Accurate estimation of wood chip volume to increase efficiency in allocating chipper and transport capacities

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Optimisation of wood chip production chains

- Joint research project
  - Technology and Support Centre
  - Bavarian State Institute of Forestry

- Funding
  - Bavarian State Ministry of Food, Agriculture and Forestry

- Cooperation
  - Bavarian State Forest Enterprise
Content

- The challenge
- Different approaches
- Our research
  - Measurements in the field
  - Maths in the office
- Recommendations for practitioners
The challenge

- Chipping operations at forest roadside as a standard procedure in Bavarian forestry
- Expected wood chip volume is an important parameter when planning wood chipping operations and logistics

- Factor for the conversion of solid timber into wood chips:
  - 1 m³ solid wood → 2.5 bulk cubic metres of wood chips
In forest wood chipping operations, we do not chip solid timber but...
Estimations may be based on three types of data:

- Total amount of wood harvested during the operation
- Number and dimension of tree parts for chipping
- Dimensions of wood piles for chipping

Two-step approach:
- Measurement of wood pile volume
- Calculation of chip volume using conversion factors

Different factors in use
Measurements on energy wood piles:
- Base length
- Upper length
- Maximum height
- Mean height
- Depth on both sides
Our research – Measurements in the field

- Measurements on energy wood piles:
  - Percentage of cut surfaces on front side
  - Diameter of tree parts
Measurement of produced wood chip volume
Our research – Maths in the office

$V_{\text{Cub}}$  Cuboid  
$V_{\text{Pri}}$  Prism  
$V_{\text{Cyl}}$  Cylinder

$V_{\text{CubM}}$  Cuboid (mean height)  
$V_{\text{FrPy}}$  Frustum of pyramid  
$V_{\text{HFrCo}}$  Halved frustum of cone
Our research – Maths in the office

- Frustum of pyramid
  - Most input parameters
  - Back side dimensions
  - Visually best fitting for majority of piles
Volume calculations

[Graph showing volume calculations for forest residues and energy roundwood. The graph includes data for different volume calculations methods, such as $V_{Fr}$, $V_{FrPy}$, $V_{HFCo}$, $V_{Cyl}$, and $V_{Pri}$. The graph displays means, ± SD, and min./max. ranges for each method.]
Conversion factors

<table>
<thead>
<tr>
<th>Forest Residues</th>
<th>Energy Roundwood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.32 ± 0.15</td>
</tr>
<tr>
<td>± SD</td>
<td></td>
</tr>
<tr>
<td>Min./Max.</td>
<td></td>
</tr>
</tbody>
</table>

n = 20

n = 36
Cut surfaces on front side

Conversion Factor $y = 0.0273 \times x - 0.1163$

$R^2 = 0.7914$
Recommendations for practitioners

- Estimation of pile volume
  - As accurate as possible with the least number of measured parameters
  - No measurements on back side

- Forest residues:
  Volume of cylinder
  \[ V_{\text{ForRes}} \approx \frac{\pi}{4} \times l_{bf} \times h_{\text{maxf}} \times d_{\text{mean}} \pm 10 \% \]

- Energy roundwood:
  Volume of cuboid with mean height
  \[ V_{\text{EneRou}} \approx l_{bf} \times h_{\text{meanf}} \times d_{\text{mean}} \pm 10 \% \]
Recommendations for practitioners

- Conversion factors:
  - Forest residues:
    Percentage of cut surface area: 20.2%

<table>
<thead>
<tr>
<th>Cut surface area [%]</th>
<th>15</th>
<th>20</th>
<th>25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conversion factor</td>
<td>0.3</td>
<td>0.4</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Conversion factors:

Energy roundwood:
Percentage of cut surface area: 61.5 %

<table>
<thead>
<tr>
<th>Cut surface area [%]</th>
<th>50</th>
<th>60</th>
<th>70</th>
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<tbody>
<tr>
<td>Conversion factor</td>
<td>1.2</td>
<td>1.5</td>
<td>1.8</td>
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</tbody>
</table>
Thank you for your attention!

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