Factors that Affect Fuel Consumption in Logging Systems

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National Average Fuel Prices for the Past 8 Years

U.S. No 2 Diesel Ultra Low Sulfur (0-15 ppm) Retail Prices

Dollars per Gallon

Source: U.S. Energy Information Administration
Objectives

- Evaluate how many gallons of fuel it takes to produce one ton of wood.
- Evaluate factors that could possibly influence this rate of fuel consumption such as:
  - Average tree size of the harvested tract
  - Type of harvest- (clearcut vs. thinning)
  - Soil moisture of the harvested tract
  - Average slope of the harvested tract
Methods

- Conduct a literature study, gather fuel data from machine production reports.
  - Evaluate machine fuel use for each report

- Survey loggers to gather more up to date fuel consumption records while noting important harvest characteristics such as:
  - Machine type, makes, and models
  - Harvest Type (Clearcut or Thinning)
  - Slope of the harvested tract
  - Soil Moisture of the harvested tract
  - Average tree size of the harvested tract
Methods - Data Collection

- Fuel consumption will be measured in gallons of fuel used for each ton of wood produced (gal/ton)

- Collect Data from independent logging contractors in two ways:
  - Weekly Fuel Consumption
  - Fuel Consumption by Tract
<table>
<thead>
<tr>
<th>States Visited</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alabama</td>
</tr>
<tr>
<td>Florida</td>
</tr>
<tr>
<td>Georgia</td>
</tr>
<tr>
<td>North Carolina</td>
</tr>
<tr>
<td>South Carolina</td>
</tr>
<tr>
<td>Virginia</td>
</tr>
<tr>
<td>Mississippi</td>
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<tr>
<td>Maine</td>
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<tr>
<td>Ohio</td>
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<tr>
<td>Minnesota</td>
</tr>
<tr>
<td>Wisconsin</td>
</tr>
<tr>
<td>Tennessee</td>
</tr>
<tr>
<td>Arkansas</td>
</tr>
<tr>
<td>Louisiana</td>
</tr>
</tbody>
</table>
Upon evaluation of the machine production reports, it was noticed that a ground based operation consisting of a feller-buncher, grapple skidder, and a loader would average 0.66 gal/ton fuel consumption.

<table>
<thead>
<tr>
<th>Row Labels</th>
<th>Average Gal/Hr</th>
<th>Total Sources of Data</th>
<th>Std Dev of Gal/Hr</th>
<th>Average Gal/Cubic Meter</th>
<th>Std. Dev of Gal/Cubic Meter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delimber</td>
<td>4.57</td>
<td>7</td>
<td>1.15</td>
<td>0.13</td>
<td>0.05</td>
</tr>
<tr>
<td>Feller Buncher</td>
<td>6.94</td>
<td>33</td>
<td>2.52</td>
<td>0.29</td>
<td>0.44</td>
</tr>
<tr>
<td>Forwarder</td>
<td>2.93</td>
<td>9</td>
<td>0.44</td>
<td>0.16</td>
<td>0.04</td>
</tr>
<tr>
<td>Grapple Skidder</td>
<td>6.24</td>
<td>43</td>
<td>6.10</td>
<td>0.27</td>
<td>0.35</td>
</tr>
<tr>
<td>Harvester</td>
<td>5.57</td>
<td>20</td>
<td>2.04</td>
<td>0.42</td>
<td>0.20</td>
</tr>
<tr>
<td>Loader</td>
<td>6.95</td>
<td>9</td>
<td>0.71</td>
<td>0.10</td>
<td>0.03</td>
</tr>
<tr>
<td>Processor</td>
<td>5.96</td>
<td>14</td>
<td>1.09</td>
<td>0.18</td>
<td>0.09</td>
</tr>
</tbody>
</table>
Results

Tract Data Total Tons by Crew(s)

<table>
<thead>
<tr>
<th>Crew</th>
<th>Total Tons Harvested</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crew 1</td>
<td>23,000</td>
</tr>
<tr>
<td>Crew 2</td>
<td>700</td>
</tr>
<tr>
<td>Crew 3</td>
<td>8,000</td>
</tr>
<tr>
<td>Crew 4</td>
<td>6,865</td>
</tr>
<tr>
<td>Crews 5-9</td>
<td>9,800</td>
</tr>
</tbody>
</table>

Tract Data Total Tons: 48,365

Weekly Data Total Tons by Crew

<table>
<thead>
<tr>
<th>Crew</th>
<th>Total Tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crew A</td>
<td>119,000</td>
</tr>
<tr>
<td>Crew B</td>
<td>91,000</td>
</tr>
<tr>
<td>Crew C</td>
<td>111,000</td>
</tr>
<tr>
<td>Crew D</td>
<td>19,000</td>
</tr>
<tr>
<td>Crew E</td>
<td>94,000</td>
</tr>
<tr>
<td>Crew F</td>
<td>52,000</td>
</tr>
</tbody>
</table>

Weekly Data Total Tons: 486,000

• Tract Data
  • 9 crews
    • Ground-based full tree systems
    • 4 crews from Southeast U.S.
    • 5 crews from the Lake States

• Weekly Data
  • 6 crews
    • Ground-based full tree systems
    • AL and FLA crews
    • High production crews
• Some Lake States crews did not report felling data due to chainsaw felling (Crew 6 and Crew 8).

• Due to a presence of little sample size of tracts, tract data was not considered in the statistical analysis.
Weekly Data average fuel consumption was 0.51 gal/ton.

Lowest fuel consumption came from Crew E with 0.42 gal/ton.

Highest fuel consumption was 0.60 gal/ton from Crew F.
Weekly Production Among Crews

- The most productive crew was Crew E which averaged 1810 tons/week.
- The least productive crew was Crew D which averaged 843 tons/week.
- Crew B submitted the most weeks (81).
- Crew D submitted the least amount of weeks (23).
Felling Analysis ranged from 0.13 gal/ton (Crew C) to 0.24 gal/ton (Crew F).

The overall average fuel consumption for the felling class was 0.17 gal/ton.
The lowest skidding fuel consumption was 0.15 gal/ton by Crew A.

The highest skidding fuel consumption was by Crew F with 0.24 gal/ton.

Average skidding fuel use was 0.18 gal/ton.
The lowest loading fuel consumption was from Crew E with 0.07 gal/ton.

The highest loading fuel consumption was from Crew B with 0.15 gal/ton.

The average loading fuel consumption was 0.11 gal/ton.
Evaluating Factors that could Affect Fuel Consumption

- Soil Moisture, Slope, Average tree size, Harvest Type

- Soil Moisture and Slope evaluated for felling and skidding classes (Loading excluded from evaluation).

- Average tree size in diameter converted to Average Merchantability Class (pulpwood=6” & 7” DBH, chip-n-saw=8”-11” DBH, sawtimber= 12”-up DBH).

- Harvest Type evaluated for each machine and total logging system.
Soil Moisture Effect

Felling Fuel Use by Soil Moisture

Skidding Fuel Use by Soil Moisture
Slope Effect

**Fuel Use by Slope (Felling)**

![Box plot showing fuel use by slope grade for felling.]

**Fuel Use by Slope (Skidding)**

![Box plot showing fuel use by slope grade for skidding.]

- **0%**
- **1-15%**
- **16-35%**

Gal/Ton
Average Merchantability Class - Felling

Felling Fuel Use by Merchantability Class

Gal/Ton

- pulpwood
- chip-n-saw
- sawtimber

Crew
Average Merchantability Class - Skidding

Skidding Fuel Use by Merchantability Class

- Pulpwod
- Chip n saw
- Sawtimber

Gal/Ton

Crew
Average Merchantability Class

Loading Fuel Use by Merchantability Class

Crew

pulpwood  chip-n-saw  sawtimber

Gal/Ton
## Harvest Type Effect

<table>
<thead>
<tr>
<th>Crew</th>
<th>% Tons TH</th>
<th>% Tons CC</th>
<th>Total Tons</th>
<th>Total Weeks TH</th>
<th>Total Weeks CC</th>
<th>Total tons TH</th>
<th>Total Tons CC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crew A</td>
<td>78%</td>
<td>22%</td>
<td>118,920</td>
<td>63</td>
<td>16</td>
<td>92,370</td>
<td>26,550</td>
</tr>
<tr>
<td>Crew B</td>
<td>78%</td>
<td>22%</td>
<td>91,465</td>
<td>63</td>
<td>18</td>
<td>71,524</td>
<td>19,941</td>
</tr>
<tr>
<td>Crew C</td>
<td>5%</td>
<td>95%</td>
<td>110,800</td>
<td>6</td>
<td>71</td>
<td>5,784</td>
<td>105,016</td>
</tr>
<tr>
<td>Crew D</td>
<td>18%</td>
<td>82%</td>
<td>19,399</td>
<td>5</td>
<td>18</td>
<td>3,567</td>
<td>15,832</td>
</tr>
<tr>
<td>Crew E</td>
<td>59%</td>
<td>41%</td>
<td>88,693</td>
<td>29</td>
<td>20</td>
<td>52,571</td>
<td>36,122</td>
</tr>
<tr>
<td>Crew F</td>
<td>57%</td>
<td>43%</td>
<td>46,114</td>
<td>21</td>
<td>16</td>
<td>26,314</td>
<td>19,800</td>
</tr>
<tr>
<td>All Crews</td>
<td>53%</td>
<td>47%</td>
<td>475,391</td>
<td></td>
<td></td>
<td>252,130</td>
<td>223,261</td>
</tr>
</tbody>
</table>
Harvest Type Effect - Felling

Gal/Ton

Gal/Ton TH

Gal/Ton CC

Crew A: 0.19
Crew B: 0.19
Crew C: 0.19
Crew D: 0.12
Crew E: 0.13
Crew F: 0.12

All Crews: 0.17

0.27
Harvest Type Effect - Crew Fuel Use Comparison

- Crew A: Thinning 0.50, Clearcut 0.40
- Crew B: Thinning 0.56, Clearcut 0.56
- Crew C: Thinning 0.54, Clearcut 0.54
- Crew D: Thinning 0.46, Clearcut 0.50
- Crew E: Thinning 0.42, Clearcut 0.41
- Crew F: Thinning 0.63, Clearcut 0.56
Comparing Lit Review and Survey Findings

The bar chart compares fuel consumption data for different equipment types:

- **Feller Buncher**
  - Lit Review: 0.29 Gal/m³
  - Survey Data: 0.17 Gal/Ton

- **Grapple Skidder**
  - Lit Review: 0.27 Gal/m³
  - Survey Data: 0.18 Gal/Ton

- **Loader**
  - Lit Review: 0.11 Gal/Ton
  - Survey Data: 0.1 Gal/Ton
Comparing a Similar Study

![Bar chart comparing Gal/Ton for different categories: FB, SK, and LD. The chart includes data from the Survey Study and the Baker et al. (2014) study.](Image)
Conclusions - System and Machine Fuel Use

- Full tree ground based logging operations average 0.51 gal/ton fuel consumption
- Felling machines average 0.17 gal/ton fuel consumption
- Skidding machines average 0.18 gal/ton fuel consumption
- Loading machines average 0.11 gal/ton fuel consumption.
Conclusions

• Evaluation of soil moisture and slope did not result in a statistically significant effect on fuel consumption.

• Crew differences contributed to a great deal of variability in fuel consumption.

• Evaluation of harvest type effect on fuel consumption showed that thinnings use more fuel than clearcuts in the felling class as well as the overall logging system.
Conclusions

- Average merchantability class of harvested trees had a statistically significant effect on fuel consumption in all three harvesting classes.
  - Felling pulpwood uses more fuel than felling chip-n-saw wood
  - Skidding sawtimber uses more fuel than skidding pulpwood
  - Loading sawtimber uses more fuel than loading chip-n-saw wood and pulpwood
Acknowledgements

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- Many thanks to the loggers who participated.
Questions?