Farm Energy IQ

Field Crop Production – Activity Sheet

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ACTIVITY 1A: BUYING NEW OR USED TRACTORS: COMPARING FUEL EFFICIENCY

Farmer Green is planning to buy a new tractor. Although price and durability are important to him, he also recognizes that he expends a lot of money on tractor fuel during the season. Thus, he would like to compare power performance and fuel efficiency among the tractors he is considering. Based on Nebraska Tractor Test Laboratory (tractortestlab.unl.edu) data, the following two tables present examples of performance data provided by the tractor test lab. Fuel efficiency is expressed in terms of gal/hr and hp-hr/gal. Review the following tables to understand key fuel efficiency performance indicators.

POWER TAKE-OFF PERFORMANCE

Power HP *(kW)*	Crank shaft speed rpm	Gal/hr *(l/h)*	lb/hp.hr *(kg/kW.h)*	Hp.hr/gal *(kW.h/l)*	Mean Atmospheric Conditions
MAXIMUM POWER AND FUEL CONSUMPTION					
Rated Engine Speed (PTO speed-1100 rpm)					
86.2 *(64.3)*	2200	5.66 *(21.44)*	0.458 *(0.279)*	15.23 *(3.00)*	
Standard Power Take-off Speed (1000 rpm)					
87.2 *(65.0)*	2000	5.35 *(20.27)*	0.428 *(0.261)*	16.28 *(3.21)*	
VARYING POWER AND FUEL CONSUMPTION					
86.2 *(64.3)*	2200	5.66 *(21.44)*	0.458 *(0.279)*	15.23 *(3.00)*	Air temperature
75.5 *(56.3)*	2264	5.23 *(19.81)*	0.484 *(0.294)*	14.42 *(2.84)*	73°F *(23°C)*
57.4 *(42.8)*	2294	4.40 *(16.64)*	0.535 *(0.325)*	13.05 *(2.57)*	Relative humidity
38.5 *(28.7)*	2312	3.59 *(13.58)*	0.649 *(0.395)*	10.75 *(2.12)*	33%
19.4 *(14.5)*	2328	2.73 *(10.32)*	0.980 *(0.596)*	7.12 *(1.40)*	Barometer
-- --	2353	1.59 *(6.01)*	-- --	-- --	29.7" Hg *(100.5 kPa)*

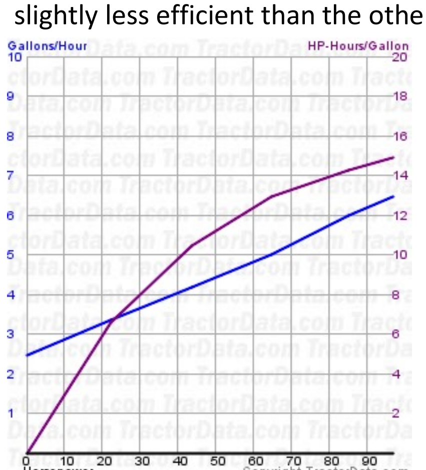
Maximum Torque - 268 lb.-ft. *(364 Nm)* at 1400 rpm
Maximum Torque Rise - 30.4%
Torque rise at 1800 engine rpm - 22%

DRAWBAR PERFORMANCE
(Unballasted–Front Drive Engaged)
FUEL CONSUMPTION CHARACTERISTICS

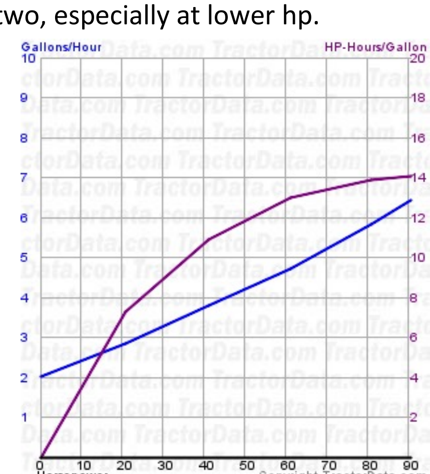
Power Hp (*kW*)	Drawbar pull lbs (*kN*)	Speed mph (*km/h*)	Crank-shaft speed rpm	Slip %	Fuel Consumption lb/hp.hr (*kg/kW.h*)	Hp.hr/gal (*kW.h/l*)	Temp.°F (°C) cool-ing med	Air dry bulb	Barom. inch Hg (*kPa*)
Maximum Power—6th (3LoDD) Gear									
74.0 (*55.2*)	7005 (*31.16*)	3.96 (*6.38*)	2202	5.0	0.538 (*0.327*)	13.10 (*2.58*)	185 (*85*)	59 (*15*)	29.4 (*99.5*)
75% of Pull at Maximum Power—6th (3LoDD)) Gear									
58.2 (*43.4*)	5255 (*23.38*)	4.15 (*6.68*)	2270	3.5	0.611 (*0.372*)	11.51 (*2.27*)	181 (*83*)	63 (*17*)	29.4 (*99.5*)
50% of Pull at Maximum Power—6th (3LoDD) Gear									
39.8 (*29.7*)	3510 (*15.61*)	4.26 (*6.85*)	2301	2.4	0.722 (*0.439*)	9.75 (*1.92*)	180 (*82*)	64 (*18*)	29.4 (*99.5*)
75% of Pull at Reduced Engine Speed—7th (1HiTA) Gear									
58.2 (*43.4*)	5260 (*23.40*)	4.15 (*6.68*)	1904	3.4	0.493 (*0.300*)	14.26 (*2.81*)	181 (*83*)	66 (*19*)	29.4 (*99.5*)
50% of Pull at Reduced Engine Speed—7th (1HiTA) Gear									
39.8 (*29.7*)	3495 (*15.55*)	4.27 (*6.88*)	1936	2.3	0.587 (*0.357*)	11.98 (*2.36*)	180 (*82*)	66 (*19*)	29.4 (*99.5*)

ACTIVITY 1B: BUYING NEW OR USED TRACTORS: COMPARING FUEL EFFICIENCY

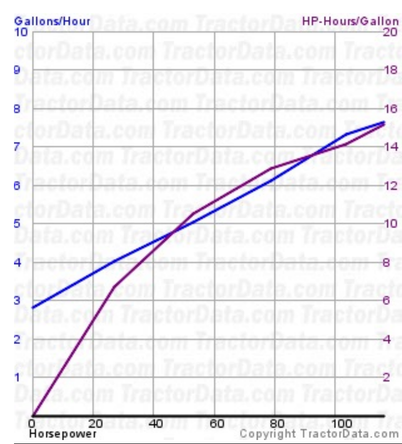
Farmer Smith is in need of a 90-100 hp tractor for tilling and planting and is considering buying a used tractor. Price and condition are important criteria, but due to the high cost of fuel, efficiency of operation is also important. She is considering three different tractors and wants to determine the fuel efficiency of each. Using Nebraska Tractor Test Laboratory data as presented graphically on the website, www.tractordata.com, help Farmer Smith select an efficient tractor to meet her tilling and planting needs. On the website, choose a tractor make and model and click on "tests" to get a graphical presentation of performance like the ones below for three tractors: an IH 966 (left), a JD 4020 (center), and an IH 1066 (right). Note the similarity in the IH 966 and JD 4020 in line separation compared to the IH 1066. If you were going to use a moldboard plow that required 90 hp, the IH 966 might be slightly more fuel efficient. If you were just using 40 hp (e.g., planting) a lot of the time, the JD 4020 would be more efficient. The IH 1066 is a heavier weight, larger hp tractor, thus for this reason and others it is slightly less efficient than the other two, especially at lower hp.



IH 966 Performance



JD 4020 Performance



IH 1066 Performance

ACTIVITY 2: FUEL REQUIREMENTS FOR FIELD OPERATIONS

Farmer Jones wants to save fuel in his tillage program. Using Table 1 below, he can compare primary tillage tools relative to their average fuel use in gal/acre. They are: Moldboard plow 1.81; Chisel plow 1.36; Offset Disk 1.11.

If he were tilling a 40-acre field he could save 18 gal of fuel by using a chisel plow in place of a moldboard plow, resulting in savings of more than $60. Thus, if our field crop practices allow, we can often use a chisel plow or offset disk to save fuel and perhaps leave some residue on the soil surface to reduce erosion. Similar options may exist for other equipment.

Soil conditions, soil depths, and other factors affect fuel efficiency considerably and are worth evaluation. For example, for every 1-in. increase in moldboard plow depth, an extra 0.15 gal of fuel is required. Thus plowing 12-in. deep compared to 8 in. uses 0.6 gallons more fuel per acre.

Table 1. DIESEL FUEL CONSUMPTION (GALLONS PER ACRE) FOR FIELD OPERATIONS

Operation	Michigan Farm Energy Audit *			Average from other States**
		Range		
	Average	High	Low	
Primary Tillage				
Moldboard Plow	1.81	3.50	0.90	1.87
Chisel Plow	1.36	3.50	0.80	1.09
Offset Disc	1.11	1.20	0.90	0.97
Subsoiler	1.54	2.30	1.10	1.56
Secondary Tillage				
Disc	0.93	3.30	0.30	0.65
Field Cultivator	0.78	1.80	0.30	0.68
Spring Tooth Harrow	0.73	1.80	0.20	0.48
Fertilizer/Chemical Application				
Pesticide Spraying	0.33	2.90	0.10	0.13
Chemical Incorporation	0.80	1.10	0.50	----
Spreading Fertilizer	0.30	0.50	0.10	0.19
Knife in Fertilizer	0.58	1.30	0.20	1.05
Planting				
Row Crop Planter	0.51	1.00	0.20	0.54
Grain Drill	0.56	2.31	0.10	0.33
Potato Planter	0.95	1.90	0.90	0.95
Broadcast Seeder	0.28	1.12	0.10	0.15
No-Till Planter	0.68	----	----	0.43
Cultivation				
Cultivator	0.39	1.90	0.10	0.42
Rotary Hoe	0.23	0.70	0.10	0.21
Forage Harvesting				
Mower/ Conditioner	0.72	1.80	0.30	0.66
Rake	0.46	1.26	0.20	0.24
Baler	0.65	2.90	0.10	0.69
Large Round Baler	0.80	---	---	---
Forage Harvester/Green Chop	1.57	2.00	0.20	1.87
Corn Silage Harvester	3.14	6.70	|1.70	2.69
Crop Harvesting				
Small Grain or Bean Combine	1.23	1.80	0.70	1.01
Corn Combine	1.51	2.20	0.70	1.37
Corn Picker	1.84	3.00	1.20	1.10
Pull & Window Beans	0.52	1.10	0.30	0.34
Beet Harvester	1.37	1.90	0.90	1.91
Topping Beets	0.83	1.20	0.40	1.47
Potato Harvester	2.69	---	---	1.73
PTO Operated (gal/hr)				
Forage Blower	2.19	6.20	0.90	
Irrigation	3.41	4.40	1.10	
Grinding	3.84	6.90	2.20	

*Adapted from Helsel, Z. and T. Oguntunde. 1985.Fuel Requirements for Field Operations with Energy Saving Tips. In: Farm Energy Use: Standards, Worksheets, Conservation C. Myers(ed). Michigan State University, East Lansing, MI
**Iowa, Pennsylvania, Nebraska, Missouri, New York, Ontario, Oklahoma, North Dakota

ACTIVITY 3: WHEEL SLIP

Wheel slip is a term which denotes loss of productive traction when driving a tractor, on a road or freshly tilled field--the former resulting in little wheel slip whereas the latter resulting in greater loss of tractive efficiency. To reduce wheel slip, we can add more ballast/weight to the tractor but by doing so the tractor expends more fuel to move the tractor, thus some wheel slip is acceptable (in a field 10-15%) for top power and fuel performance. To get an appreciation for the concept of wheel slip, take a toy tractor, put a chalk mark on a rear tire and roll the tractor across a flat table moving 5 revolutions of the tire mark. Measure the distance in feet that the tractor traveled on the table. Then measure the circumference of the tire in feet and use the formula below to calculate percent wheel slip. The result should be about 1.0. Now with your hand, spin the tire a bit as you move along the table for 5 rotations of the tire, measure the length moved along the table and recalculate how much slip you created(the number will be greater than 1,if you truly made the wheel slip). Alternately, if you have a small motorized toy car, truck, or other vehicle, you can place them on a slightly greased surface or in a sandbox and make the same measurements. Ideal slip should be between 1.10 and 1.15.

$$Slip = \frac{Wheel\ Circumference\ (ft) x\ Number\ of\ Rotations}{Field\ Pass\ Length\ (ft)}$$

ACTIVITY 4A: LEGUMES AND MANURES TO SAVE ENERGY BY REDUCING NITROGEN FERTILIZER NEEDS

Farmer Evans has learned that not only is nitrogen (N) fertilizer costly, but that it is also very energy intensive to manufacture (given that it takes about 1 gal of gasoline equivalent [gge] to manufacture and apply 6 lb of N). Assume he wishes to produce 150 bu/acre corn and recommendations call for 180 units of N. How many gge could he save by using fields that have at least 50% alfalfa stand on moderately productive soils (see Table 1 from the Penn State Agronomy Guide below).

$$\frac{110\ lb\ N\ equivalent}{\frac{6\ lb\ N}{gge}} = \sim 18\ gge$$

Table 1 Residual Nitrogen Contribution from Legumes

Previous Crop[1]	Percent Stand	Highly-productivity fields	Moderate-productivity fields	Low-productivity fields
First year after alfalfa			Nitrogen credit (lbs/A)	
	>50	120	110	80
	25-49	80	70	60
	<25	40	40	40
First year after clover or trefoil				
	>50	90	80	60
	25-49	60	60	50
	<25	40	40	40
First year after soybeans harvested for grain	1 lb N/bu soybean produced previous year			

ACTIVITY 4B: BENEFITS OF LEGUMES AND MANURES ON SAVING ENERGY IN NITROGEN

Assume Farmer Landis has access to a neighbor's horse manure that would allow her to apply 10 ton/acre to a 40 acre field. How many gge of N could she save assuming 12 lb N/ton of horse manure? (See PSU Agronomy Guide table below/)

Answer: She could save 2 gge/ton of manure applied or 2 x 10 x 40 = 800 gge total and at today's N prices, she would save $2,400 (12 x 10 x 40 x $0.50) of fertilizer N.

Table 1.2-13. Average daily production and total content of manure.

Animal type	*Daily production*	*Manure % dry matter*	*Analysis units*	*N*	*P_2O_5*	*K_2O*
Dairy cattle						
Lactating cows, liquid	13 gal/AU/day	<5	lb/1,000 gal	28	13	25
Lactating cows, solid	111 lb/AU/day	12	lb/ton	10	4	8
Dry cow	51 lb/AU/day		lb/ton	9	3	7
Heifer	60 lb/AU/day		lb/ton	10	3	7
Calf	80 lb/AU/day		lb/ton	10	3	4
Veal	7 gal/AU/day	2	lb/1,000 gal	19	13	25
Beef cattle						
Cow and calf	90 lb/AU/day	12	lb/ton	11	7	10
Calf	90 lb/AU/day	12	lb/ton	11	7	10
Finishing cattle	65 lb/AU/day	8	lb/ton	14	5	8
Swine						
Farrow to wean (includes sows)	11 gal/AU/day	2.5	lb/1,000 gal	18	18	11
Nursery	14 gal/AU/day	1.5	lb/1,000 gal	19	8	14
Wean to finish	5.5 gal/AU/day	4	lb/1,000 gal	37	23	21
Grow to finish	7 gal/AU/day	4	lb/1,000 gal	31	24	22
Swine, anaerobic lagoon	These figures apply only to a treatment lagoon.					
Supernatant	—	0.25	lb/1,000 gal	2.9	0.6	3.2
Sludge	—	7.6	lb/1,000 gal	25	23	63
Sheep/Goats	40 lb/AU/day	25	lb/ton	23	8	20
Horse	55 lb/AU/day	20	lb/ton	12	5	9
Poultry						
Layer (364 d)[1]	26 lb/AU/day	41	lb/ton	37	55	31
Pullet (126 d)[1]	48 lb/AU/day	35	lb/ton	43	46	26
Light broiler (44 d)[1]	22 lb/AU/day	66	lb/ton	79	62	42
Heavy broiler (57 d)[1]	20 lb/AU/day	75	lb/ton	66	63	47
Turkey (tom) (123 d)[1]	13 lb/AU/day	60	lb/ton	52	76	42
Turkey (hen) (88 d)[1]	11 lb/AU/day	65	lb/ton	73	88	46
Duck (dry)	110 lb/AU/day	27	lb/ton	21	26	15
Duck (wet)	13 gal/AU/day	5	lb/1,000 gal	33	23	16

Note: When possible, have manure analyzed. Actual values may vary over 100 percent from averages in the table.
1. Typical production days.

ACTIVITY 5: GRAIN DRYER ENERGY EFFICIENCY

Farmer Bean has a bin batch dryer and he is concerned about the high price of LP gas to run the unit. He wonders how much fuel could be saved by using natural air drying to remove 3% moisture (from 18.5% to 15.5%) from 1000 bu of corn?

Answer: Using the table below:

0.03 (% units moisture) x 1000 bu x 56 lb/bu x ~500 Btu extra per lb of water removed (i.e., 1500 Btu/lb for bin-in-batch compared to 1000 Btu/lb for natural air) **= 840,000 Btu or ~7 gge**

Estimated Drying Energy Requirements by Dryer Type

Dryer Type	BTU's/lb. of Water Removed
Natural Air	1000-1200
Low Temperature	1200-1500
Batch-in-Bin	1500-2000
High Temperature	
Air Recirculating	1800-2200
W/O Air Recirculating	2000-3000

Figure 1. Source: North Dakota State University Fact Sheet AE-701.
http://www.ag.ndsu.edu/graindrying/publications/ae-701-grain-drying

ACTIVITY 6: IRRIGATION PUMPING

Farmer Cook is considering installing moisture meters in his fields to better estimate crop water needs during the growing season. A company representative suggests that, by using moisture meters in place of his current method of using guesstimates, he could reduce irrigation needs by half. Pump specifications suggest it takes about 2.63 gal of fuel or 37 kWh to pump an acre-in. of water from 150 ft lift at 60 psi (factoring losses in efficiency beyond the pump, these numbers would increase to nearly 4 gal and more than 50 kWh).

1. If readings from the new meters indicate that Farmer Cook only needs to apply 1 acre-in. compared to the 2 acre-in. he typically applies, how much energy would be saved at the pump head (Answer: about half)
2. If diesel fuel costs $3.50/gal and electricity costs $0.14/kwh, which type of pump is cheaper to operate? (Answer = Electric ($3.50 x 4 gal = $14 vs $0.14 x 50 kWh = $7))
3. If Farmer Cook reduces lift head, would energy needs increase or decrease? (Answer: decrease)
4. If Farmer Cook reduces system pressure, would energy needs increase or decrease? (Answer: decrease)

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