Evaluation of Large Scale Willow Biomass Crop Harvesting Using a Recently Developed Single-Pass Cut-and-Chip Harvest System

Based on a New Holland Forage Harvester and SRC Woody Crop Header

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Objective

Evaluate Performance

- Single-pass, cut and chip harvesting system in short rotation woody crops
  - New Holland FR-9000 series forage harvester
  - FB-130 short rotation coppice header

Short Rotation Woody Crops
Focus on the Harvesting System

- Single largest cost for delivered chips from short rotation woody crops
- 30 to 40% delivered cost in willow biomass crops
- Second largest source of GHG emissions after N fertilizer in the production system

Willow Biomass Production Cycle

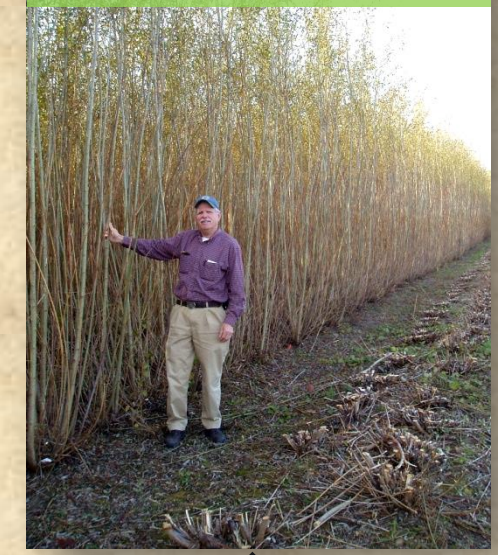
Site Prep Once

Plant Once

Coppice Once

Rapid Re-growth

3 – 4 Years Growth



Harvest Woody Biomass

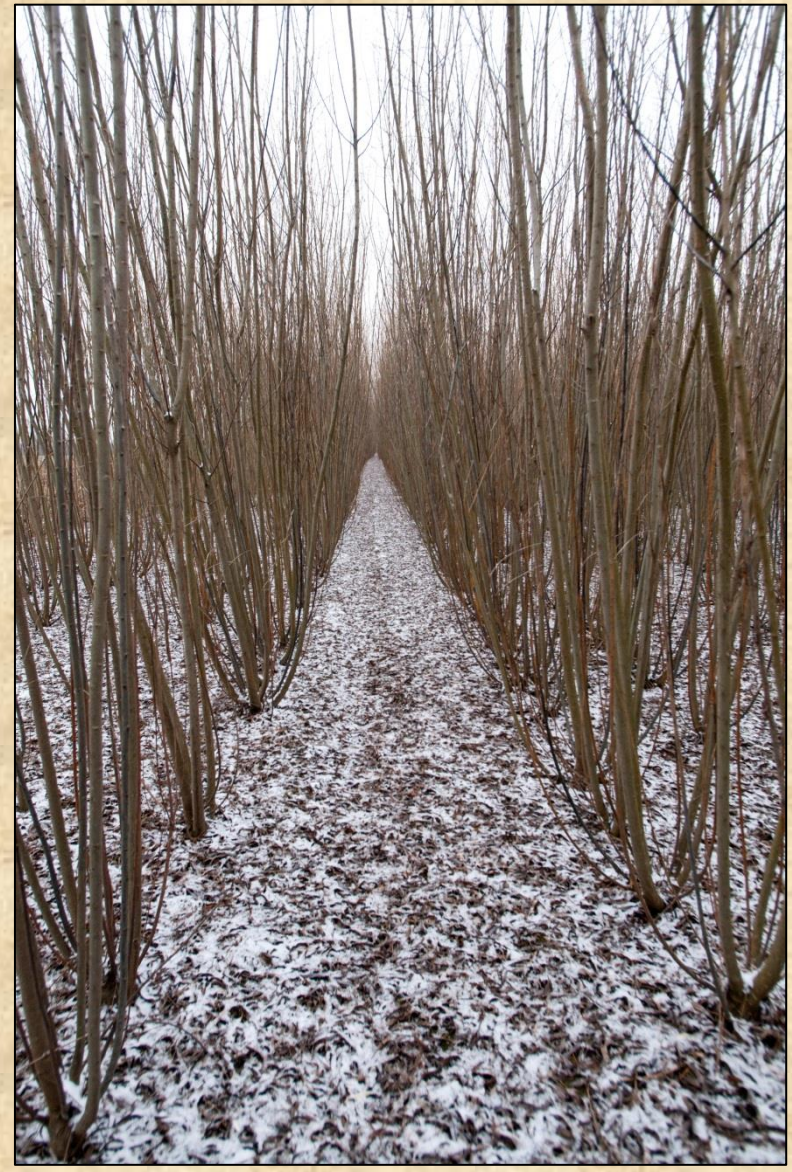
7 Crop Harvests

Auburn and Groveland Harvests

Operational Characteristics

- Commercial-scaled (54 ha in total)
  - But had spacing and headland issues
- Experienced operator
- Locally-sourced collection system
- Optimize throughput
  - Harvester engine loading at or near 100%

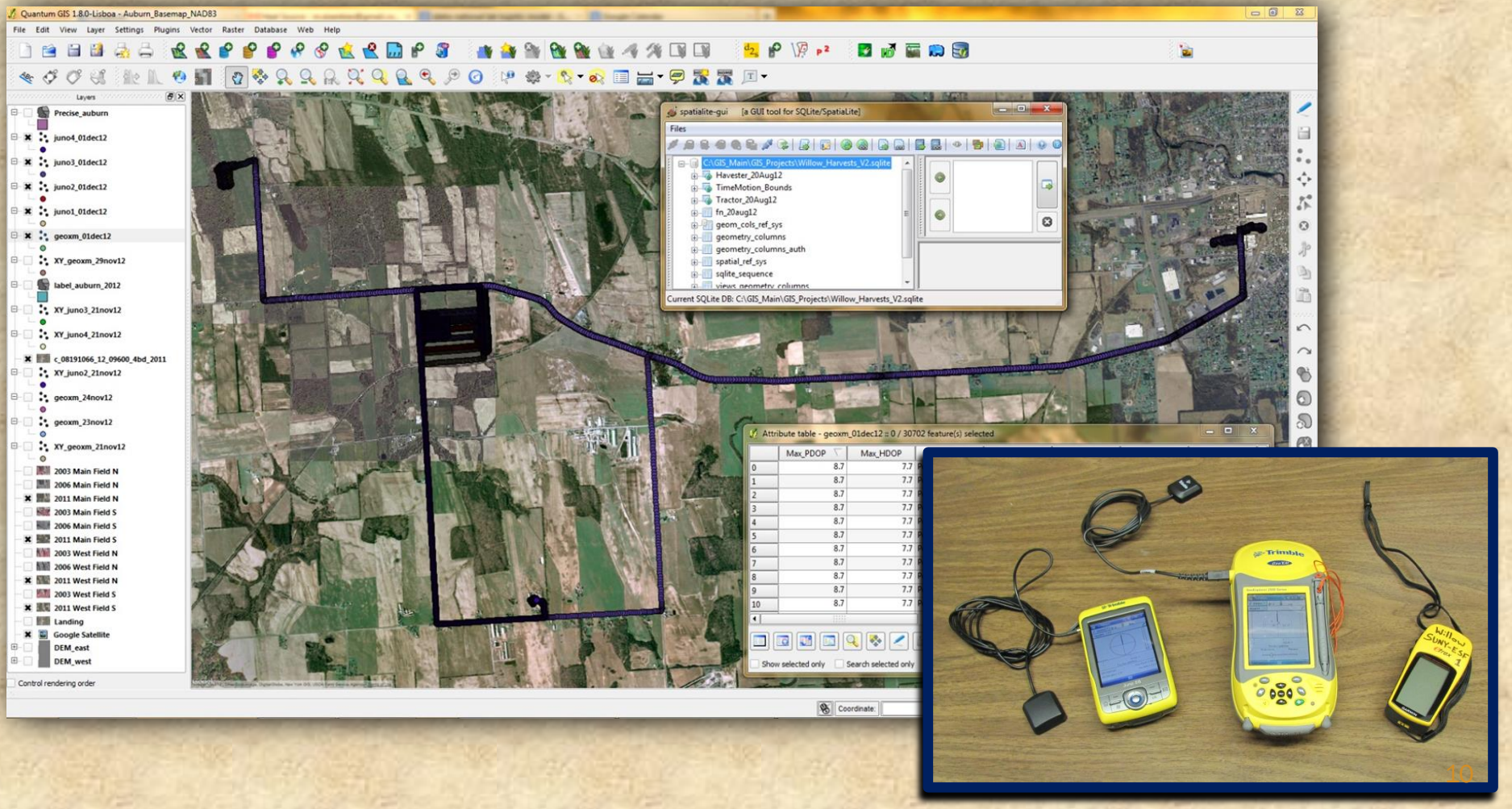
Three Years Old Shrub Willow



Harvesting Willow Biomass Crops

Time Motion Methods

- 1 harvester and 2-4 collection vehicles operating per day; over 1,000,000 GPS data points collected

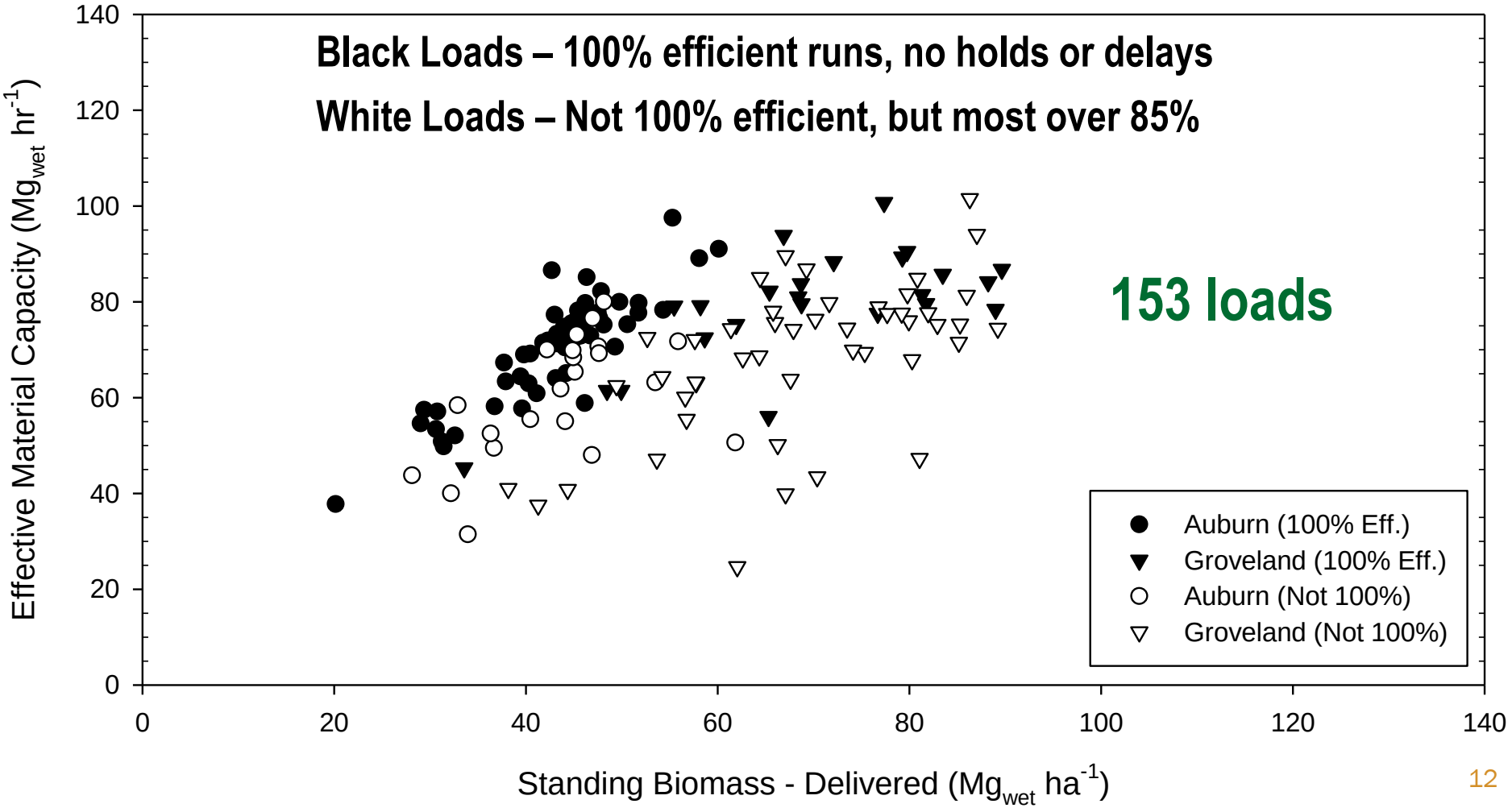


Harvester Performance

Site	Effective Field Capacity (ha hr^{-1}) SPEED	Effective Material Capacity (Mg_{wet} hr^{-1}) THROUGH PUT	Standing Biomass Delivered (Mg_{wet} ha^{-1})
Auburn	1.6 ± 0.02	67 ± 1.4	43 ± 0.8
Groveland	1.1 ± 0.2	72 ± 1.9	68 ± 1.6

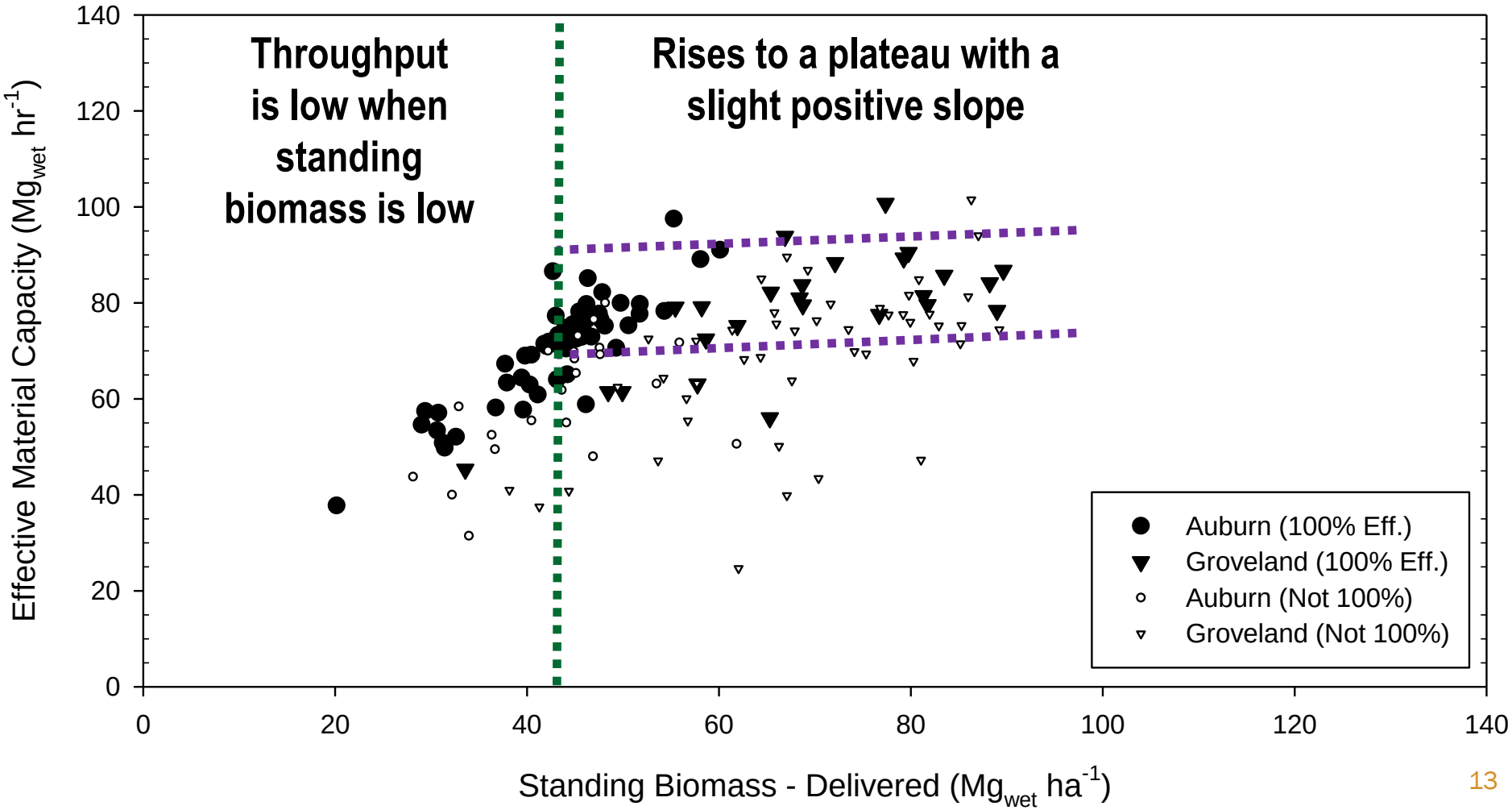
Harvester In Field Performance

Throughput vs Std Biomass



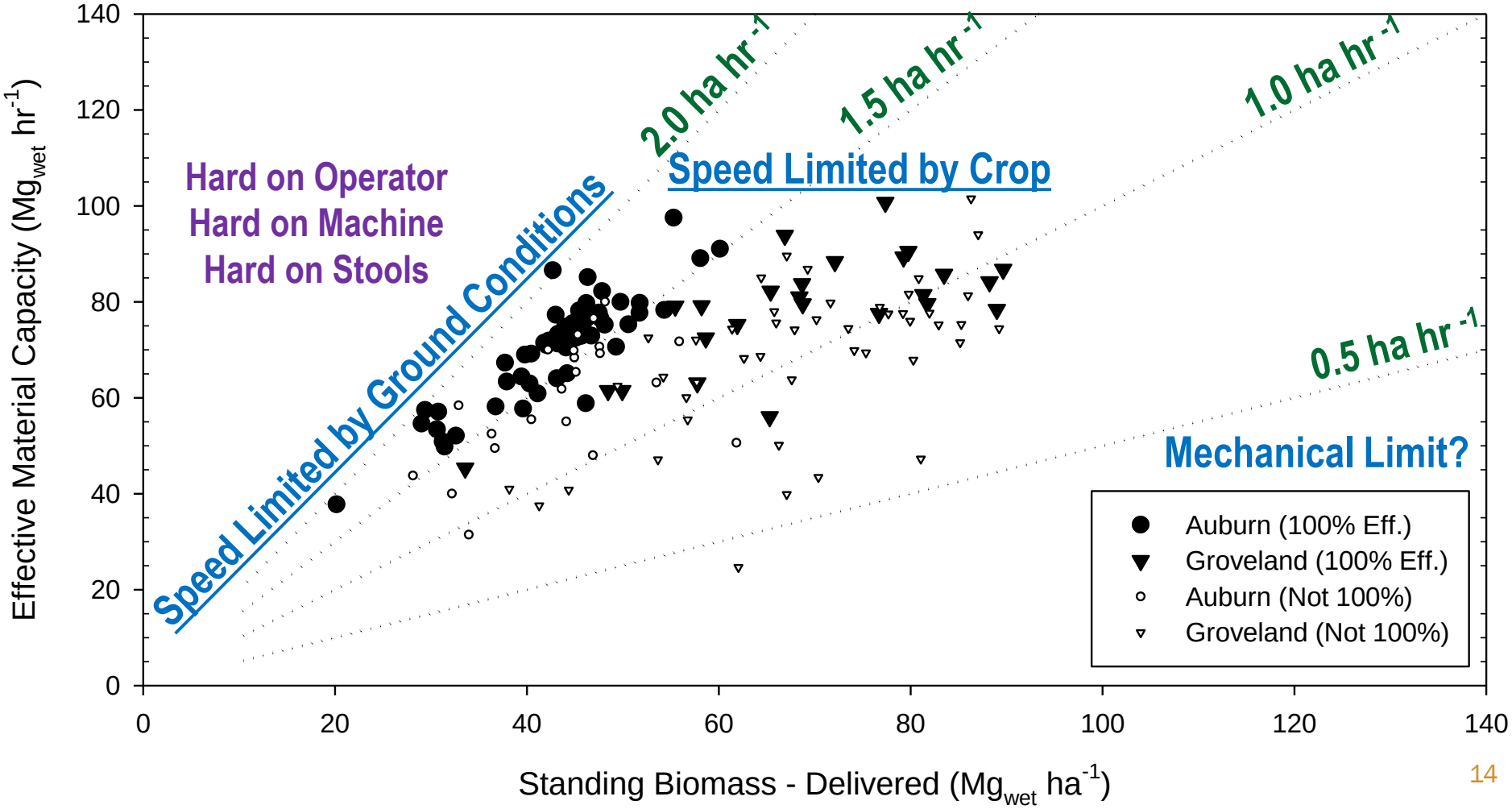
Harvester In Field Performance

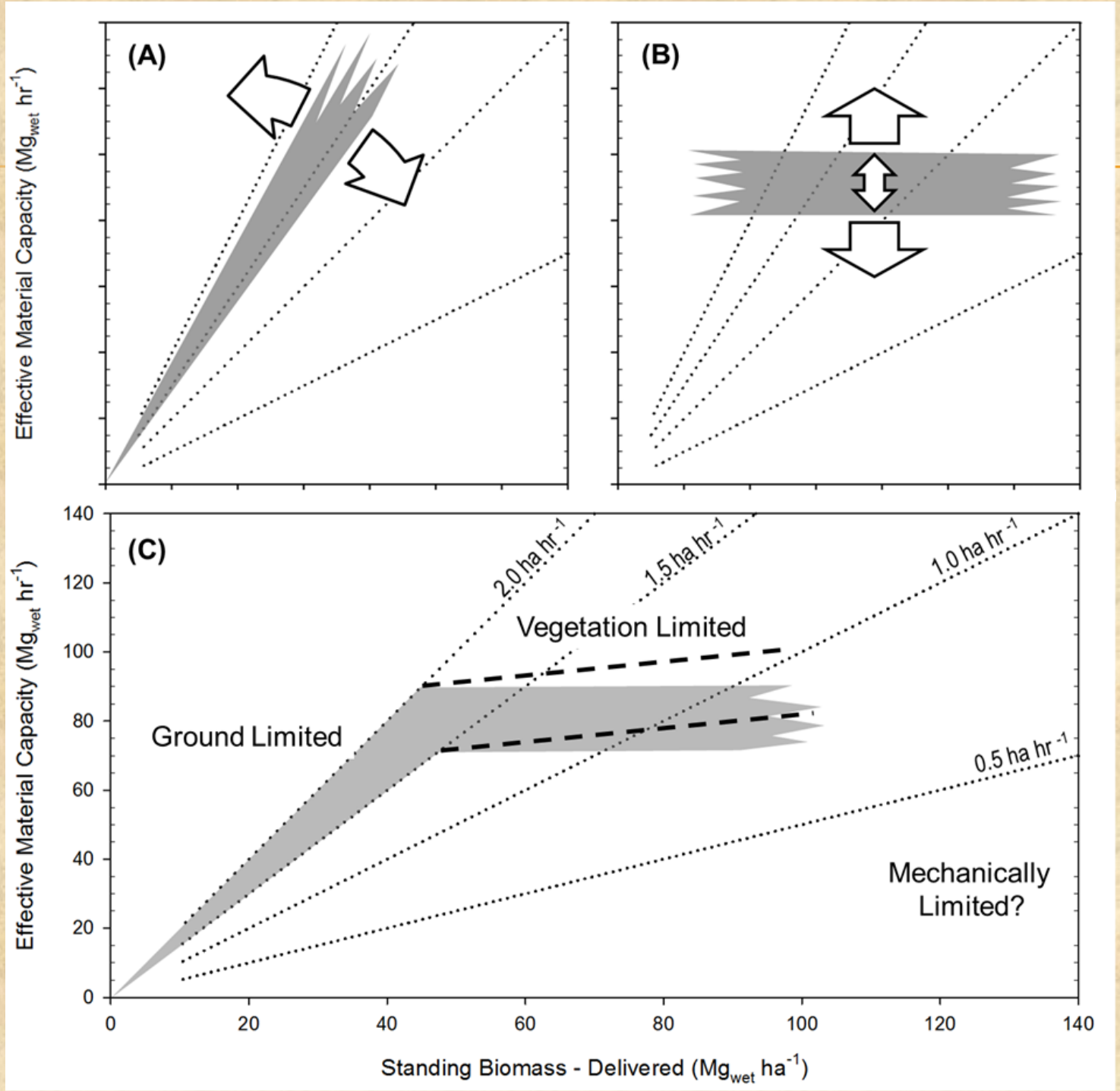
- Throughput becomes consistent over 40 Mg ha^{-1}



Harvester In Field Performance

- Speed isolines:
  - Contour lines
  - Standing biomass limits speed over 40 Mg ha^{-1}

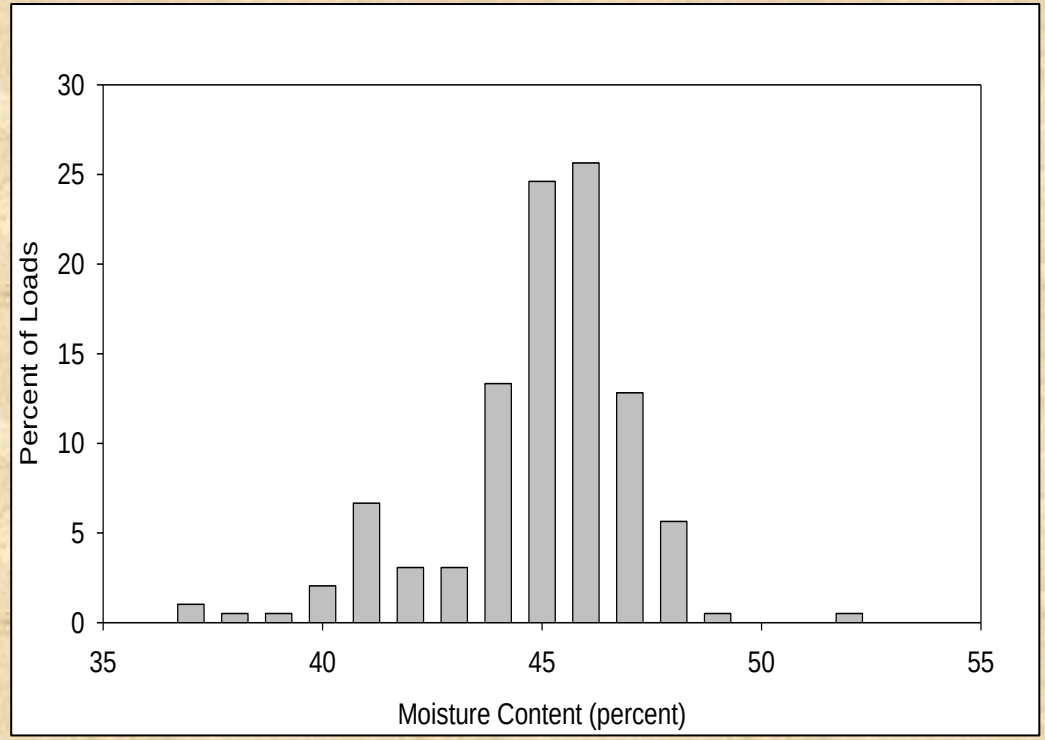



(A)
(B)
(C)
Effective Material Capacity (Mg$_{wet}$ hr^{-1})
Standing Biomass - Delivered (Mg$_{wet}$ ha^{-1})
2.0 ha hr^{-1}
1.5 ha hr^{-1}
1.0 ha hr^{-1}
0.5 ha hr^{-1}
Vegetation Limited
Ground Limited
Mechanically Limited?
0
20
40
60
80
100
120
140

What about chip quality?

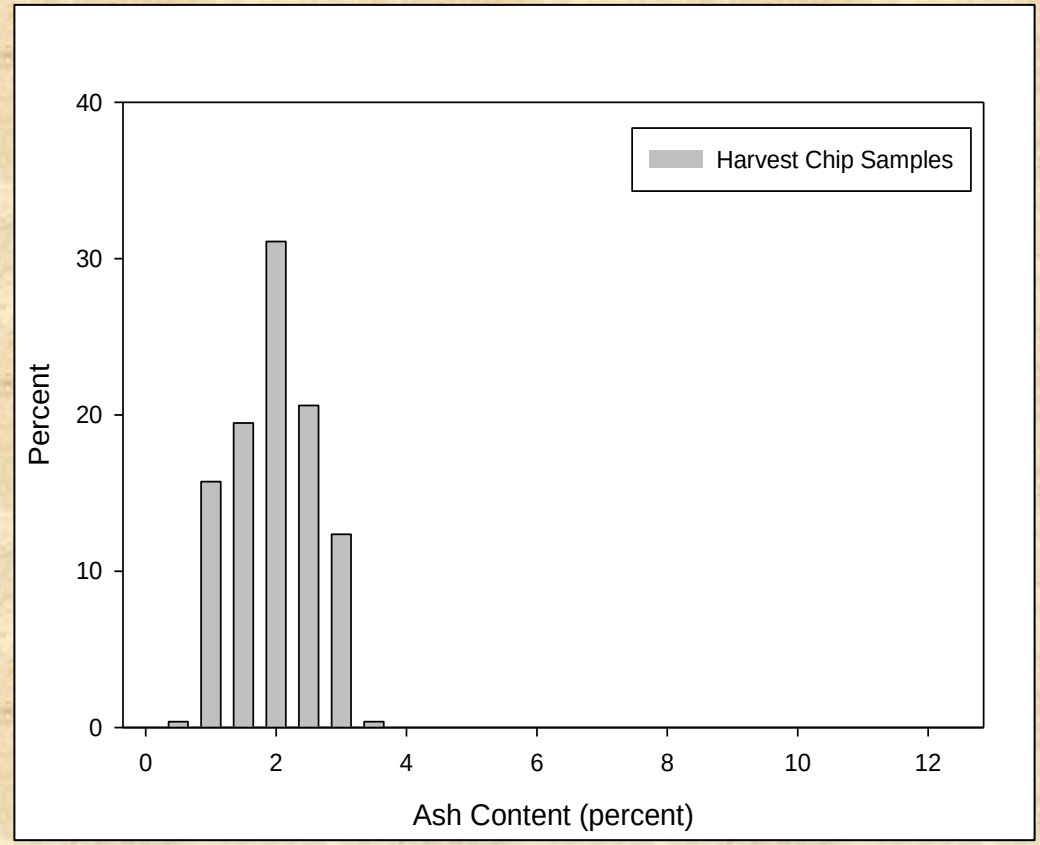
- Concern from end users (consistency, size, ash content)
- No chip quality data from large scale willow biomass harvesting
- International Organization for Standardization (ISO) standards on wood chips

Willow Biomass Quality – Moisture



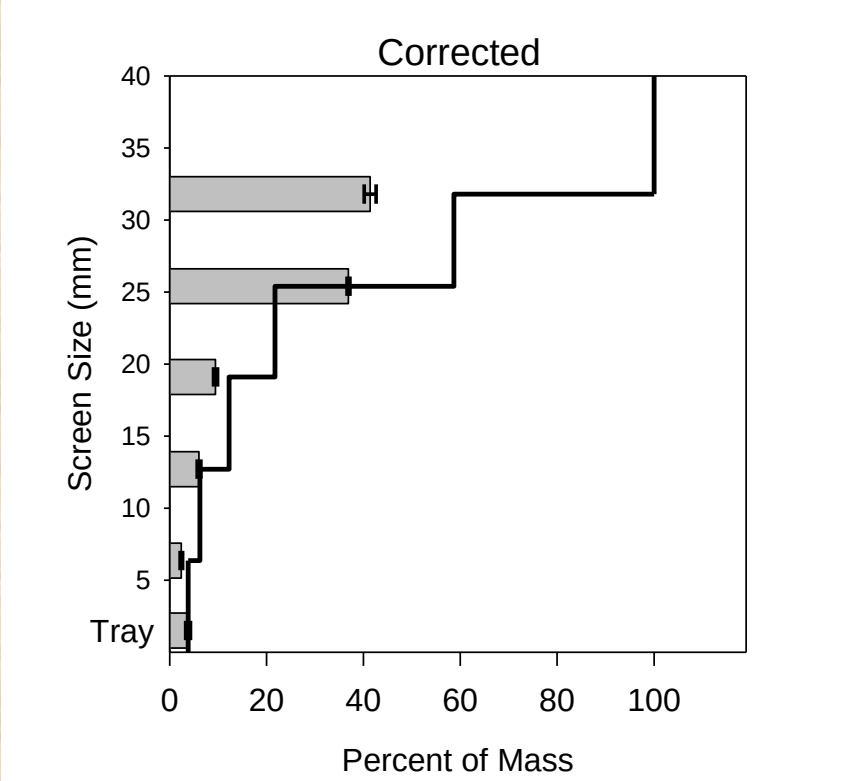
- 195 samples
- 44.4 ± 2.2%
- Only 0.5% of the samples were greater than 50%

Willow Biomass Quality – Ash



- 2.2 ± 0.6%
- About 12% of the samples had an ash content above 3% (ISO standard for class B1 wood chips)

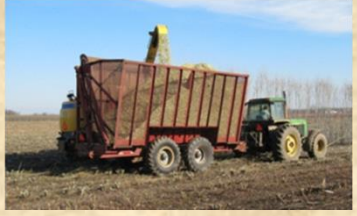
Willow Biomass Quality – Particle Size



- Consistent chip sizes were produced across 14 willow cultivars and under different weather conditions
- ISO class: P45S
- More than 80% of the chips were between 25 and 45 mm (1.0 and 1.8 in)
- Less than 3% were smaller than 6.4 mm (0.25 in)







Conclusions regarding this system

- Harvester is reliable and predictable
  - ✓ Over 70 Mg_{wet} hr^{-1} on areas with over 40 Mg_{wet} ha^{-1}
- Quality of woody biomass produced is consistent
  - ✓ Meet ISO Class B1 standard
- Next:
  - ✓ Evaluate and improve collection system efficiency

Questions?

For more information:

- Shun Shi, shshi@esf.edu, 315-470-4924
- Eisenbies, M.H., Volk, T.A., Posselius, J., Foster, C., Shi, S., Karapetyan, S., 2014. Evaluation of a Single-Pass, Cut and Chip Harvest System on Commercial-Scale, Short-Rotation Shrub Willow Biomass Crops, BioEnergy Research , 1-13.