Farm Energy IQ

Farms Today Securing Our Energy Future

Energy Conservation in Field Crop Production

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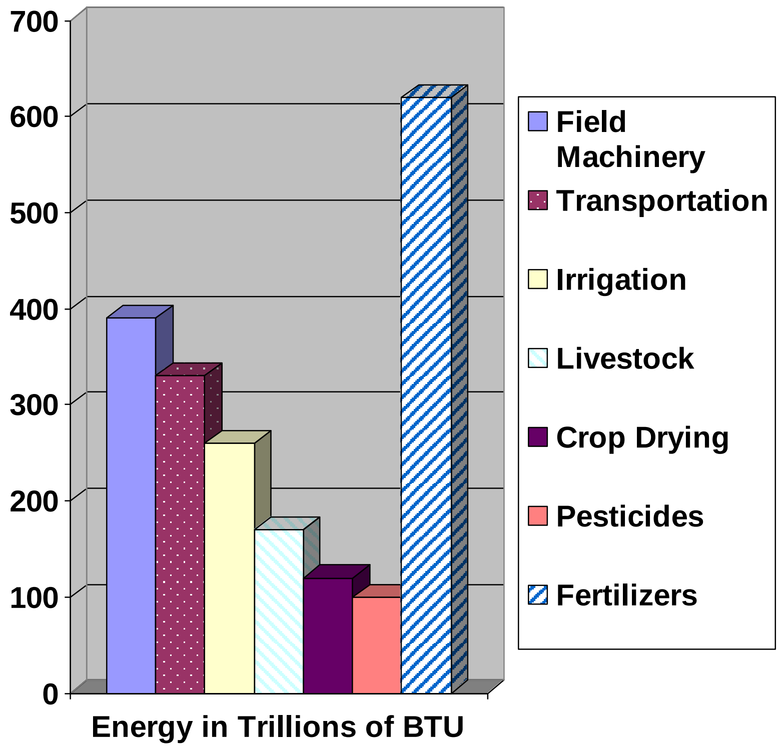
NORTHEAST SARE
Sustainable Agriculture Research & Education

Fuel Savings in Field Operations

Photo credit: http://newscenter.nmsu.edu/Photos/get/3647/full/Leyendecker_research.jpg

Energy Use in U.S. Production Agriculture



Source: USDA/FEA. 1976. Energy and U.S. Agriculture: 1974 Database (v. I), FEA/D-76/459. Washington, DC.: USGPO

Steps to Determine Fuel Use

1. Top off tank
2. Conduct field operation on a certain acreage
3. Refill tank and record gallons
4. Divide gallons of fuel by acreage (gals/acre)
5. Compare usage to the benchmarks for similar operations (next slide)

Photo credit: C. MiKittrick , NJAES, Rutgers University

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

Benchmark fuel usage by type of operation

How does your usage compare?

If > 10% more than average, determine why

Buying a New/Used tractor

- Consult Nebraska Tractor Test Laboratory (NTTL) data

Nebraska Tractor Test Laboratory Reports

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

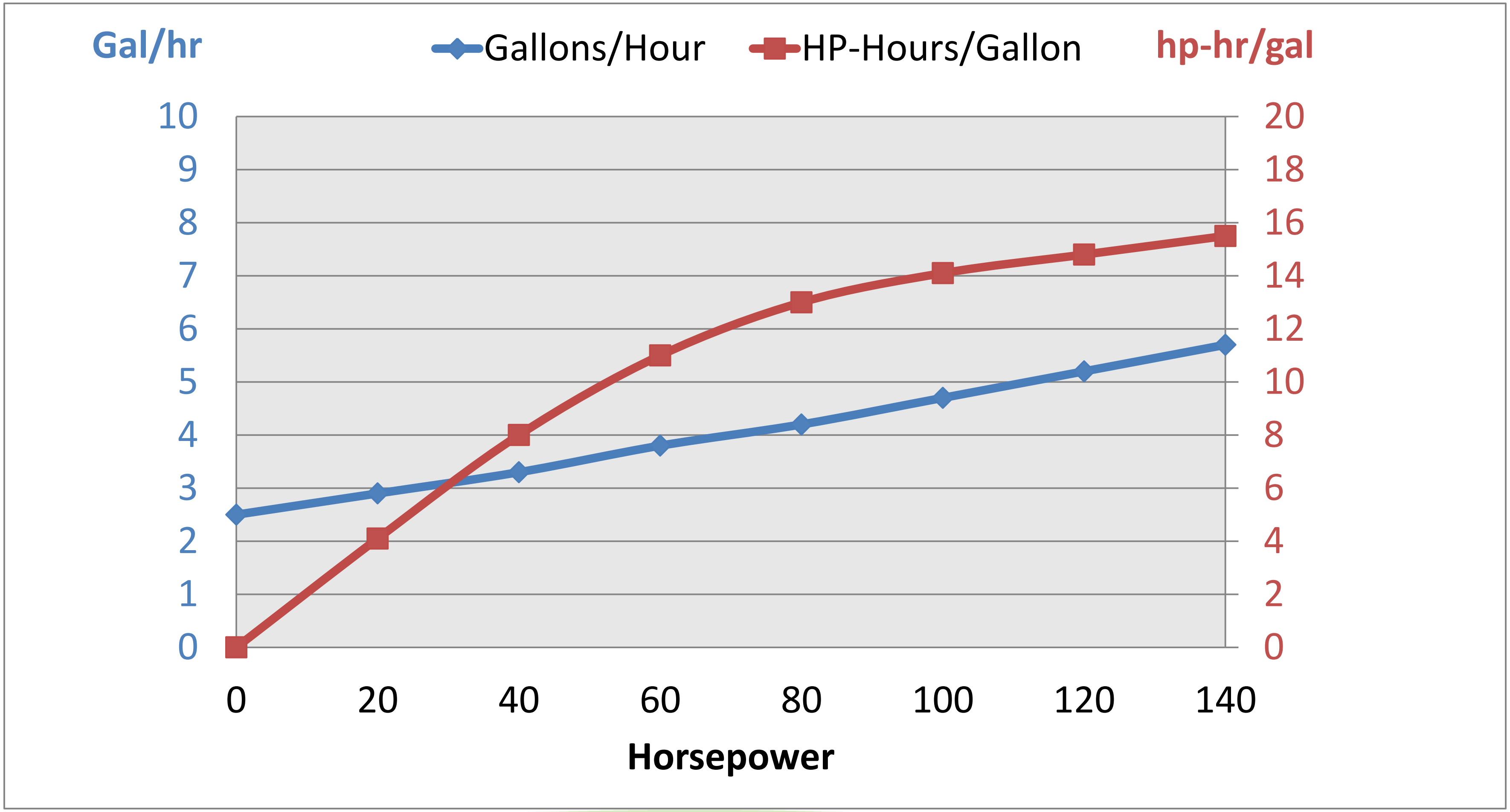
(Unballasted-Front Drive Engaged)

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)*	Fuel Consumption Hp.hr/gal *(kW.h/l)*	Temp. °F (°C) cool-ing med	Temp. °F (°C) 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)*

Source: Nebraska Tractor Test Laboratory website: http://tractortestlab.unl.edu/

Nebraska Tractor Test Laboratory data



Generic adaptation from http://www.tractordata.com

Tillage System Equipment Fuel Use

Tillage Systems					
---------------Diesel Fuel Gal/A---------------					
Traditional		**Reduced Tillage**		**No-Till**	
Plow	1.8				
Disc	.9	Chisel	1.4		
Disc	.9	Disc	.9		
Drag	.7	Drag	.7		
Plant	.5	Plant	.5	Plant	.6
Spray	.3	Spray	.3	Spray	.3
Total	**5.1**	**Total**	**3.8**	**Total**	**0.9**

Match Tractor and Implement—use small (older) tractors for light jobs

Photo credit: Rachel Brickner http://commons.wikimedia.org/wiki/File:NAA_pulling_hay_rake.jpg#filehistory

Match Tractor and Implement
Use large tractors for combination tillage tools

Photo credit: http://extension.udel.edu

Alternative Equipment

- Use least energy-requiring equipment to accomplish task.
- Example: Use a chisel plow instead of a moldboard plow to save ½ gal fuel/acre

Make equipment adjustments to reduce draft (energy)

Proper Tillage Depth

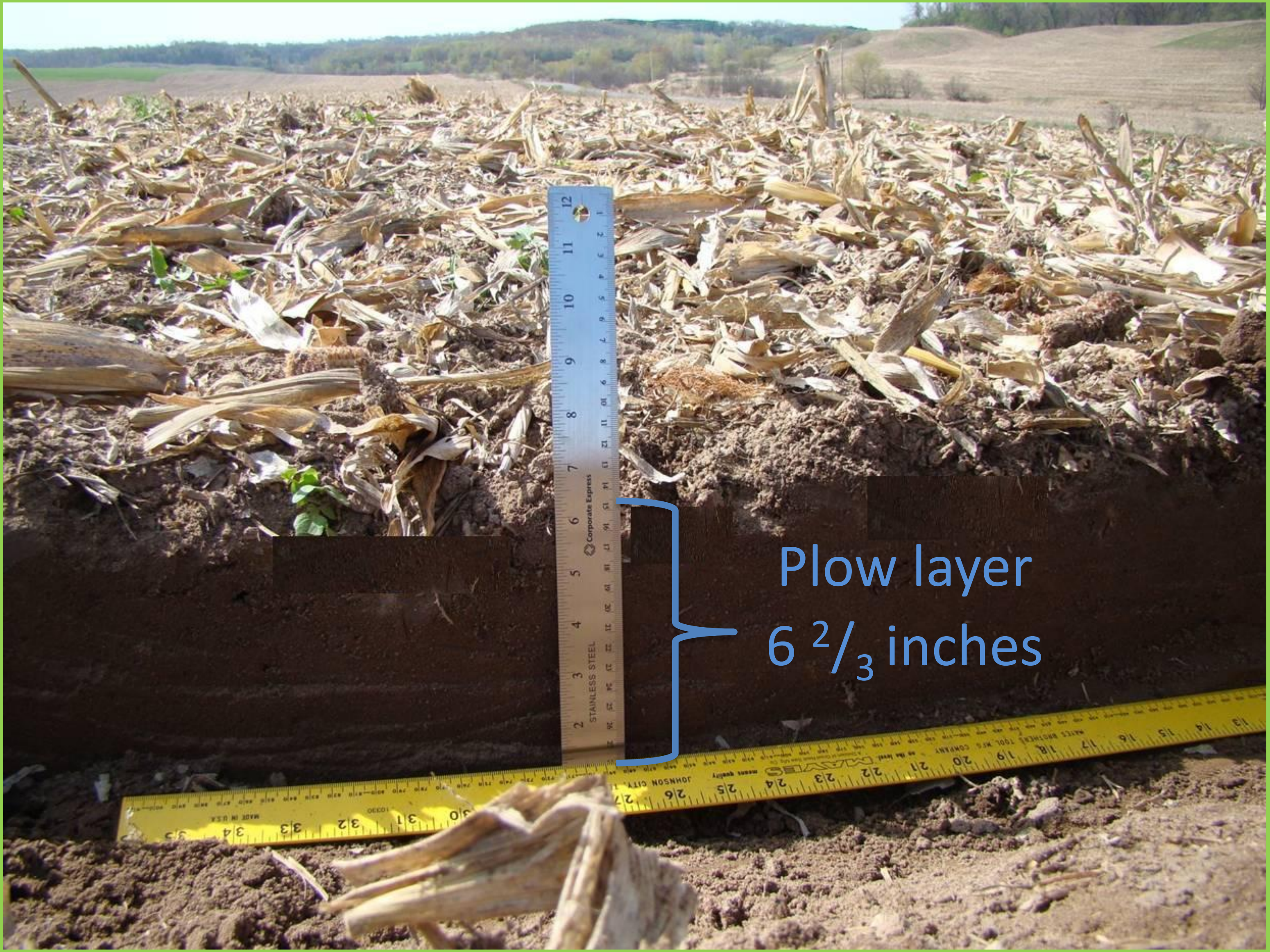


Photo adapted from Kevan Klingberg, University of Wisconsin Extension

Tillage Depth

Secondary tillage (1/2 depth of primary)

Primary tillage

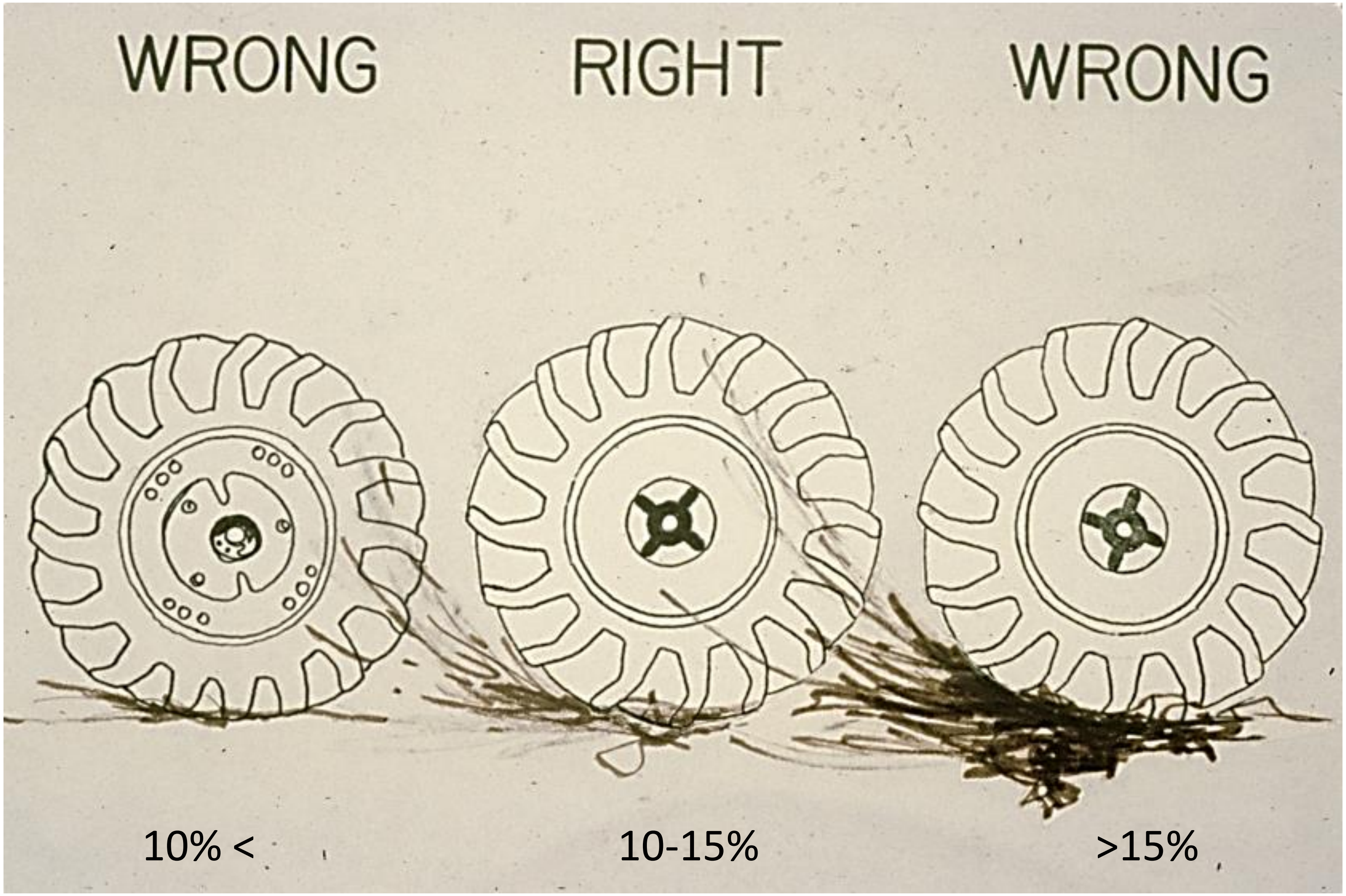
Gear Up/Throttle Down

Use highest gear and lowest RPMs in older tractors (no visible soot)

New Tractors—Constant Variable Transmission (CVT) Replaces Gear/Throttle

Photo credit: Margy Eckelkamp/Farm Journal Media

Wheel Slippage



Wheel Slip

$$1.10 < \frac{\text{Wheel circumference (ft) X Number of rotations}}{\text{Field pass length (ft)}} < 1.15$$

Proper Weight/Ballasts - don’t use if not needed

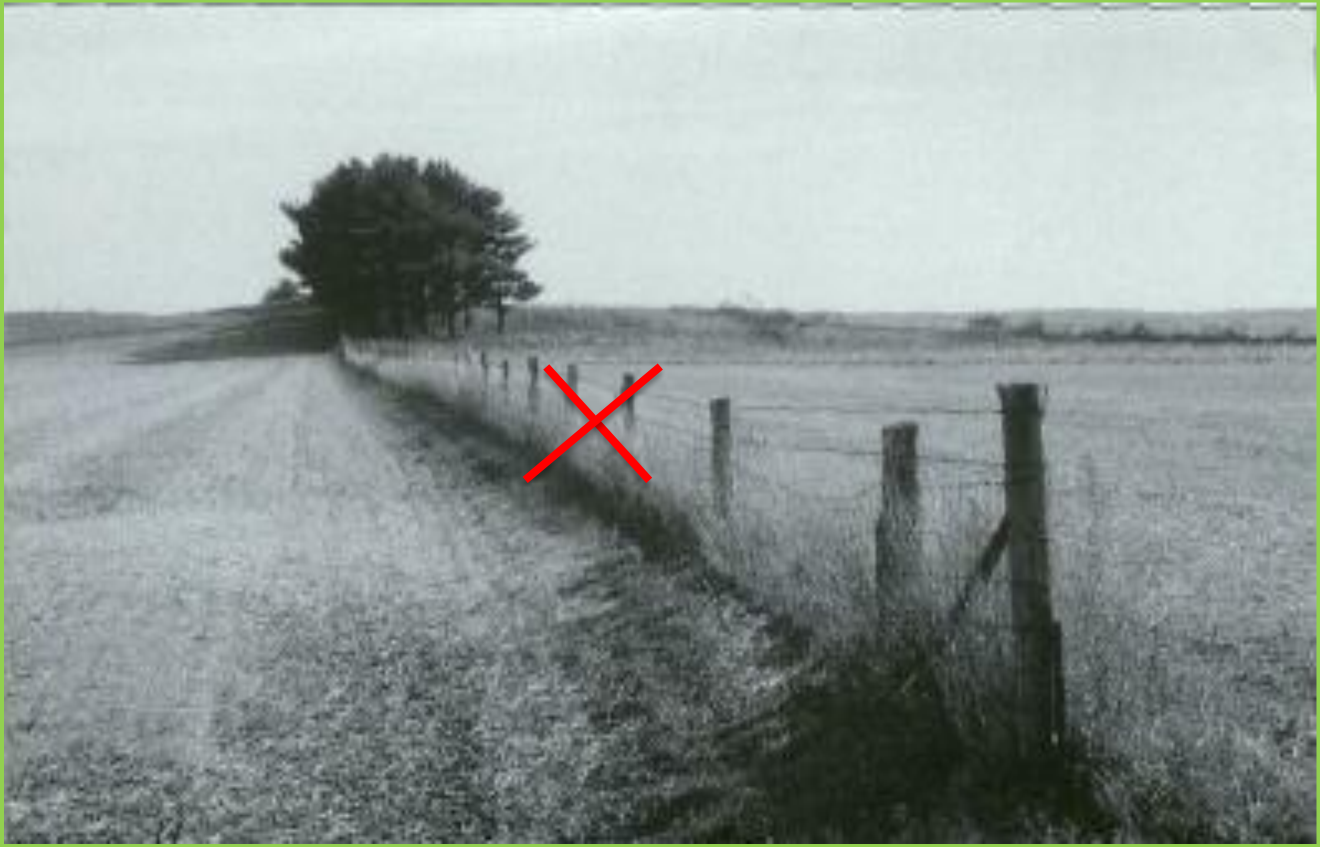
Source: http://www.extension.org/sites/default/files/w/2/2b/Tractor_ballast.JPG

Engage 4WD Only When Needed

Photo credit: C. McKittrick, NJAES, Rutgers University

Fuel Efficiency Practices

- Turn less
- Use long narrow fields
- Eliminate fence rows/obstructions



Source: http://lib.niu.edu/

Tillage/Planting

- Don't speed!
- 3-8 mph optimal

Source: http://fyi.uwex.edu/

Conserving Energy in Nutrient Use and Pest Control

Photo credit: http://www.extension.org/sites/default/files/w/4/4a/Spreading_manure.jpg

Conserving Nutrients

- Test soil
- Use less!!!
- Calibrate equipment
- Apply organic alternatives—manure, legumes
- Use efficiently (reduce losses)
- Fertigation
- Practice soil conservation techniques

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FS719

Fact sheet

Soil Fertility Test Interpretation

Phosphorus, Potassium, Magnesium, and Calcium

Joseph R. Heckman, Ph.D., Extension Specialist in Soil Fertility

Introduction

A soil fertility test evaluates the nutrient-supplying power of a soil. The results of the test are used to predict if, or how much fertilizer is required for optimum plant growth.

The conceptualized relationship between soil nutrient level and plant response is shown in Figure 1. Rutgers Cooperative Extension classifies relative fertility levels into three main categories: *Below optimum*, *optimum* and *above optimum*. *Below optimum* is divided into subcategories: *very low*, *low*, and *medium*.

These soil fertility categories gauge the probability of a plant showing a beneficial response to the addition of a given nutrient (assuming that other factors such as temperature, moisture, disease, etc. are not limiting growth).

The soil test categories as described in Table 1 are the basis for how much phosphorus (P) and potassium (K) to apply to reach optimum growth levels. For limestone recommendations, these categories indicate the concentrations of calcium (Ca) and magnesium (Mg) most suitable for use as a liming material.

Recommendations Based on Soil Test Categories

Soil test categories along with crop nutrient requirements are the basis for nutrient recommendations. Rutgers Cooperative Extension publishes production recommendation guides for vegetable, tree fruit, field crops, nursery crops and turf. These recommendation guides provide tables that indicate for various soil test categories how much phosphorus and potassium to apply to produce each crop.

For example, when the soil test category for K is *below optimum—low* the recommendation guide will indicate how much K to apply. The amount of K recommended however, varies depending on the crop. Various crops accumulate different amounts of nutrient. Generally, crops that produce large yields of harvestable material will remove large amounts of nutrients from the soil and will have a higher nutrient recommendation.

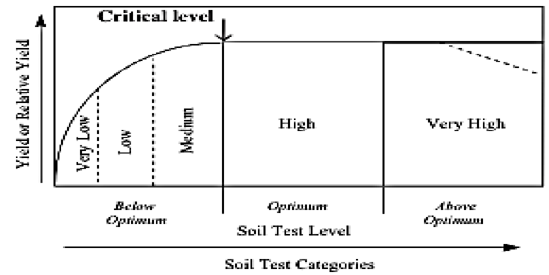


Figure 1. This conceptual soil test response curve is divided into categories that correspond with *below optimum*, *optimum* and *above optimum* soil test values. The critical level is the soil test level, below which a crop response to a nutrient application may be expected, and above which no crop response is expected. At very high soil test levels crop yield may decrease.

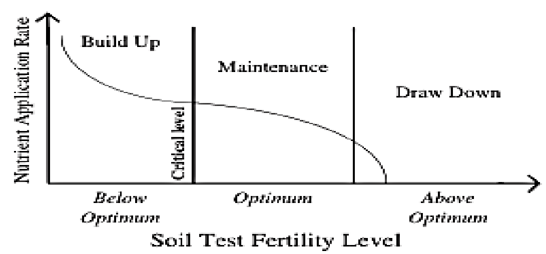
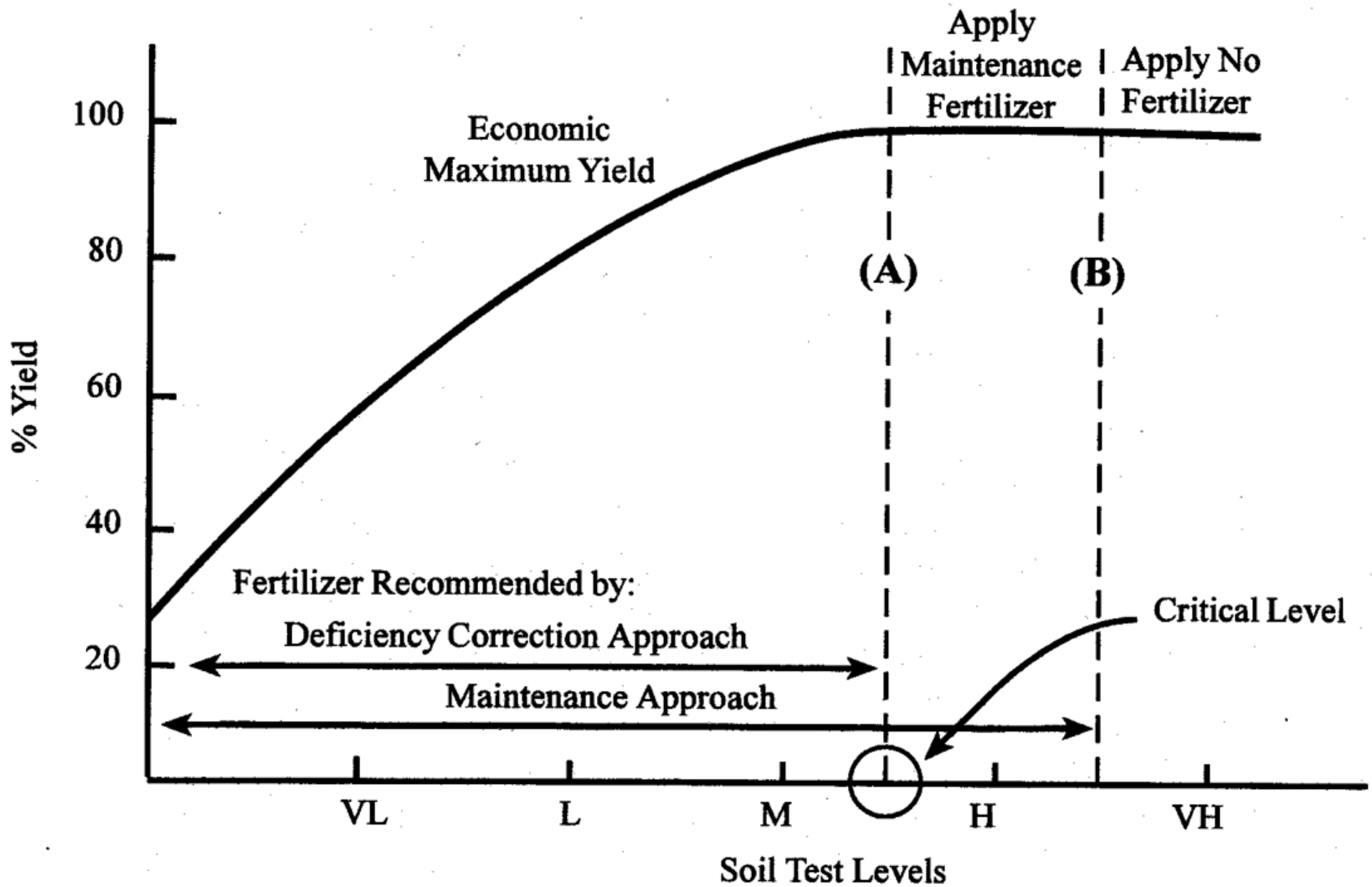


Figure 2. Nutrient application rates vary in relation to soil test category.

Crop Yield Response to Soil Fertility Levels



Source: http://passel.unl.edu/UserFiles/File/Crp.%20Prod.%20Nat.%20Res.%20Mngmt/Soils%20Lesson%2010/Fig-10.1.gif


Banding Fertilizer
A B C GROFF, INC.

Calibrate Equipment

Source: http://ncagr.gov

Use Legumes

Source: http://www.extension.org/sites/default/files/w/5/50/Sweet_clover_cover_crop.jpg

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 (lb./acre)			
	>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			

(1) When a previous legume crop is checked on the Penn State soil test sheet, the residual nitrogen for the year following the legume is calculated and given on the report. This credit should be deducted from the N recommendation on the soil test. (2) See Table 1.1-1 in the basic soil test section for information on soil production groups. Adapted from 2013-2014 Penn State Agronomy Guide.

Using Manures

- Test for nutrient availability
- Incorporate into soil
- Apply close to crop growth needs
- Calibrate equipment

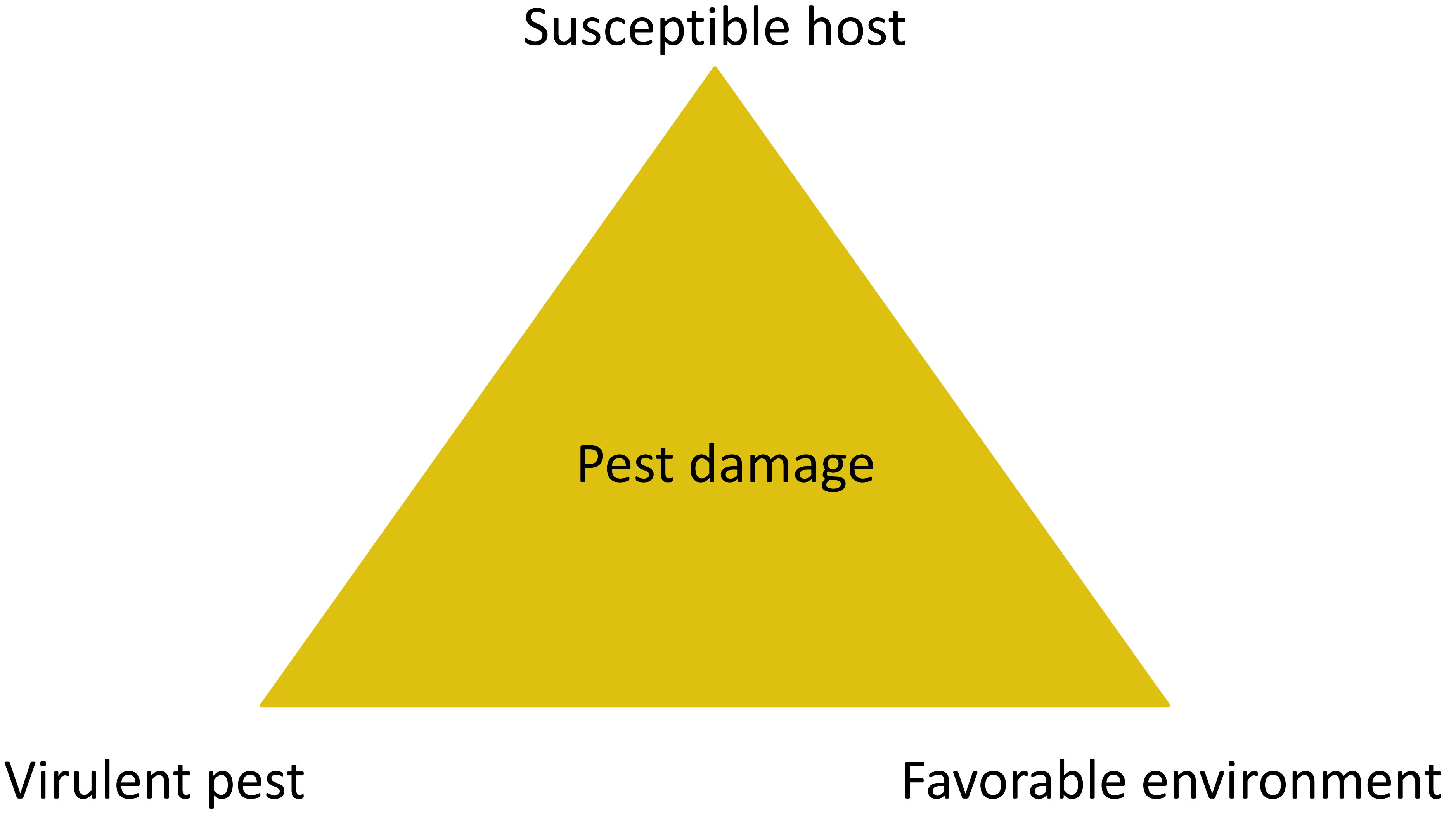
Source: http://www.uri.edu/ce/healthylandscapes/livestock/photos/BMPs/liqmaninj.jpg

Pest Control

- Integrated pest management
  - Determine presence of pests
  - Know life cycles
  - Know which crops they can impact

Understand Pest Cycles and Interactions

Pest Triangle



Effective Application of Pest Control Products

- Lowest labeled rate needed (early application)
- Low volume sprayers
- Chemigation

Fertigation and Chemigation
(Photo: C. Mckittrick, NJAES, Rutgers University)

Mechanical vs. Chemical Weed Control

Energy use for producing and applying glyphosate to corn and soybeans is about equal to energy use in rotary hoeing and two row cultivations.

Photo: http://www.organicriskmanagement.umn.edu/weed_management.pdf

Energy Efficiency in Irrigation

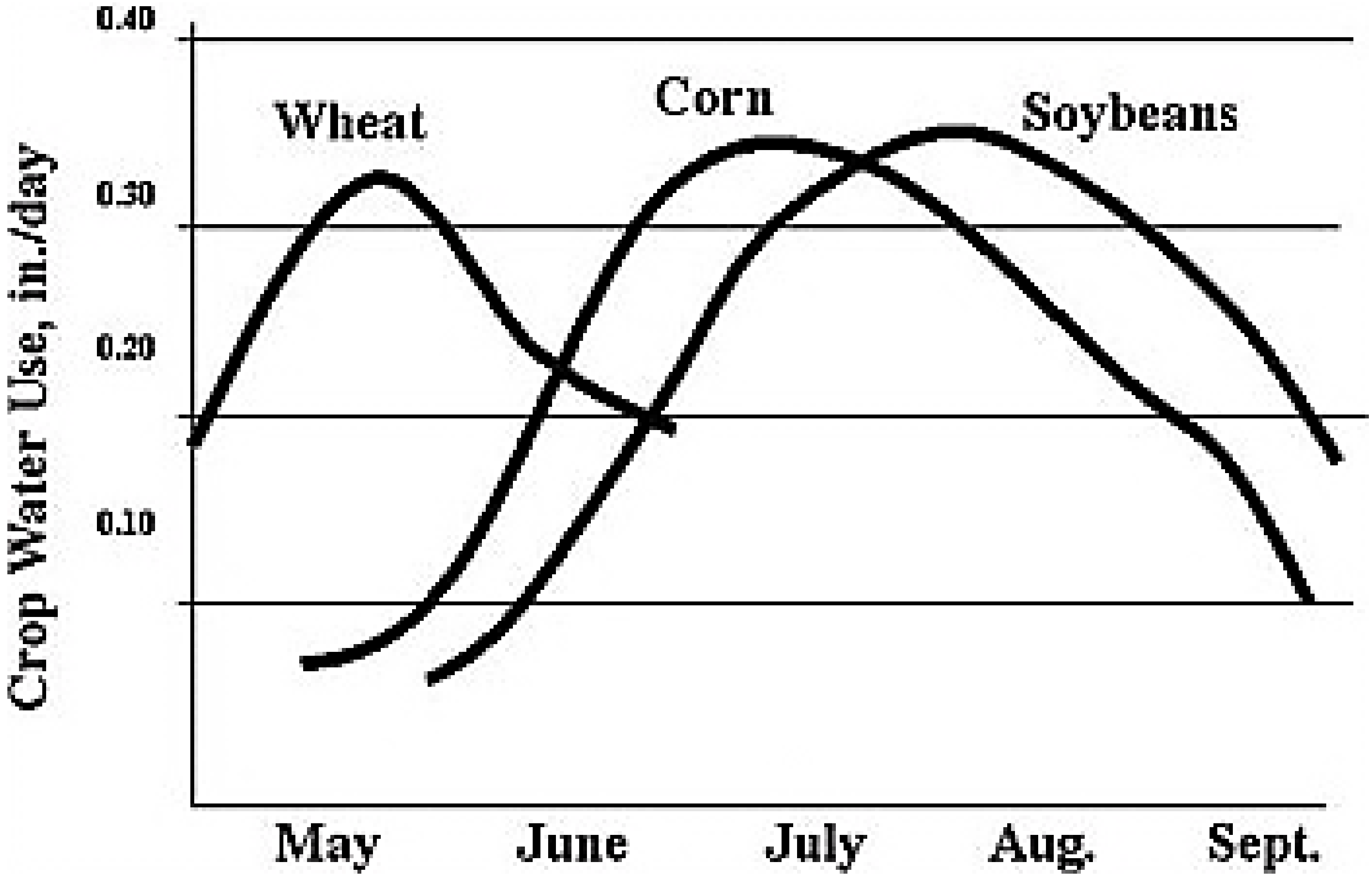
Photo: http://www.clemson.edu/irrig/images/SHTrav8.jpg

Opportunities to Reduce Energy

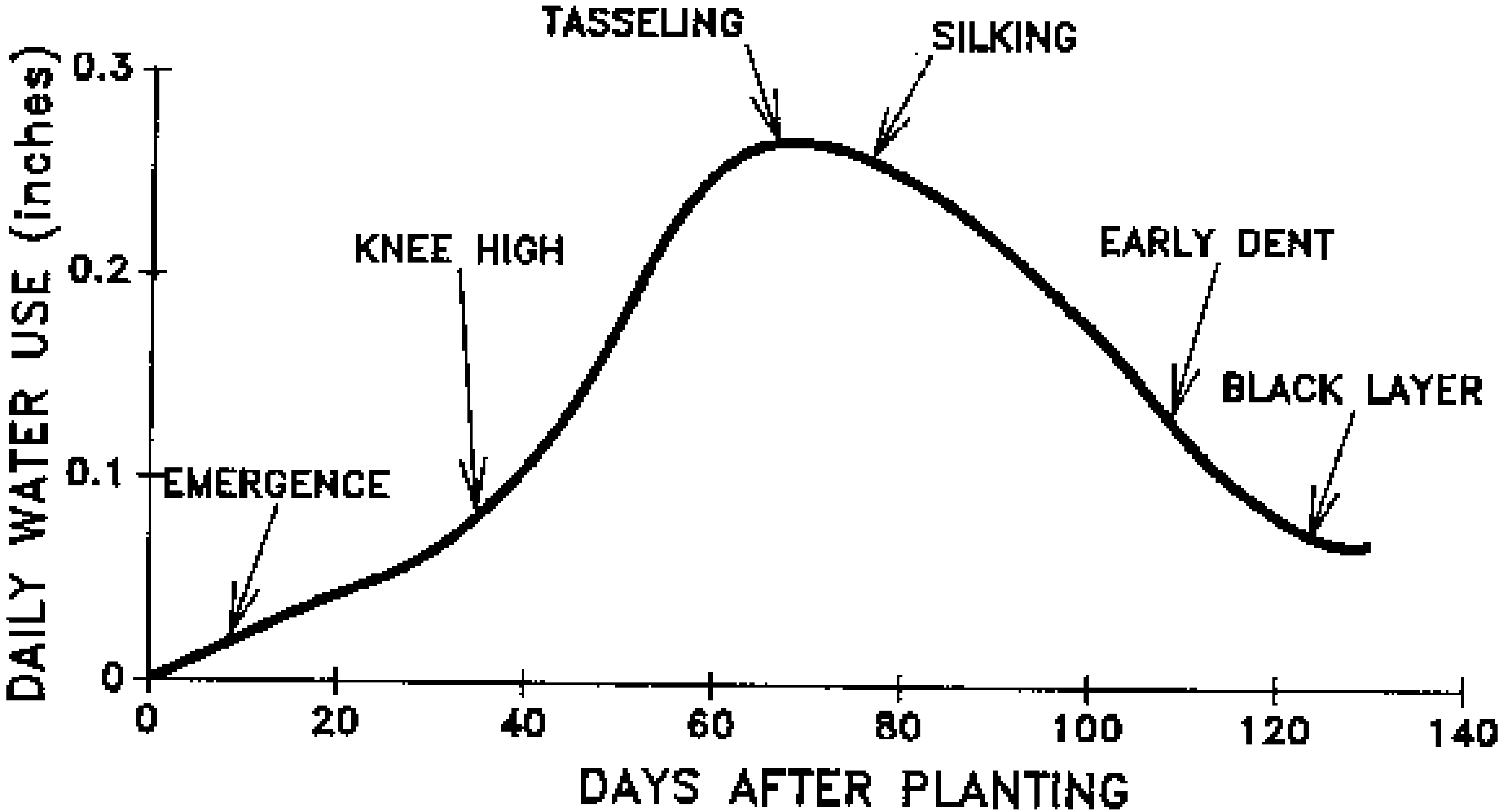
- Use least amount of water necessary
- Apply water efficiently

Crop Needs

- Each crop requires different amounts at different times
- Crop growth stage (canopy, rooting depth)
- Weather conditions (evapotranspiration caused by temperature, relative humidity, wind, sun, day length)



Source: http://www.ext.colostate.edu/pubs/crops/04720.html



http://www.bae.ncsu.edu/programs/extension/evans/ag452-1.html

Average Root Depth of Corn and Soybeans at Various Growth Stages

Corn Stage	Effective root depth* (feet)	Soybean Stage	Effective root depth (feet)
V10-12	2.0	V6	1
V16-VT	2.5	R1	1.5
R1	3.0	R3	2.0
R2	3.5	R6	2.0+
R3-5	4.0		

*Rooting depth maybe less due to compaction or limiting soil profile restrictions.

Source: National Corn Handbook

Soil Water Management

- Available water holding capacity
- Infiltration rate
- Depth restrictions

Available Water Holding Capacity

Soil		in./ft.
Sandy clay loam		2.0
Silty clay loam		1.8
Clay loam		1.8
Loam		
Very fine sandy loam	Low OM	2.0
Silt loam		
Loam		
Very fine sandy loam	High OM	2.5
Silt loam		
Fine sandy loam		1.8
Sandy loam		1.4
Loamy sand		1.1
Fine sands		1.0
Silty clay, clay		1.6

Source: Adapted from the National Corn Handbook

Suggested Maximum Water Intake for Various Soil Types	
Soil Types	Intake rate*
	in./hr.
Sands	2.0
Loamy sands	1.8
Sand loams	1.5
Loams	1.0
Slit and clay loams	0.5
Clays	0.2

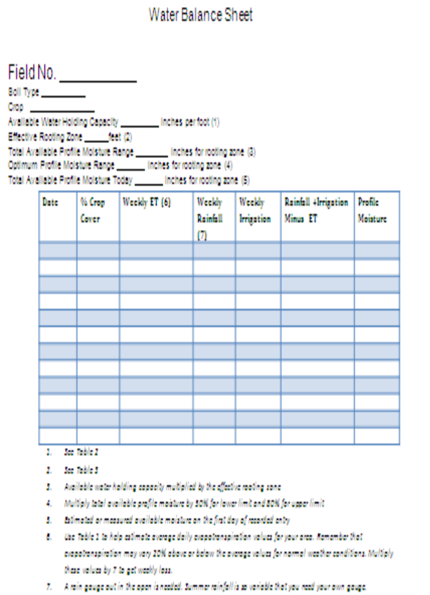
* *Assumes a full crop cover. For bare soil reduce the rate by one-half*

Source: Michigan State University CES Ag Fact 137

Measuring Available Soil H_2O

- Feel method
- “Checkbook”
- Tensiometers (light soils)
- Moisture blocks (heavy soil)

http://aces.nmsu.edu/



Water Balance Sheet

Field No. __________

Soil Type ________

Crop ____________

Available Water Holding Capacity _______ Inches per foot (1)

Effective Rooting Zone _____feet (2)

Total Available Profile Moisture Range ______ Inches for rooting zone (3)

Optimum Profile Moisture Range _____ Inches for rooting zone (4)

Total Available Profile Moisture Today _____ Inches for rooting zone (5)

Date	% Crop Cover	Weekly ET (6)	Weekly Rainfall (7)	Weekly Irrigation	Rainfall +Irrigation Minus ET	Profile Moisture

1. *See Table 2*
2. *See Table 3*
3. *Available water holding capacity multiplied by the effective rooting zone*
4. *Multiply total available profile moisture by 50% for lower limit and 80% for upper limit*
5. *Estimated or measured available moisture on the first day of recorded entry*
6. *Use Table 1 to help estimate average daily evapotranspiration values for your area. Remember that evapotranspiration may vary 20% above or below the average values for normal weather conditions. Multiply these values by 7 to get weekly loss.*
7. *A rain gauge out in the open is needed. Summer rainfall is so variable that you need your own gauge.*

www.aces.nmsu.edu

www.aces.nmsu.edu

Pumps and Plumbing

- Energy efficient power units
- Choice of pumps
- Reduce resistance/head
- Monitor efficiency
- Maintenance of system components

Photo: C. McKittrick, NJAES, Rutgers Univ

Plumbing

- Use pressure gauges
- Appropriate valves
- Check for leaks/restrictions
- Limit reducers, elbows
- Monitor coverage
- Provide uniform delivery
- Maintain system components

Grain Drying

- Managing harvest conditions
- Drying process efficiency

Source: http://corn.agronomy.wisc.edu/Management/images/L033/DryingBin.jpg

Harvest Practices to Promote Efficient Drying

- Variety/hybrid selection
- Combining
  - Proper cylinder/concave settings and fan speeds
  - Reduce stover throughput
  - Minimize splits and cracks
  - Desiccate weeds, if necessary

Drying

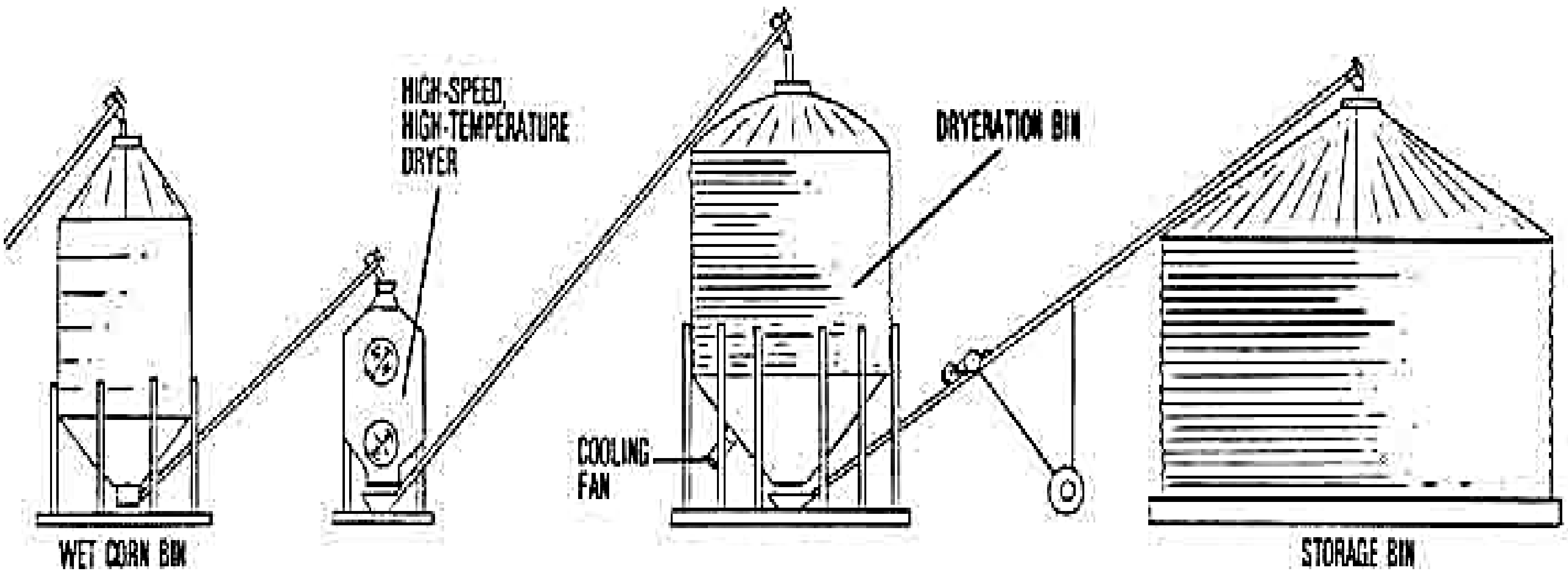
- Clean and service motors, heating units, fans
- Bin cleaning
- Proper grain loading
- Natural air, if possible
- Temperature—follow crop specs
- Dryeration or similar concepts
- Maintain moisture equilibrium throughout storage

Estimated Drying Energy Requirements by Dryer Type

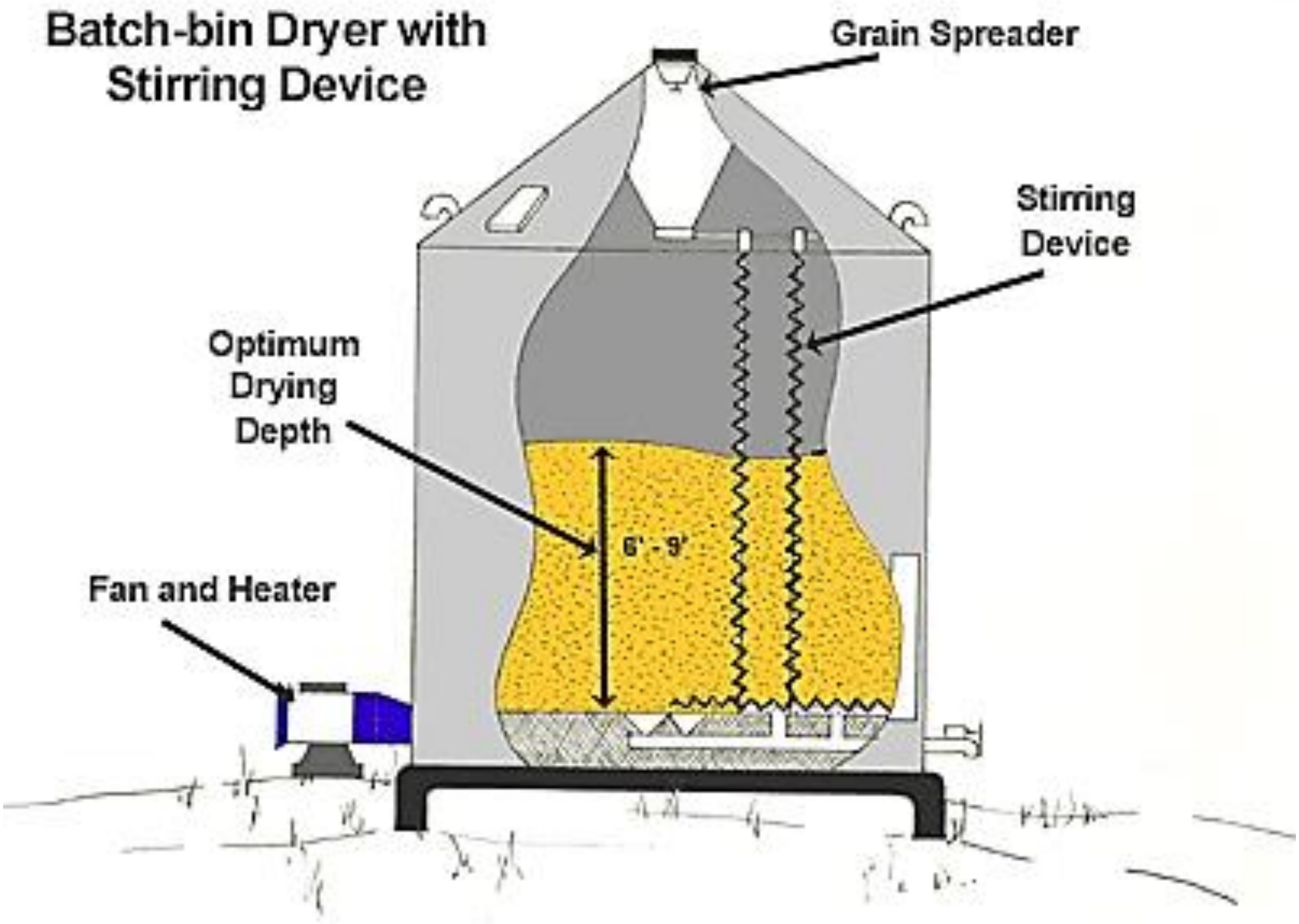
Dryer type	Btu/lb. of water removed
Natural air	1000-1200
Low temperature	1200-1500
Batch-in-bin	1500-2000
High temperature	
Air recirculating	1800-2200
No air recirculating	2000-3000

Source: http://www.ag.ndsu.edu/graindrying/publications/ae-701-grain-drying

Dryeration



Source: Purdue University Extension Service



Source: http://www.ruralenergy.wisc.edu/images/graindrying/High_Temp_Batch_Bin_Dryer.jpg

Fan Covers

Source: http://www.agndsu.edu/graindrying

Fuel Choices

- Efficient, high quality sources
  - Natural gas
  - Clean biogas
  - LP gas/propane

- Acceptable sources that offer less control and efficiency
  - Fuel oil
  - Biomass

Energy Conservation in Field Crop Production

Questions?