Managing your forage operation to save fuel

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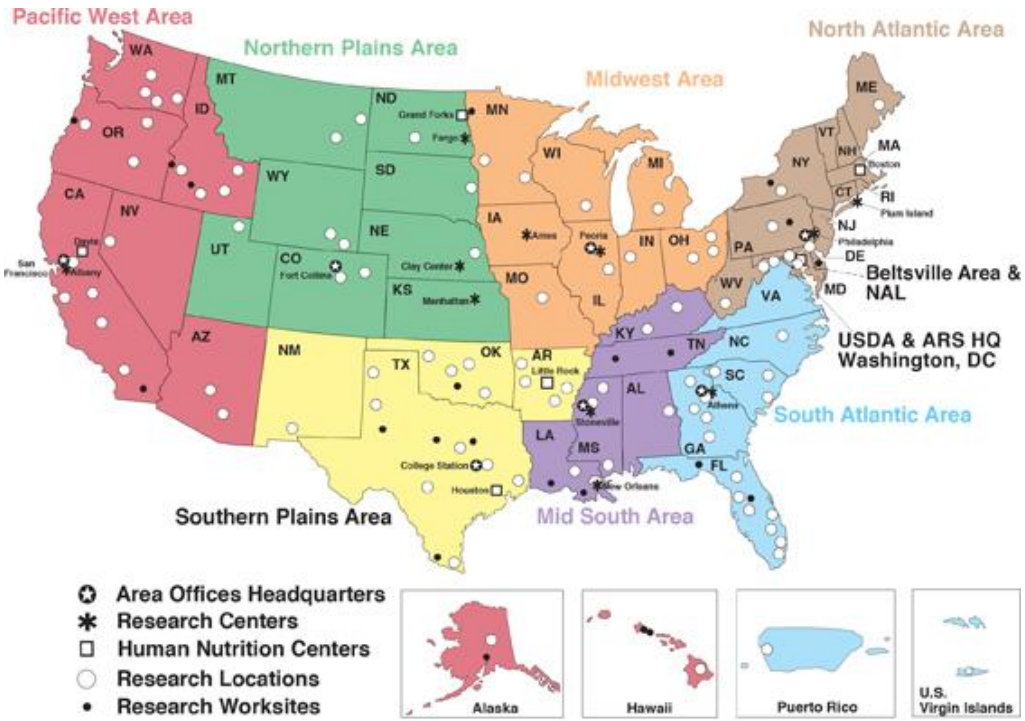
U.S. Dairy Forage Research Center (USDA-ARS)

2011 WDE Forage Toolbox Seminar

Introduction

The Agricultural Research Service is the U.S. Department of Agriculture's chief scientific research agency. Our job is finding solutions to agricultural problems that affect Americans every day, from field to table.

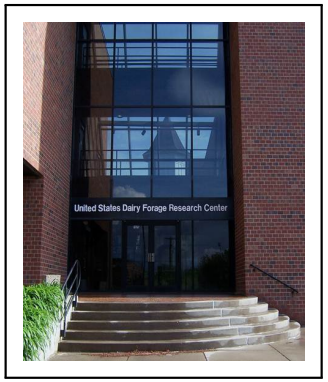
Introduction



USDA-ARS is 2200 scientists at 100 research locations

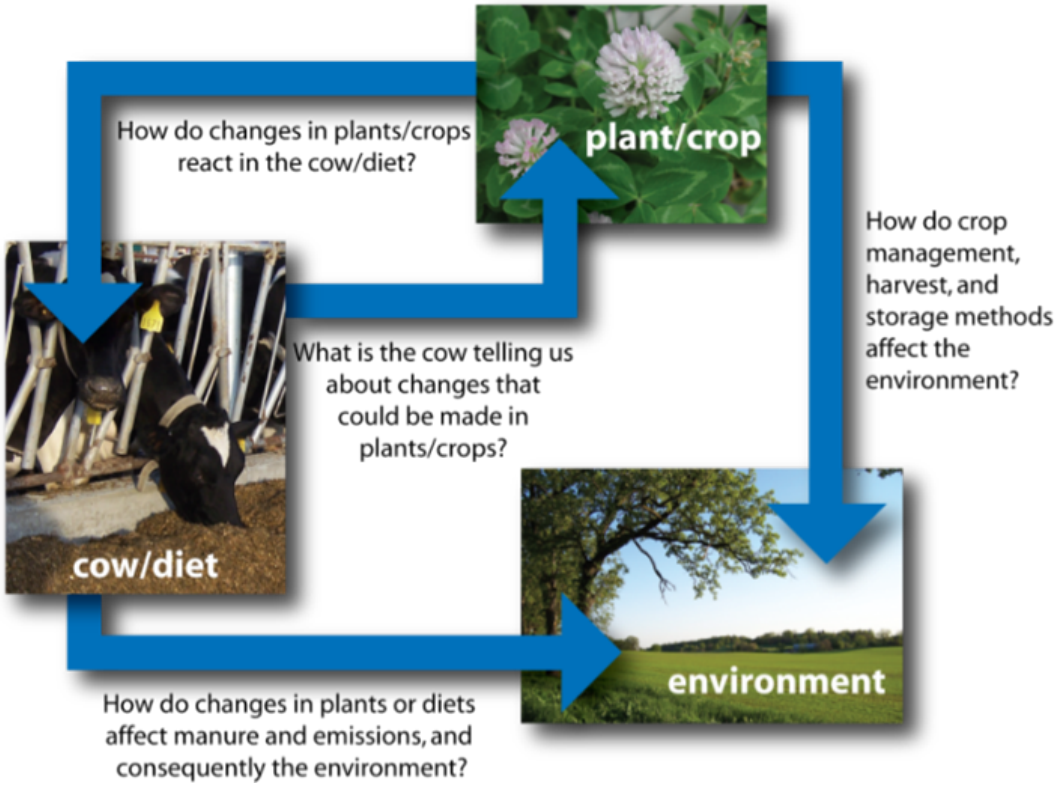
Introduction

U.S. Dairy Forage Research Center



Madison | Prairie du Sac | Marshfield

Introduction



Multidisciplinary approach to agricultural research

Introduction

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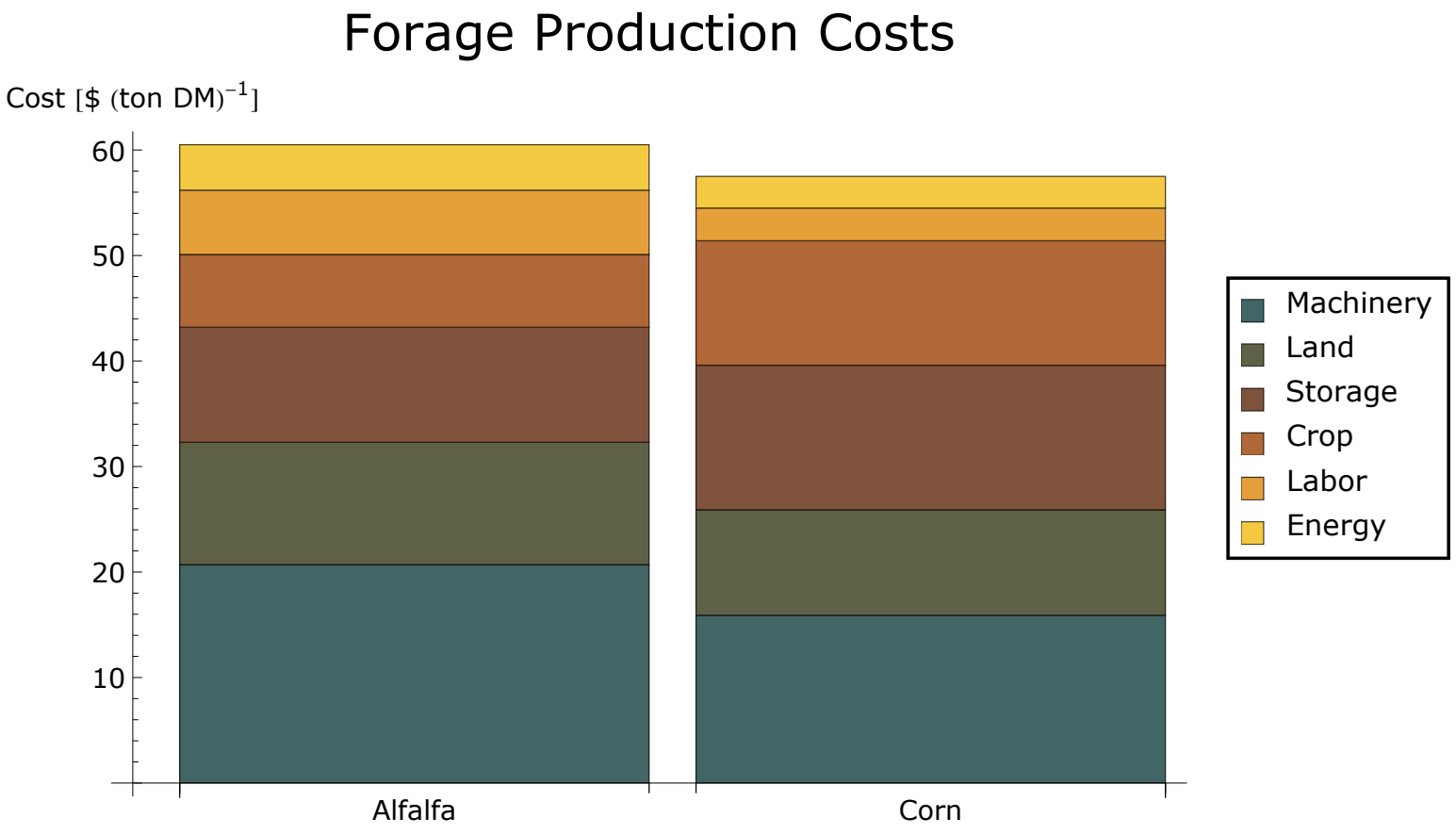
Introduction



Adapted from C.A. Rotz and T.M. Harrigan. 1996. USDFRC Research Summary

Introduction

Your conservation efforts won't go unnoticed.

Image Source: The New York Times

Outline

1. Mowing
2. Merging
3. Harvesting
4. Transport

Introduction

1. This is not an exhaustive list!
2. Some common sense is needed when considering "recommendations".
3. Many strategies not only save fuel but also time and therefore depreciation, labor and timeliness.
4. **Always follow manufacturer's safety guidelines.**

Efficient mowing

Efficient mowing

Given

1. Mower conditioner traveling at 6 mph
2. Cutting width 14 ft
3. 15% time spent turning, cleaning radiator

Solution

$$\left(\frac{6[\frac{mi}{h}]*14[ft]}{8.25}\right) * .85 = 8.7[\frac{ac}{h}]$$

Efficient mowing | Minimizing overlap

"Undercutting includes about 8% of precut area" (Hunt, 1986)

Efficient mowing | Minimizing overlap

Efficient mowing | Minimizing overlap

Efficient mowing | Minimizing overlap

Efficient mowing | Minimizing overlap

Variable	**Range Observed**
Type	Pull-type, Self-propelled, Mounted
Speed	5.5 - 12.5 mi h^{-1}
Working Width	12 - 33 ft

Efficient mowing | Minimizing overlap

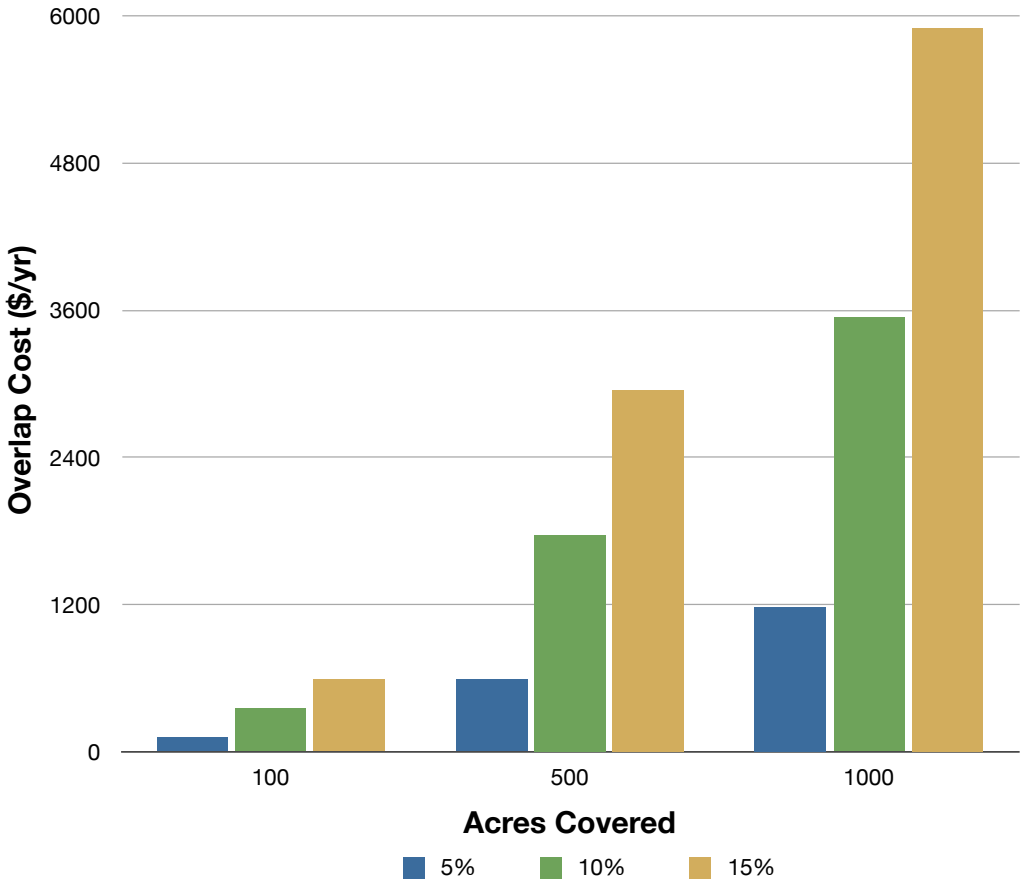
Overlap (Percent cutting width [% c.w.])		
Mean	Standard Deviation	Range
4.99	3.00	0.40 - 16.13

Efficient mowing | Minimizing overlap

Type	**Overlap** (% c.w.)
Manual	5.03_a
Automatic	2.34_b

LSD = 1.16 at $\alpha = .05$

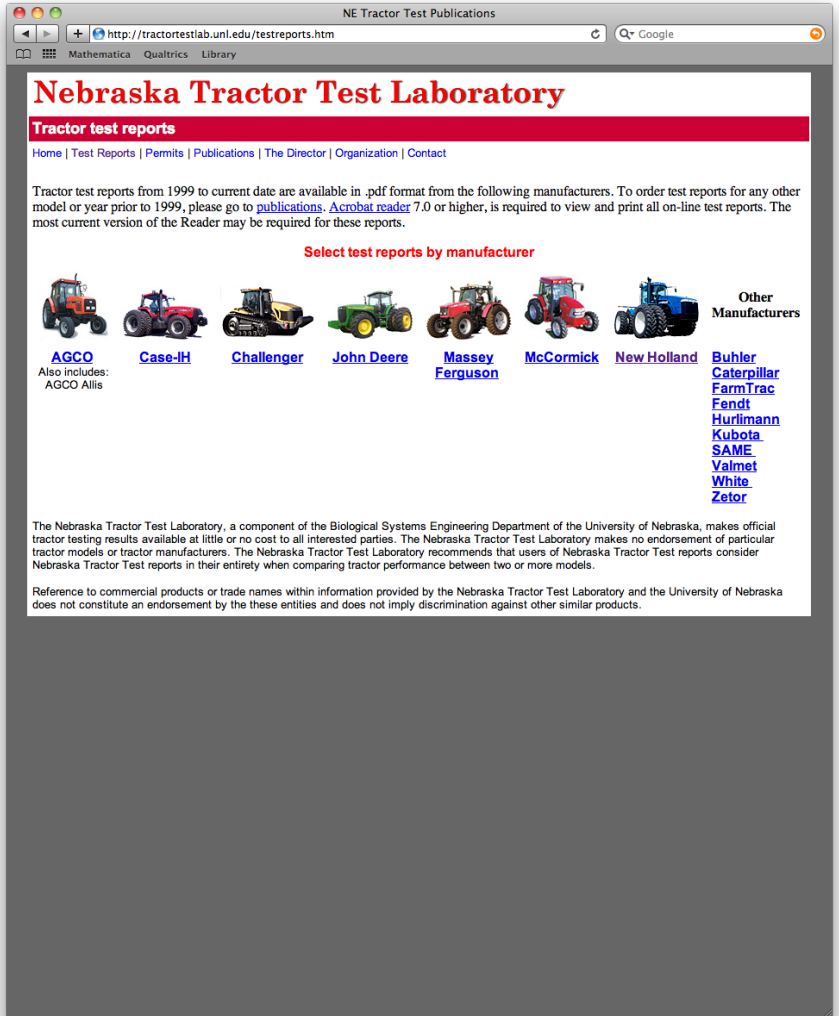
Efficient mowing | Payback?



Assumptions: Min overlap 2.5%, 4 cuttings yr^{-1}

Efficient merging

Efficient merging | Tractor selection



tractortestlab.unl.edu

SUMMARY OF OECD TEST 2493–NEBRASKA SUMMARY 673
NEW HOLLAND T6030 ELITE PC DIESEL
18 SPEED

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—1038 rpm)					
102.2 *(76.2)*	2200	6.39 *(24.18)*	0.438 *(0.267)*	15.99 *(3.15)*	
Standard Power Take-off Speed (1001 rpm)					
109.4 *(81.6)*	2121	6.53 *(24.70)*	0.418 *(0.254)*	16.76 *(3.30)*	
Maximum Power - (1 hour)					
114.3 *(85.2)*	2000	6.62 *(25.06)*	0.406 *(0.247)*	17.26 *(3.40)*	
VARYING POWER AND FUEL CONSUMPTION					
102.2 *(76.2)*	2200	6.39 *(24.18)*	0.438 *(0.267)*	15.99 *(3.15)*	Air temperature
89.2 *(66.5)*	2259	5.95 *(22.51)*	0.467 *(0.284)*	15.00 *(2.96)*	67°F *(20°C)*
67.3 *(50.2)*	2284	5.00 *(18.93)*	0.521 *(0.317)*	13.45 *(2.65)*	Relative humidity
45.6 *(34.0)*	2301	4.06 *(15.36)*	0.624 *(0.379)*	11.24 *(2.21)*	55%
22.9 *(17.1)*	2318	2.97 *(11.24)*	0.908 *(0.553)*	7.72 *(1.52)*	Barometer
-- --	2337	2.12 *(8.02)*	-- --	-- --	29.1" Hg *(98.6 kPa)*

Maximum Torque - 383.6 lb.-ft. *(520.1 Nm)* at 1000 rpm
Maximum Torque Rise - 57.2%
Torque rise at 1800 engine rpm - 34%

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)*	Fuel Consumption Hp.hr/gal *(kW.h/l)*	Temp. °F *(°C)* cooling med	Air dry bulb	Barom. inch Hg *(kPa)*
Maximum Power—8th(2Med) Gear									
74.3 *(55.4)*	6675 *(29.7)*	4.17 *(6.71)*	2202	2.1	0.588 *(0.357)*	11.93 *(2.35)*	187 *(86)*	39 *(4)*	28.9 *(97.9)*
75% of Pull at Maximum Power—8th(2Med) Gear									
57.4 *(42.8)*	5010 *(22.3)*	4.30 *(6.92)*	2273	1.5	0.663 *(0.403)*	10.57 *(2.08)*	187 *(86)*	41 *(5)*	28.9 *(97.9)*
50% of Pull at Maximum Power—8th (2Med) Gear									
38.9 *(29.0)*	3340 *(14.9)*	4.37 *(7.03)*	2295	1.1	0.792 *(0.482)*	8.84 *(1.74)*	187 *(86)*	43 *(6)*	28.9 *(97.9)*
75% of Pull at Reduced Engine Speed—9th (3Med) Gear									
57.5 *(42.9)*	5015 *(22.3)*	4.30 *(6.92)*	1887	1.4	0.588 *(0.358)*	11.92 *(2.35)*	183 *(84)*	45 *(7)*	28.9 *(97.9)*
50% of Pull at Reduced Engine Speed—9th (3Med) Gear									
38.9 *(29.0)*	3340 *(14.9)*	4.37 *(7.03)*	1908	0.9	0.705 *(0.429)*	9.95 *(1.96)*	183 *(84)*	46 *(8)*	28.9 *(97.9)*

Location of tests: Istituto per le Macchine Agricole e Movimento Terra 73, Strada delle Cacce 10135 Torino, Italy

Dates of tests: September to December, 2008.

Manufacturer: CNH Europe Holding S.A. 13, Rue Aldringen L-1118 Luxembourg

FUEL and OIL: Fuel No. 2 Diesel **Specific gravity converted to 60°/60°F *(15°/15°C)*** 0.842 **Fuel weight** 7.01 lbs/gal *(0.840 kg/l)* **Oil SAE** 15W40 **API service classification** CH-4 **Transmission and hydraulic lubricant** Akcela Nexplore fluid **Front axle lubricant** Akcela Nexplore fluid

ENGINE: Make CNH Diesel **Type** six cylinder vertical with turbocharger and air to air intercooler **Serial No.** 512747 **Crankshaft** lengthwise **Rated engine speed** 2200 **Bore and stroke** 4.094" x 5.197" *(104.0 mm x 132.0 mm)* **Compression ratio** 17.5 to 1 **Displacement** 410 cu in *(6728 ml)* **Starting system** 12 volt **Lubrication** pressure **Air cleaner** two paper elements and aspirator **Oil filter** one full flow cartridge **Oil cooler** engine coolant heat exchanger for crankcase oil, radiator for hydraulic and transmission oil **Fuel filter** one paper element **Muffler** underhood **Exhaust** vertical **Cooling medium temperature control** thermostat and variable speed fan

CHASSIS: Type front wheel assist **Serial No.** Z8BK04778 **Tread width** rear 56.3" *(1430 mm)* to 87.8" *(2230 mm)* front 52.2" *(1325 mm)* to 90.0" *(2285 mm)* **Wheelbase** 107.8" *(2739 mm)* **Hydraulic control system** direct engine drive **Transmission** selective gear fixed ratio with partial (6) range operator controlled powershift **Nominal travel speeds mph *(km/h)*** first 1.23 *(1.98)* second 1.48 *(2.38)* third 1.78 *(2.86)* fourth 2.14 *(3.44)* fifth 2.52 *(4.05)* sixth 3.03 *(4.87)* seventh 3.58 *(5.76)* eighth 4.30 *(6.92)* ninth 5.16 *(8.31)* tenth 6.21 *(10.00)* eleventh 7.30 *(11.75)* twelfth 8.78 *(14.13)* thirteenth 10.33 *(16.62)* fourteenth 12.42 *(19.98)* fifteenth 14.91 *(24.00)* sixteenth 17.93 *(28.86)* seventeenth 21.08 *(33.93)* eighteenth 25.35 *(40.80)* reverse 3.29 *(5.29)*, 3.95 *(6.36)*, 4.75 *(7.64)*, 5.70 *(9.18)*, 6.70 *(10.79)*, 8.07 *(12.98)* **Clutch** wet disc hydraulically actuated by foot pedal **Brakes** wet disc hydraulically actuated by two foot pedals that can be locked together **Steering** hydrostatic **Power take-off** 540 rpm at 1969 engine rpm or 1000 rpm at 2120 engine rpm **Unladen tractor mass** 13230 lb *(6000 kg)*

Efficient merging | Tractor selection

Work

- Moving an object a distance
- Work $[ft - lb_f]$ = Force $[lb_f]$ * Distance $[ft]$

Power

- Work done per unit time
- Power $[\frac{ft-lb_f}{s}] = \frac{Work[ft-lb_f]}{Time[s]}$

  Note: 1 Hp = 550 $[\frac{ft-lb_f}{s}]$

Efficient merging | Tractor selection

Specific Fuel Consumption (Tractor Fuel Efficiency)

- Work that can be performed per gallon of fuel
- Expressed as 1 Hp expended over one hour per gallon of fuel $\frac{Hp.h}{gal}$
- Independent of engine size
- Good average: 13.5 Hp.h gal^{-1}

Efficient merging | Tractor selection

DRAWBAR PERFORMANCE
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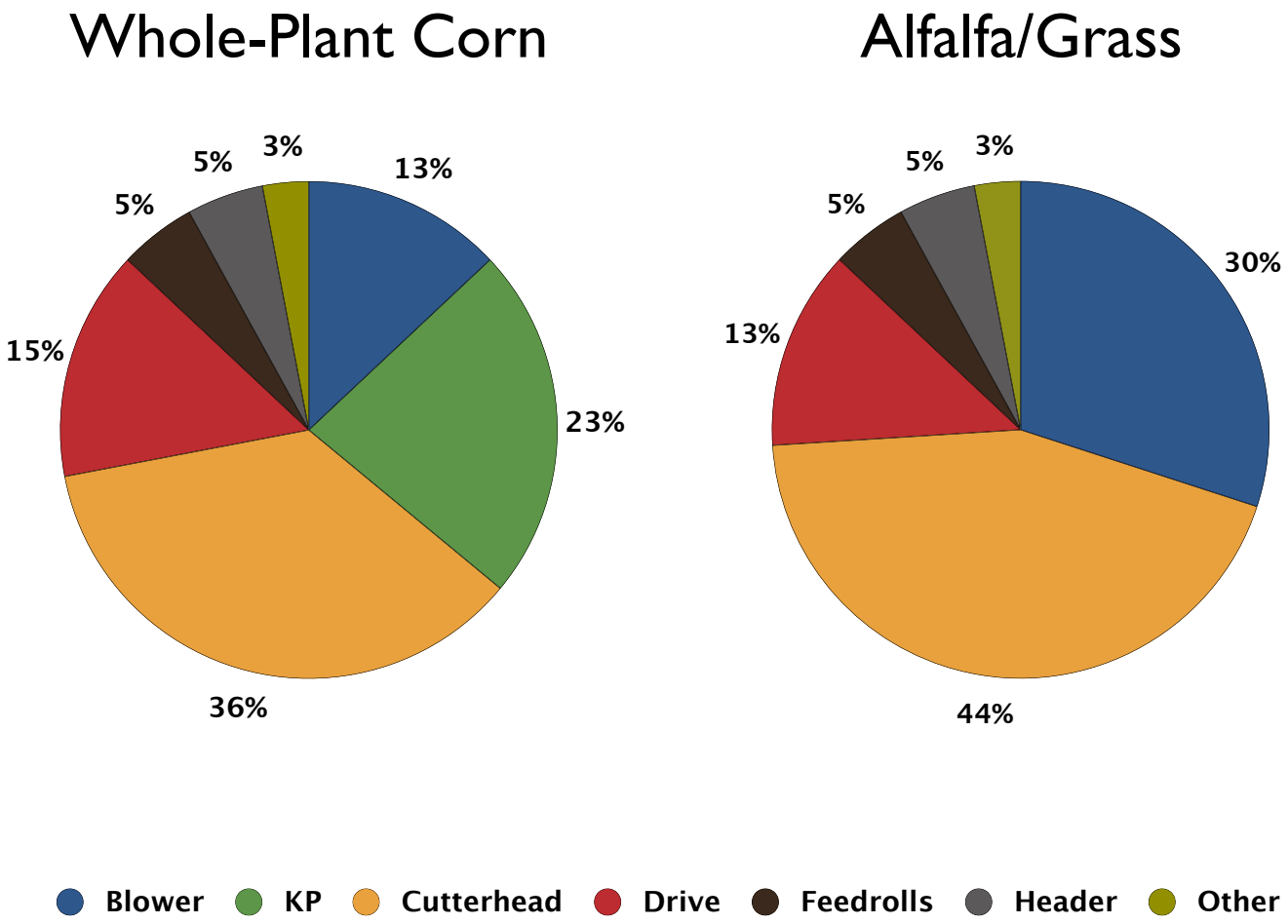
Efficient merging | Tractor selection

Tractor	**Fuel use** (gal h^{-1})	**Fuel Savings** (\$ yr^{-1})
Deere 7630	6.72	1190
Deere 7930	7.17	403
Deere 8130	7.29	193
Deere 8430	7.40	0

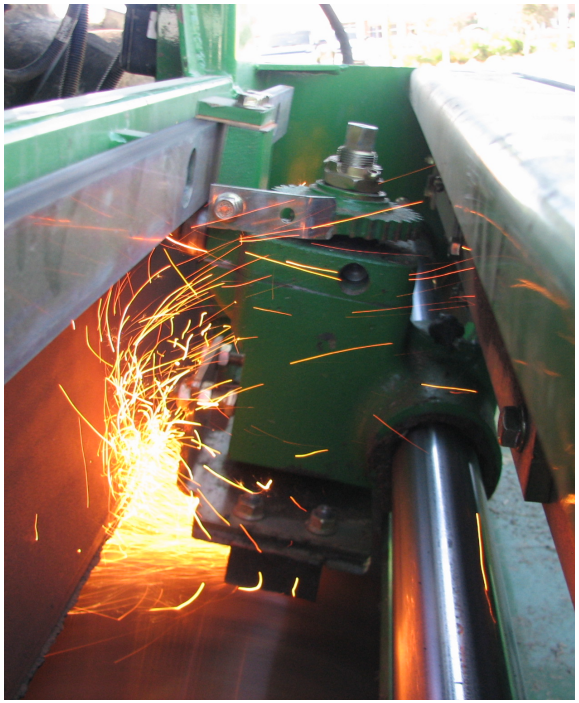
Adapted from K.J. Shinners; Assumptions: 110 hp required, 500 h yr^{-1}, 3.50 $\$gal^{-1}$

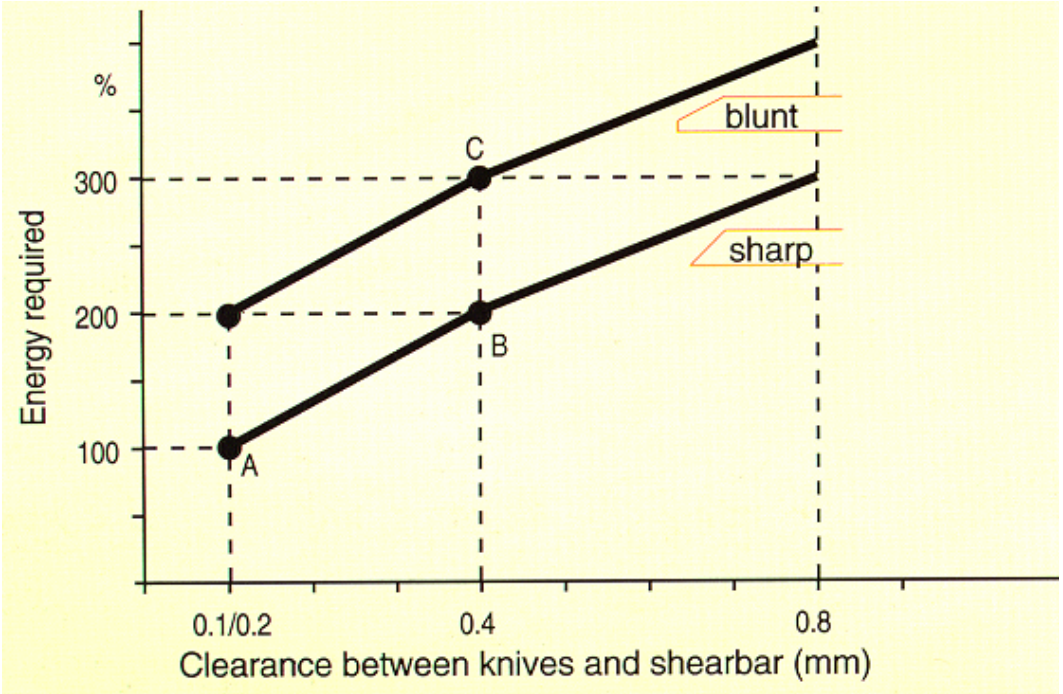
Efficient harvesting

Efficient harvesting



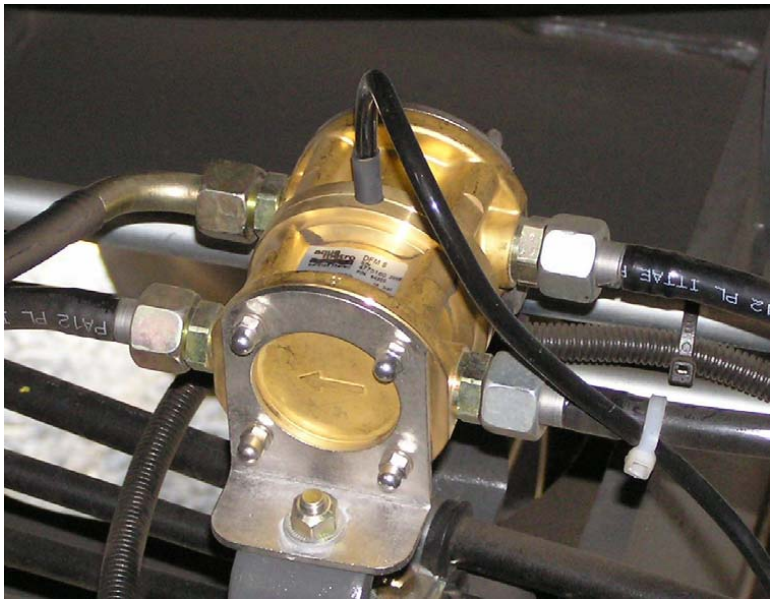
Efficient harvesting | Knives & shearbar





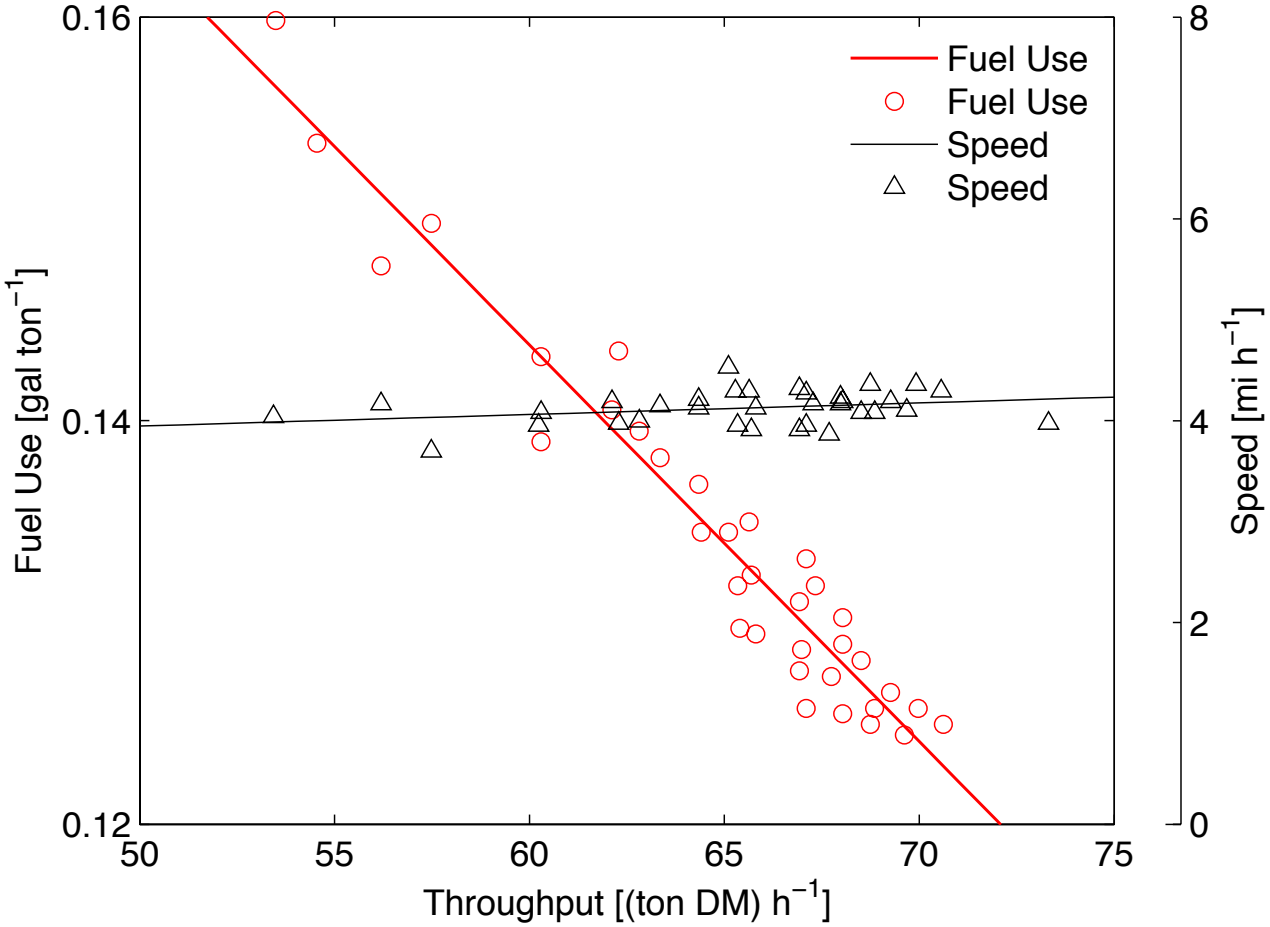
Source: McClure and Hall, 1992

Efficient harvesting | Harvesting at capacity



Source: Wild et al. 2009. ASABE Paper No. 097077

Efficient harvesting | Harvesting at capacity



Source: Wild et al. 2009. ASABE Paper No. 097077

Efficient transport

Efficient transport | Ballast

	Speed (mi h^{-1})	**Weight** (lb (PTO hp)$^{-1}$)
Light	> 6	120
Moderate	5 - 6	145
Heavy	< 4	180

Efficient transport | Ballast

Tractor setup

1. T6030 specific fuel consumption: $8.84[\frac{hp-h}{gal}]$
2. Optional ballast: 2,458[lb]

Fuel savings - removing extra weight

1. Rolling resistance adjustment: 2,458*.2 = 492[lb]
2. $\frac{6[\frac{mi}{h}]*492[lb]}{375} = 7.9[hp]$
3. $\frac{[gal]}{8.84[hp-h]} * 7.9[hp] = .89[\frac{gal}{h}]$
4. $\frac{.7[gal]}{[h]} * \frac{3.50[\$]}{[gal]} = 3.13[\frac{\$}{h}]$

Efficient transport | Idle time

Tractor idle time

1. New tractors need 30 s - 2 min
2. Older tractors specify 3 - 5 min
3. T6030 (102 hp)
   - 1.14 gal h^{-1}
   - \$0.07 min^{-1}

Summary

1. Don't mow the same ground twice
2. Look at fuel efficiency and size when selecting a tractor
3. Keep knives sharp and knife to shear bar clearance tight
4. Maximize harvester's capacity at low speeds (merge, header size)
5. Shed the extra weight; minimize unnecessarily long idle times