwnTractor is not a comprehensive tractor analysis program where tractor capacity is considered against specific amounts and types of field operations. Rather, it assumes the user knows the size of tractor needed, but that he would like to consider purchasing tractors of different brands, age, and accumulated hours. Thus, *OwnTractor* uses all of the machinery ownership and operating cost categories described above except for two: labor and fuel and lubrication. The assumption is that two tractors that are approximately the same size will have similar labor and fuel requirements. In this manner, *OwnTractor* results in a "dollars per hour" cost number that makes it easy to compare alternative tractors being considered in a tractor purchase. Additionally, the cost per hour number can be directly compared with per hour tractor rental and leasing rates from machinery dealers.

The goal of machinery investors is assumed to be maximizing after-tax (i.e., income tax) profits. Thus, wherever necessary, *OwnTractor* computes after-tax values. However, because decision makers are used to comparing observed costs, which are intrinsically pre-tax (e.g., tractor rental rates), *OwnTractor* converts after-tax to pre-tax values in the final analysis.

Following a discussion around tractor valuation, this paper proceeds directly into a description of using the *OwnTractor* spreadsheet. A brief discussion of underlying concepts and assumptions, on an issue-by-issue basis, is provided in that section.

Market Valuation (Depreciation)

A key requirement of the tractor investment decision is a reasonable expectation of market valuation (depreciation) over time. That is, how much will a new or used tractor purchased for *X* dollars today be worth *Y* years from now, after being used for *Z* hours each year? To be most reliable, machinery market valuation formulas should be based on many years of observed market data. Consequently, the market valuation formulas in *OwnTractor* were developed using information extracted from Iron Solutions, The Official Guide of the Equipment Industry (the Guide). The Guide is essentially the "Blue Book" of the North American Equipment Dealers Association (NAEDA). It shows expected market values for many brands of tractors, from new to 20+ years old. It shows the typical hours expected on a tractor and has formulas for adjusting market value if the hours are different from expected. Additionally, it shows how to value numerous tractor options, for example tire duals, 3 point hitches, power-take-offs, and mechanical front wheel drive. The Guide is designed so that a machinery dealer can look up the value for a particular used tractor today. Since tractors depreciate over time, it is important for the dealer to have access to the most recent information, and consequently, the Guide is published quarterly.

Although it would be conceptually possible to construct a large computer lookup program based on information from the Guide, that would be most cumbersome and would require constant updating with each new issue. To overcome such problems, *OwnTractor* does two things. First, it uses only *rate of depreciation* information extracted from the Guide, and does not depend on using the Guide's actual value predictions. Second, *OwnTractor* depends on an expected tractor purchase price that is provided by the user. In addition to always being current, that expected purchase price embodies a great deal of other information. For example, a mechanical front wheel drive (MFWD) tractor will have a higher purchase price than a straight two wheel drive. Thus, it is left up to the user to be sure "apples" are not being compared with "oranges." In the MFWD example, tractors with and without

MFWD should not be directly compared unless the user is willing to make an expected price adjustment to the purchase price. All in all, relying on the Guide for only depreciation rate information, and relying on the user for a reliable purchase price, means *OwnTractor* should be reasonably reliable for several years to come.

It should be noted that the tractor market price series from the Guide used in *OwnTractor* is the series referred to as the Resale Cash Value. As defined in the Guide, it "is a reference point for what the unit will be worth on the lot, after reconditioning, on a cash basis. It does not take into account the added dealer costs of offering interest-free financing, extended warranty, etc." Essentially, this price series embodies all repair and rebuilding costs to ensure the tractor is in top running condition given its age and hours. We considered using an alternative price series, referred to as the Trade Value Premium series, which is typically about 90% of the Resale Cash Value for 1-year-old tractors and diminishes to 60%-70% of the Resale Cash Value series for 20-year-old tractors. However, the engineering type formulas we use for repair calculations (described later) assume tractors are kept in top condition with all of the necessary repair and rebuilding costs. Thus, if a user is accustomed to thinking of used tractor value being that which he can obtain from a dealer given the dealer will do some reconditioning when he gets the tractor in, then *OwnTractor* might slightly overstate expected future market value for a used tractor. However, given the engineering-type repair calculations, the spreadsheet will probably slightly overstate repairs for such users. Consequently, on the balance, the two overstatements should offset each other, providing a reasonable measure of total tractor costs.

In the analysis behind *OwnTractor*, we fundamentally considered depreciation as a separate function of age and of hours of use. That is, aging a tractor without putting hours on it will cause it to depreciate at a certain rate and putting more hours on a tractor without making it any older will cause it to depreciate at a different rate. We also tested a number of more complex relationships. For example, we examined whether the depreciation due to age might change due to hours and vice versa. We also tested whether tractors with different horsepower depreciate at different rates. Although adding complexity to the depreciation formulas always resulted in predicting market value more accurately for some tractors, when we tried to generalize the formulas across different tractors, it would cause other tractors' market value to be predicted less accurately. Consequently, *OwnTractor* uses the more simple depreciation relationship, where only age and hours are considered independently.

Considering the tradeoff between predictive accuracy and the generality that fosters usability of *OwnTractor*, we settled on six classes of tractors, with each class having its own age and hours depreciation factors:

Class 1: John Deere 2wd or MFWD
Class 2: Case-IH 2wd or MFWD
Class 3: AGCO 2wd or MFWD
Class 4: John Deere full time 4wd
Class 5: Case-IH full time 4wd
Class 6: New Holland-Versatile full time 4wd

Based on the analysis undertaken, we believe that *OwnTractor* will be reasonably reliable for 2wd tractors (with or without MFWD) in the 125-250 pto hp range and for 4wd tractors in the 200-400 hp range. We do not consider tractor options (e.g., 3 point hitch, power shift transmission, pto) to be particularly problematic for the analysis – though the user is cautioned to compare tractors with similar options. For tractor classes not explicitly considered, the user should simply insert the class he believes is most like the tractor being considered.

Using the *OwnTractor* Spreadsheet

The *OwnTractor* spreadsheet calculates ownership and operating costs for tractors using internal calculations based on inputs provided by the user. Blue numbers in the spreadsheet are user inputs and black numbers are calculated from the blue numbers. Simply put, if the user wants a black number to change, he must change a blue number. The spreadsheet accounts for both time-dimensioned variables as well as those that are fixed over time. This section of the paper describes each of the spreadsheet inputs, assumptions, and related calculations. The end result is an annually amortized pre-tax cost per hour that can be compared across alternative tractor ownership strategies as well as directly with rental rates.

In *OwnTractor*, the time a purchase decision is made is considered year 0. The first year a tractor is actually used is considered to be year 1, and so on. Although income taxes typically are not paid until early in the year after they are accrued, for simplicity, we assume taxes are paid in the same year as accrued. This should result in little distortion overall, and potentially none for those paying income tax estimates quarterly. Thus, with these assumptions, because the tractor is considered purchased in year 0, that is also the first year that tax depreciation is taken. Conceptually, for a tractor that is to be used for 3 years, it is probably best to think of purchasing it on December 31 in year 0, using the tractor for farming operations throughout the year-1, year-2, and year-3 seasons, and subsequently selling the machine on December 31 in year 3.

Notice that *OwnTractor* assumes the tractor is explicitly sold following the last year of use rather than traded in. Because trading a machine results in a change in tax basis rather than in depreciation recapture, results would be different than those calculated in the spreadsheet. However, as long as treatment of exiting machines is consistent (as it is here, where exiting machines are always considered sold), then using *OwnTractor* to evaluate different tractors is still appropriate – whether or not a tractor is in fact sold or traded.

The *OwnTractor* spreadsheet has three main sections: 1) user input and related calculations section, 2) time and tax (TT) section, and 3) analysis summary section. User inputs are entered in the user input section. This section also shows related calculations for use elsewhere or otherwise of interest to the user. The time and tax section displays the time-dimensioned variable values over time, ultimately leading to a computation of after-tax net present value of costs. The tractor analysis summary section condenses the results of the analysis into a breakdown of pre-tax tractor ownership and operating costs by year and by hour, providing costs that easily can be compared across alternative ownership strategies and directly with rental rates.

The following is a step-by-step discussion of the inputs required in the *User Input* section.

Step 1. Select the tractor's class, age, and accumulated hours at the time of purchase

Step 2. Select the tractor's expected purchase price
This is the dollar amount expected to be paid for a tractor in question (without a trade-in).

Step 3. Select the tractor's market price
The tractor's market value determines a number of costs in the spreadsheet. First, it determines a new equivalent price (*NEP*), which is used to determine accumulated repair costs over time and thus annual repair costs. Additionally, it is used to initialize the market value series that ultimately determines annual market depreciation, opportunity interest costs, and TIS (property taxes, insurance, and shelter) annual costs. Intuitively, these annual costs should not vary based on whether a tractor buyer happened to get an especially good or especially bad deal on the tractor purchase. Consequently, the spreadsheet needs to isolate the purchase price from the market price of the tractor in question.

In practice, the tractor's purchase price and market price typically should be the same. At least a user should start that way. Then, the user can examine the impact of "talking the dealer down" simply by inserting a lower purchase price in that cell. On the other hand, a buyer might believe that "paying over the market" is appropriate for a tractor in especially good condition. Inserting a market price that is lower than the purchase price means that the resultant dollars of annual depreciation will be lower than it would have been had it been keyed off of the purchase price (since, given a tractor usage rate, depreciation is a constant *percent* of market value) – precisely what is desired for someone purchasing a mint condition tractor, for example.

Step 4. Select a cash downpayment
As already discussed, there is an opportunity interest cost associated with an investment whether or not money is actually borrowed – because equity funds could just as well be invested elsewhere to earn a return. Thus, for a tractor investment, the choice of financing does not impact profitability or cost. However, to aid understanding, *OwnTractor* allows for a user-selected downpayment. Then, *OwnTractor* shows (in the TT section) the cash flows associated with an interest-only loan, followed by a balloon principal payment at the end of the last year of use for the tractor. Other loan structures, such as an annually amortized loan, are not considered in *OwnTractor*. Of course, such alternative structures would not impact profitability or cost. Users might select different downpayment amounts to see that tractor costs do not change.

Step 5. Select the number of seasons (years) the tractor will be used before it is sold

Step 6. Select the number of hours the tractor is expected to be used annually

Step 7. Select the Repair Adjustment Factor (RAF)
To allow for repairs that increase as tractors age with use, *OwnTractor* calculates repairs following procedures developed by the American Society of Agricultural Engineers. Based on the publication ASAE D497.4 JAN 98 Agricultural Machinery Management Data, obtained from ASAE's website, and which describes the standards for 2001, accumulated repairs are described by the formula:

accumulated repairs = $NEP*RF1*(\text{accumulated hours}/1000)^{RF2}$,

where *NEP* is the new equivalent price of the machine, and *RF1* and *RF2* are repair factors. Then, annual repairs is calculated by subtracting last year's accumulated repairs from this year's accumulated repairs. According to the ASAE publication, the *RF1* factor should be 0.007 and 0.003 for two-wheel drive and four-wheel drive tractors, respectively. *RF2* is 2.0 for both two- and four-wheel drive tractors. Since many tractors today are mechanical front wheel drive (MFWD), and such were actually the tractors whose depreciation was modeled in the background research for *OwnTractor*, we arbitrarily set *RF1* = 0.005 for the first three classes of tractors considered, which is halfway between that recommended for 2wd and 4wd tractors by the ASAE.

If a user considers the expected future annual repairs calculated by the spreadsheet to be inconsistent with other information he might have, then he can set the RAF factor at some value other than 1.0. The RAF factor does a simple proportionate scaling. That is RAF = 0.90 and RAF = 1.10 imply annual repairs that are 10% higher or 10% lower, respectively, than what would be predicted using the ASAE formula.

Given the related discussion in the Market Valuation section, the user is cautioned against setting the RAF to something below 1.0 merely because he believes the projected repairs are too high. Rather, he should look also at the expected future market value, which might also be too high by his assessment, and thus the two values would more-or-less offset each other. Additionally, it is easy for a farmer who does his own repairs to forget the cost of his labor and the cost of keeping up his shop. It is also easy to forget to prorate large and infrequent overhaul charges across years. In either case, the farmer's intuition about repair costs might be on the low side.

Step 8. Select the property tax, insurance, and shelter (TIS) percentage

The cost associated with property taxes, insurance, and shelter is considered to be a fixed percent of tractor market value. Assuming no property taxes, *MF2244* suggests a value of 1.5%.

Step 9. Select a bank interest rate, income and self-employment tax rates

The selected bank interest rate should be the typical borrowing rate expected from lenders. The combined state and federal income tax rate should be the rate expected on the next taxable dollar earned. Typically, federal income tax rates for sole proprietors are either 15% or 28%, with state rates around 4% to 5%. For many users, a dollar of expense saves both income tax and self-employment tax. Thus, *OwnTractor* allows for including self-employment tax (currently 15.3%). Further, because tax depreciation saves income and self-employment tax, yet depreciation recapture when a used tractor is sold garners only income tax, *OwnTractor* distinguishes income tax from self-employment tax rates.

Step 10. Enter tax depreciation information

OwnTractor allows for the Section 179 expensing deduction for depreciable assets. The Section 179 deduction reduces taxable income by that amount in the year of purchase. This deduction is taken before any IRS formula-based tax depreciation schedule is applied. The maximum allowed in 2002 is $24,000 and goes to $25,000 in 2003.

Beginning in 2001, a bonus first-year depreciation of 30% is allowed on only new machines. *OwnTractor* allows a user to use this tax deduction by inserting a 1 in the appropriate spreadsheet cell. The 30% bonus depreciation is taken *after* any Section 179 deduction. Like the Section 179 deduction, it reduces taxable income by that amount in the year of purchase. Also like the Section 179 deduction, it directly reduces the dollar amount to which any IRS formula-based tax depreciation schedule is applied. When a 1 is used to signal use of the 30% bonus depreciation, the spreadsheet double checks that the tractor is actually 0 years old at the time of purchase.

After accounting for the Section 179 and 30% bonus depreciation deductions, *OwnTractor* uses the MACRS tax depreciation percentages for 7-year property to play out tax depreciation across the years that a tractor is considered owned. As the spreadsheet is currently structured, faster depreciation (if applicable) can be accommodated by changing the cell values appropriately, with some cells perhaps set to 0. When changing, care should be taken that the values sum to 100%.

Cash flows and economic variable calculations over time (understanding the TT section)
The time and tax (TT) section of the *OwnTractor* spreadsheet calculates the expected values for those variables that change over time. Some columns are not strictly needed, but are included to aid understanding (e.g., loan interest and loan principal, as discussed in Step 4, or the annual breakdown of per hour repairs). Most columns are self-explanatory, while others can be understood by examining the formulas they contain. Essentially, this section tracks all cash flows over time, with future cash flows appropriately discounted to year 0 (the present). Tax savings due to business expenses and tax depreciation is considered a cash flow because it would reduce taxes paid.

After discounting for time, all cash flows in this section are summed to provide the after-tax net present value of costs (NPVc). Since the only time-dimensioned variables considered in *OwnTractor* are interest, depreciation, repairs, and TIS, the NPVc value must be prorated among these four cost categories. Because opportunity interest and market depreciation are ultimately the relevant interest and depreciation cost categories, prorating NPVc is not immediately straightforward. *OwnTractor* handles this as follows. First, though they do not impact cash flows, market depreciation and opportunity interest columns are included in the TT section. Then, the after-tax discounted NPV for each of these two columns, along with that of the repairs and TIS columns, is calculated. Finally, the relative share that each of the four values is of the total of all four, determines the NPVc proration portions.

Tractor analysis and summary section
First, this section repeats a few of the underlying user inputs and calculated values to facilitate printing a report. Second, based on after-tax amortization of values from the TT section, followed by conversions to pre-tax values, this section reports the ownership and operating costs associated with the tractor analyzed. To facilitate cost and rental rate comparisons, categorical costs are reported as annual costs and as per hour costs.