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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Funding Support

US Department of Energy – Biomass Program

New York State Energy Research and Development Authority

NYSTAR - Technology Transfer Incentive Program

United States Department of Agriculture

National Institute of Food and Agriculture
Project Partners
Manufacturers - Growers – End-users
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
- 3 – 4 Years Growth
  - Rapid Re-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

New Holland Forage Harvester and FB 130 Coppice Header
Time Motion Methods

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

<table>
<thead>
<tr>
<th>Site</th>
<th>Effective Field Capacity (ha hr⁻¹) SPEED</th>
<th>Effective Material Capacity (Mg wet hr⁻¹) THROUGH PUT</th>
<th>Standing Biomass Delivered (Mg wet ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auburn</td>
<td>1.6 ± 0.02</td>
<td>67 ± 1.4</td>
<td>43 ± 0.8</td>
</tr>
<tr>
<td>Groveland</td>
<td>1.1 ± 0.2</td>
<td>72 ± 1.9</td>
<td>68 ± 1.6</td>
</tr>
</tbody>
</table>
Harvester In Field Performance

Throughput vs Std Biomass

Black Loads – 100% efficient runs, no holds or delays
White Loads – Not 100% efficient, but most over 85%

153 loads
Harvester In Field Performance

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

- Throughput is low when standing biomass is low
- Rises to a plateau with a slight positive slope
Harvester In Field Performance

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

Mechanical Limit?

- Hard on Operator
- Hard on Machine
- Hard on Stools

Standing Biomass - Delivered (Mg\(_{\text{wet}}\) ha\(^{-1}\))

Effective Material Capacity (Mg\(_{\text{wet}}\) hr\(^{-1}\))
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%

![Histogram of moisture content](image)
Willow Biomass Quality – Ash

- $2.2 \pm 0.6\%$
- 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$_{\text{wet}}$ hr$^{-1}$ on areas with over 40 Mg$_{\text{wet}}$ ha$^{-1}$
- Quality of woody biomass produced is consistent
  - Meet ISO Class B1 standard
- Next:
  - Evaluate and improve collection system efficiency
Questions?

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