Selecting Forage Machinery

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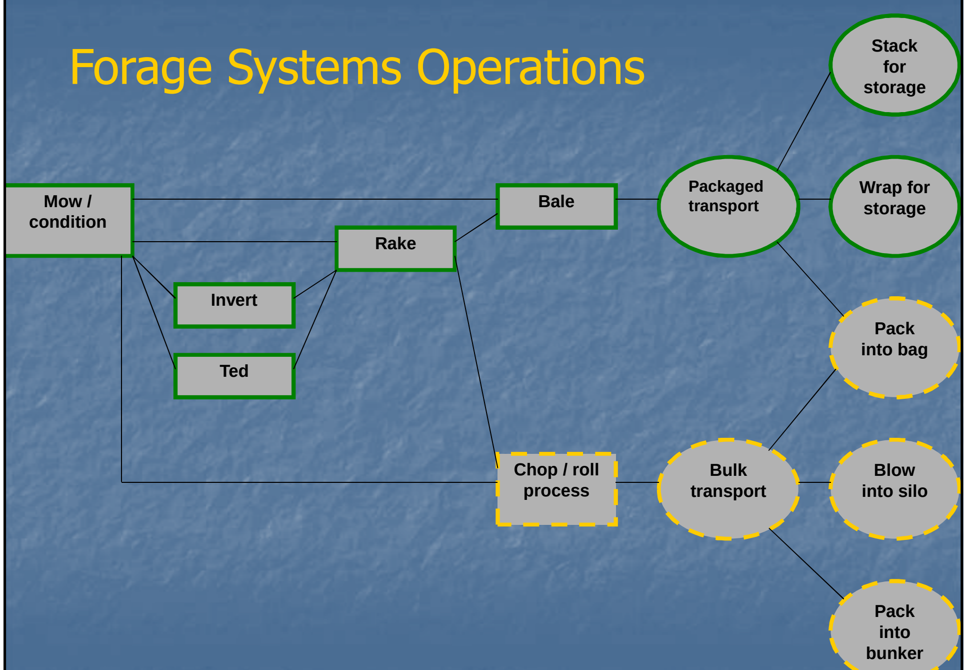
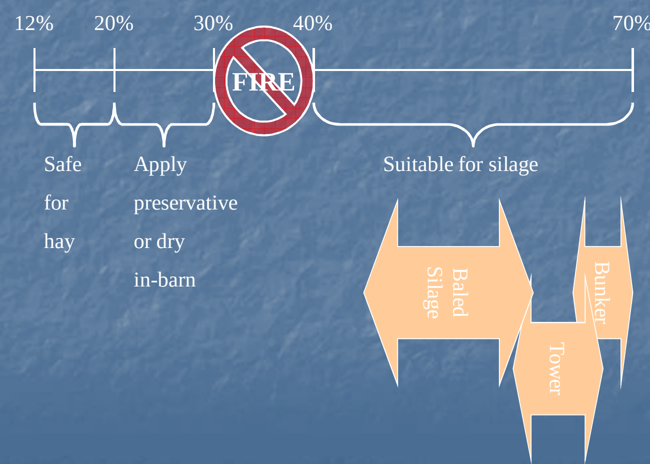
2010 Kentuckiana Dairy Exchange

Forage Systems Operations



Forage Moisture Continuum



Hay vs Silage

HAY: Low moisture so respiration stops and bacteria, fungi, and yeasts cannot survive.

SILAGE: Create anaerobic environment and reduce pH to a level where bacteria, fungi, and yeast growth is inhibited.

Presentation Outline

- General principles
  - Capacity equations
  - Forage equipment features & tractor matching
- Silage machinery matching
  - Harvester capacity/power relationship
  - Putting it away (blower, bagger, bunker)
  - Transporter requirements

Machine Capacity

- Potential Limits to Machine Capacity (any single operation)
  - Power
  - Throughput
  - Speed
  - Traction (hopefully not a factor with haymaking equipment)

Machine Capacity
Mower-Conditioner

- Potential Limits to Machine Capacity
  - Power (particularly with disc cutting)
  - Throughput (perhaps of conditioner)
  - Speed (particularly with sickle cutting)

Machine Capacity
Rakes & Inverters

- Potential Limits to Machine Capacity
  - Power (not likely)
  - Throughput (perhaps)
  - Speed (likely excessive loss at high speeds)

Machine Capacity
Balers

- Potential Limits to Machine Capacity
  - Power (possibly)
  - Throughput
  - Speed (exceed suitable speed for the pickup)

Required Capacity

$$C_{ac/h} = \frac{A_{ac}}{B_{days}\ G_{h/day}\ PWD_{decimal}}$$

Example:

Mow 150 acres in 14 calendar days if 3 of 10 days suitable for working (pwd=.3). 8 h/d available for mowing.

C = 150/[(14)(8)(0.3)] = 4.5 ac/h

Machine Capacity

$$C_{ac/h} = \frac{S_{mph}\ W_{ft}\ E_f}{8.25}$$

Example: 9' Sickle mower-conditioner at 5.0 mph. Typical field efficiency is 80%

C = (5.0)(9)(0.8)/8.25

C = 4.4 ac/h

Matched ≠ same capacity

Pondering …

$$C_{ac/h} = \frac{A_{ac}}{B_{days}\ G_{h/day}\ PWD_{decimal}}$$

Example:

- Mower 4.5 ac/h
- Rake ____ ac/h
- Baler ____ ac/h

Simple Capacity Tool

MACHINERY CAPACITY ESTIMATOR
DRB 8/00

PART 1: Capacity of a machine

SELECT A MACHINE FROM THIS LIST
- Forage blower
- Forage harvester
- Forage harvester (SP)
- Forage wagon
- Grain drill
- Heavy-duty disk
- Large rectangular baler
- Large round baler
- Moldboard plow
- Mower
- Mower (Rotary)
- Mower-conditioner
- Mower-conditioner (rotary)

SELECT A SPEED: Low / Typical / High

SELECT A FIELD EFFICIENCY: Low / Typical / High

SELECT A WIDTH (feet): 9

Speed	5	mph
Width	9	feet
Field Efficiency	0.80	decimal
Capacity	**4.36**	**acres/hour**

https://engineering.purdue.edu/~dbuckmas
Outreach
Spreadsheets
Machine capacity

PART 2: Capacity needed to get the job done

Area to cover	150	acres
Probability of a working day	30	%
Hours for this work	8	h/day
Window of opportunity	14	days
Capacity needed	**4.5**	**acres/h**

The Machinery Portion of hay production costs …

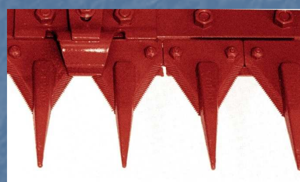
- Hay @ $100/ton with 50 lb bales is worth $2.50/bale.
- At custom rates, machinery (with labor) expense is about $1.60/bale → 64%
- Depending on the system, machinery (with labor) costs are 29 to 69/ton → 40-90%

Mower-Conditioners

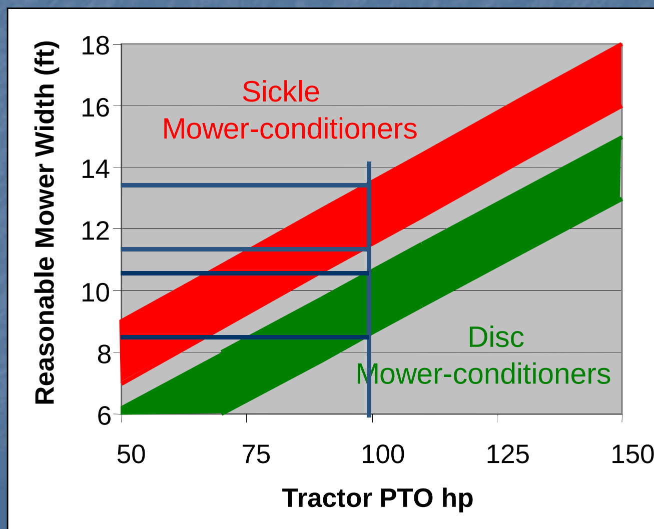
- Cut type:
  - Sickle
  - Disc
- Conditioner type:
  - Roll, "rubber"
  - Rolls, steel
  - Flail/Impellar
- Other features & options

Cut Type

- Sickle
  - Clean cut
  - Speed limited
  - Low power requirement
- Disc/Rotary
  - Good in lodged crops
  - "Never" plug
  - Higher power requirement

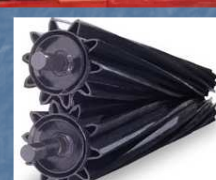


Tractor Requirements



Conditioner Type

- "Rubber" rolls
  - Crimp & crush with pressure
- Steel rolls
  - Crimp & crush with pressure
- Flail, Impellar, or Tine
  - Scuffing action
- Regardless of type, more aggressive conditioning increases drying rate and increases loss



Some Mower Features

- Side windrow attachment for wider units
- No tools adjustments (swath width, roll pressure, tine clearance, etc.)
- Split swath on wider units
- Cutterbar angle tilt adjustment
- Variable reel speed
- Suspension of cutterbar

SKIPPED CONTENT

In this presentation file, but not covered this evening …

- Rakes & other swath manipulation equipment features
- Balers & features (round, square, large square)
- Packaged hay transport options

SKIP TO SLIDE 32
SILAGE PRINCIPLES

Rakes & Other Swath Manipulation Equipment

- Rake Types
  - Parallel bar
  - Rotary
  - Wheel
- Other Swath Manipulation machinery
  - Tedders
  - Inverters
- Features

Rake Type

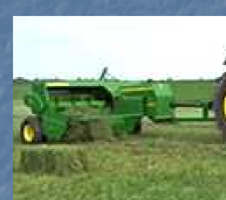
- Parallel Bar
  - Lowest loss, particularly with legumes
  - Ground or variable speed hydraulic drive
- Wheel
  - Higher speed
  - Higher potential for rock collection
- Rotary
  - Sometimes dual function (tedder & rake)

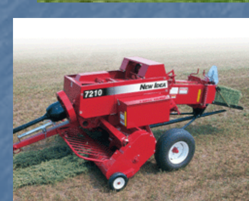
Swath Manipulation Features

- Drawbar or hitch mount
- Adjustable swath & windrow width
- Variable speed
- Hydraulic folding
- Windrow inverters & mergers
- Tedders
- Tandem axles

Small Rectangular Balers

- Sizes & Styles
  - 14”x18”, 16”x18”, 15”x22”
  - Inline & offset
- Features
  - Bale Thrower
  - Hydraulic tension control
  - Pickup heads
  - Pre-pack chamber
- Tractor Matching:
  - 35 hp minimum
  - Could use up over 100 hp



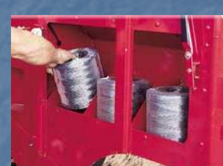


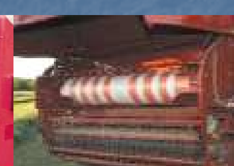
Large Round Balers

- Types
  - Fixed chamber (soft core, high density outside)
  - Variable chamber (uniform bale density)
- Tractor Requirements:
  - 4’ width – 45 to 65 hp (more with silage specials)
  - 5’ width 70-100 hp

Large Round Balers Features

- Twine or net wrap
- Hydraulic pickup (variable speed & reversible)
- Silage special (heavier bales, “sticky” crop)
- Bale slicers



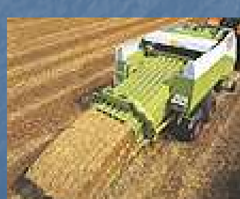


Large Round Balers Features

- Tandem axles, wider tires
- Automatic controls
- Automatic lubricators
- Integrated plastic wrapping

Large Rectangular Balers

- Need 90-200 hp
- Very high capacity (50+ tons/hr)



40 tons/hr example

- 2.5 tons/acre yield
- 6 mph
- .85 field efficiency

$$C_{tons/hr} = \frac{S_{mph}\ W_{ft}\ E_f\ Y_{tons/ac}}{8.25}$$

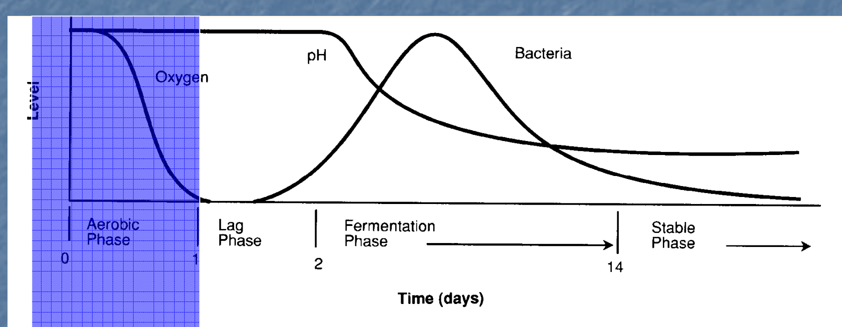
- Requires 26 ft of width
- Would cover 16 acres per hour

Packaged Hay Transport

- Small package options
  - Stack on wagon
  - Throw to wagon
  - Drop then collect
- Large package options
  - Loader & wagon or trailer
  - Auto-loading transporters

Bale Handling Equipment

Basics of Silage Making

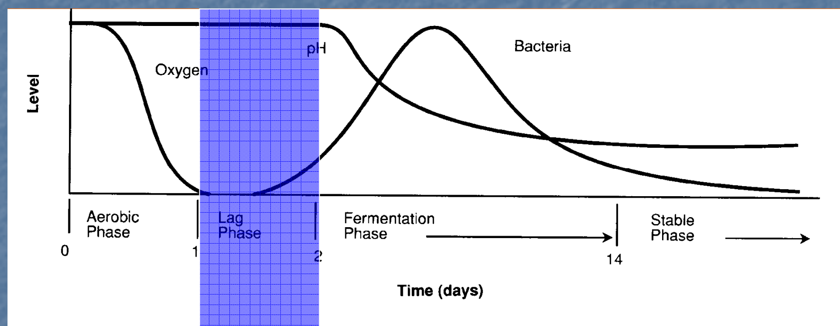


Oxygen consumed by respiration

Sugars used

Heat generated

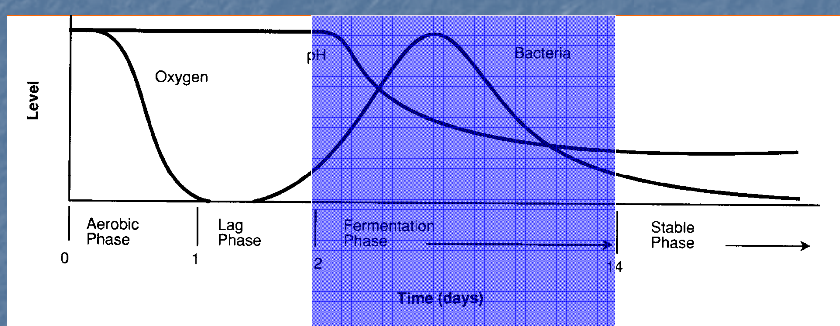
Basics of Silage Making



Oxygen supply is depleted

Acid-producing bacteria begin growth

Basics of Silage Making

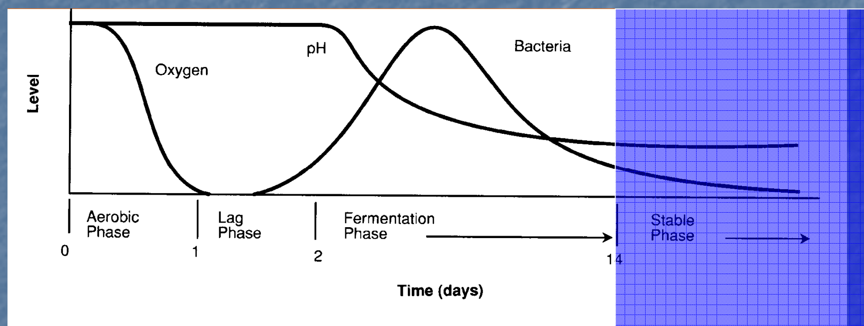


No oxygen (anaerobic)

Bacteria produce acid, reducing pH

Bacteria die off after pH drops

Basics of Silage Making

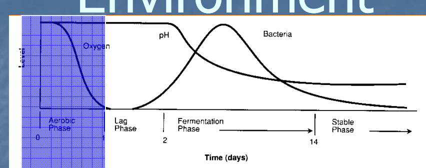


pH is lowered

Microbial population is dead

Anaerobic conditions remain

Creating an Anaerobic Environment



$C_6H_{12}O_6$ + $6O_2$ ⇨ $6CO_2$ + H_20 + heat
(sugar) (oxygen) (carbon dioxide) (water)

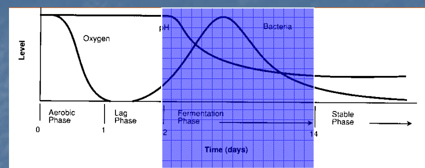
<u>Potential Problems</u>

heat generation
reduced sugars available for fermentation
higher dry matter losses

<u>Proper Methods</u>

fill quickly
high density (proper TLC, moisture, baler operation
seal soon

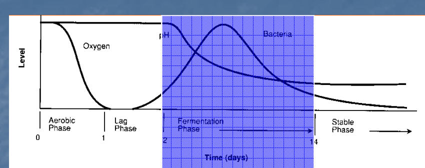
Fermentation (anaerobic process)



(sugar) + (bacteria) ⇨ (acid) + (carbon dioxide)
+ (ammonia) + (hydrogen)

Lactic acid producing bacteria are most desirable because they reduce pH most efficiently with least sugar consumption

Fermentation (anaerobic process)



(sugar) + (bacteria) ⇨ (acid) + (carbon dioxide)
+ (ammonia) + (hydrogen)

Important Factors

- Moisture
- Sugar
- Crop species
- Bacteria number and type

Baled silage checklist

- ☑**Bale Moisture:** Proper moisture for baleage is 45 to 60%.
- ☑**Bale Density:** Bale density should be as high as possible.
- ☑**Bale Sealing:** If wrapped, bales should be wrapped with four layers of plastic with 50% overlap. Seal holes with proper tape.
- ☑**Bale Seal Delay:** Bales should be sealedd within a few hours of baling.

Baled silage checklist

- ☑**Storage site:** The storage site should be constructed to minimize punctures, standing water, and rodent or bird damage.
- ☑**Bale Stacking:** Avoid stacking of bales and, if possible, place them on their ends.
- ☑**Forage Quality as Baled:** Forage should not be overly mature or have experienced significant rain damage.
- ☑**Additive Use:** Inoculants should be used when wilting temperatures are cool and wilting time is short.

Wrappers & Tubers

Potential Capacity Limiters

- Throughput capability
- Power
- Traction
- Speed
- Waiting on others

Hopefully well-matched

Ideally reasonably minimized

Waiting …

- Requires analysis of each system component and their interactions
- First … individual components

Harvester

- Whole-plant corn silage

  Top-end long-term cap

  tons/h = HP/2.5

  OR 2.5 hp h/ton

EXAMPLE:
300 hp
300/2.5 = 120 tons/h corn
300/4 = 75 tons/h haycrop

- Haycrop silage

  Top-end, long-term capacity

  tons/hour = HP/4.0

  OR 4.0 hp h/ton

Blower

- Whole-plant corn silage
  - 180 tons/h likely max
  - Some idle time (~25%)
    - 1.6 hp h/ton
- Haycrop silage
  - 110 tons/h likely max
  - Some idle time (~25%)
    - 2.1 hp h/ton

EXAMPLE:
200 hp
200/1.6 = 125 tons/h corn
95 tons/h avg w/ idle time
200/2.1 = 95 tons/h haycrop
70 tons/h avg w/ idle time

Bagger

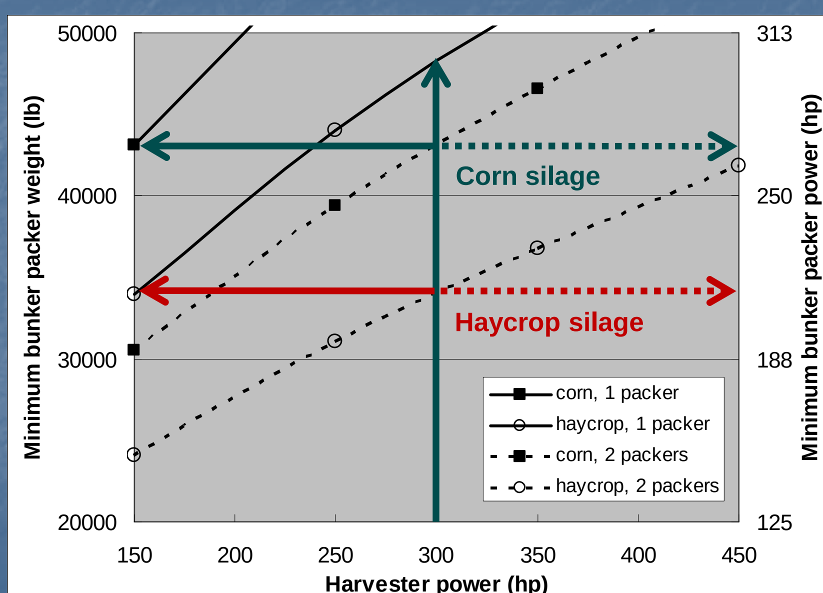
- Whole-plant corn silage
  - 1 hp h/ton
- Haycrop silage
  - 1.5 hp h/ton

EXAMPLE:
120 hp
120/1 = 120 tons/h corn
120/1.5 = 80 tons/h haycrop

Bunker Packer

- Holmes & Muck (WI) model
  - 65% moisture
  - 6” layers
  - Target density of 16 lb DM/ft^3
  - Continuous packing
  - 160 lb/PTO hp maximum practical ballast limit
  - … summary chart …

Bunker Packer



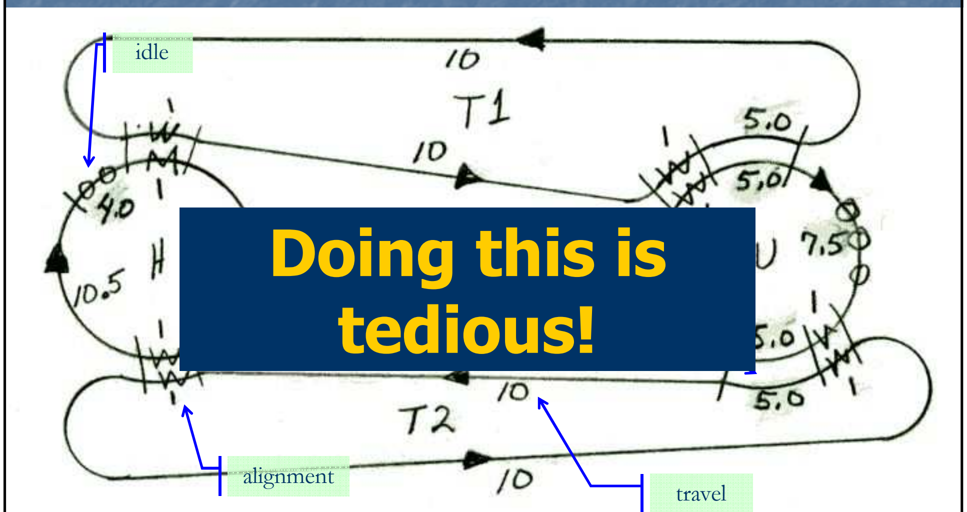
Transport Needs

Cycle Analysis

Where I'm going …

- Graphical example: Pull-type harvester
- Spreadsheet implementation results
  - Pull-type harvester examples
  - SP harvester aid

PT Harvester Cycle Diagram



PT Harvester – haycrops

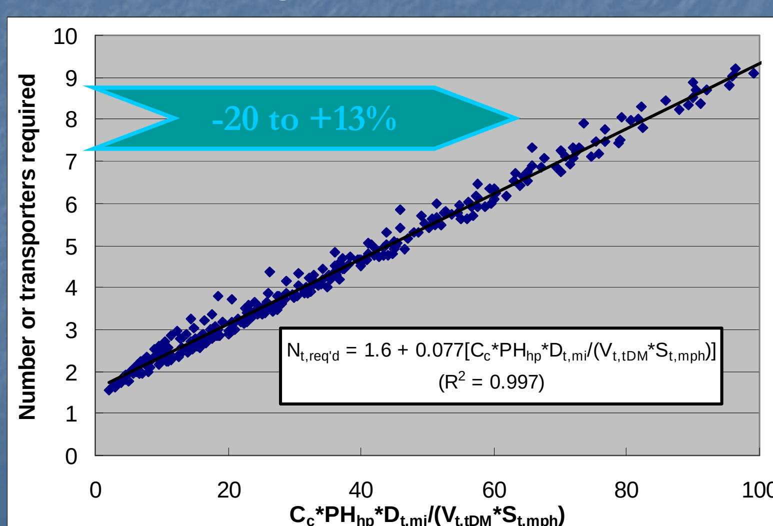
Harvester Power (hp)	Round Trip Distance (mi)	Wagons required to keep harvester busy (or very nearly so)	Capacity with harvester busy (tons/hr)	Capacity with one less wagon (tons/hr)
150	2	3	30	19
150	4	[illegible]	30	26
200	**2**	**3**	**39**	**21**
200	**4**	**4**	**39**	**29**
250	2	4	46	23
250	4	3	45	30

46% decrease
26% decrease

Transport Needs via Cycle Analysis

- Worked "backwards" can yield number of transporters needed to keep the harvester busy
- Simulation mode of operation
  - Harvesters harvest directly into transport units (trucks)
  - Harvester power :: 200 hp to 575 hp
  - Maximum field efficiency of the harvester (system non-limiting) was 85%
  - Round trip transport distance :: 1 to 7 miles
  - Capacity of transport units :: 2 to 4 t DM
  - Speed of transport units :: 10 to 25 mph

Transport Needs with large SP harvesters



Transport Needs with large SP harvesters

$N_{t,req'd} = 1.6 + 0.077[C_c*PH_{hp}*D_{t,mi}/(V_{t,tDM}*S_{t,mph})]$

- EXAMPLE:
- 350 hp harvester
- Haycrop silage (C_c=1)
- 4 miles round trip
- 30 mph average transport speed
- 2 tons DM per load

$N_{t,req'd} = 1.6 + 0.077[1*350*4/(2*30)] = 3.4$

Transport Needs with large SP harvesters

Base scenario (350 hp with haycrop silage)

$N_{t,req'd} = 1.6 + 0.077[1*350*4/(2*30)] = 3.4$

6 miles round trip

$N_{t,req'd} = 1.6 + 0.077[1*350*6/(2*30)] = 4.3$

Corn silage, 5 miles round trip

$N_{t,req'd} = 1.6 + 0.077[1.6*350*5/(2*30)] = 5.2$

Thank you for
your attention.

For a copy of this presentation & related materials:

https://engineering.purdue.edu/~dbuckmas/outreach