Automatic wheel load control system as a contribution to improve soil protection and technical trafficability

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Background

- using modern (6- or 8-wheel) and high specialized forest machines is essential
  - Efficiency / Economic reasons
  - Stand conservation / soil protection
  - Just in Time supply for sawmills at al weather conditions
  - Occupational safety
- machines become heavier and more powerful
- consequence: soil compaction and deep tracks
  - permanent applied skid trail network is required
  - maintaining technical trafficability
- skid trail conservation: increase traction / enlarge contact area
  - restrict wheel / axle load
  - equal load distribution on all wheels
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Problem

- traction force / travel movements can provoke a raising effect at a bogie axis
  - reduced wheel load at front-wheel
  - increasing wheel load at the rear-wheel
  - conventional static wheel load calculation is misleading

→ no quantitative information about this effect
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**Objective**

- Characterize the variability of wheel load changes, induced by changing traction force

- Developing an automatic wheel load control system (WLCS) for a forest machine with bogie axis

- Scientific verification of the wheel load control system (WLCS) and its effect of soil protection and technical trafficability
Automatic wheel load control system as a contribution to improve technical trafficability

Material and Methods

• 6-wheel universal skidder (Type: Welte 130K)

• 4 weighing platforms
  → range from 50 to 10,000 kg, 50 kg steps and a tolerance of +/- 50 kg

• Traction force measuring instrument
  → range from 0 to 220 kN in 1 kN steps

• Troxler 3440 nuclear density gauge
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**Material and Methods**

- Characterization the variability of wheel load changes, induced by changing traction force
  - bogie axis wheels positioned on 4 weighing platforms
  - test machine was fixed with a 30 mm non elastic steel cable
  - displayed weights were noted under static conditions
  - Increasing traction forces were applied (driving against the steel cable) until max. ~105 kN
  - displayed weight of each wheel was noted
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**Material and Methods**

- Developing an automatic wheel load control system for a forest machine with bogie axis
  
  → Construction of a hydraulic wheel load regulation cylinder
  
  → Programming an automatic wheel load control system (hydraulic + electronic), based on hydraulic driving pressure, the wheel load and traction force
Material and Methods

- Scientific verification of the wheel load control system and its effect on soil protection and technical trafficability

→ Comparative measurements with and without the control system before and after passing the test trail with the forest machine

→ 2 test sites were applied on sandy loam

1. prepared field site:
   - Milling 60 cm depth
   - Homogenous soil
   - Free from soil influence (roots, gravel …)

2. practiced conditioned forest site
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Material and Methods

→ measurements of soil density with troxler 3440 nuclear density gauge at 24 transects

  each transect: 9 measurements in 3 depths (10, 20, 30 cm): 648 density measurements before and 648 density measurements after passing the transects with the skidder at the same point

→ on both sites the following test scheme were applied
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<table>
<thead>
<tr>
<th>Driving Mode</th>
<th>5 km/h $V_{\text{const.}}$</th>
<th>STOP&amp;GO 0-5 km/h</th>
<th>5 km/h $V_{\text{const.}}$</th>
<th>STOP&amp;GO 0-5 km/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>STOP</td>
<td>ST 1</td>
<td>ST 2</td>
<td>ST 3</td>
<td>ST 4</td>
</tr>
<tr>
<td>4 m</td>
<td>4 m</td>
<td>4 m</td>
<td>4 m</td>
<td>4 m</td>
</tr>
<tr>
<td>75 m TF 3</td>
<td>Transect 3</td>
<td>Transect 6</td>
<td>Transect 9</td>
<td>Transect 12</td>
</tr>
<tr>
<td>50 m TF 2</td>
<td>Transect 2</td>
<td>Transect 5</td>
<td>Transect 8</td>
<td>Transect 11</td>
</tr>
<tr>
<td>25 m TF 1</td>
<td>Transect 1</td>
<td>Transect 4</td>
<td>Transect 7</td>
<td>Transect 10</td>
</tr>
</tbody>
</table>

Vehicle loaded with ~8/4 t (field/forest) short log in the timber basket
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Results: Characterization the variability of wheel load changes
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**Results:** Characterization the variability of wheel load changes

![Graph showing wheel load change with high traction force with (green) and without (red) the control system.](image)
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Results: **Scientific verification of the wheel load control system: Prepared field site**

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**Soil density before and after passing with constant speed [5 km/h] without WLCS**

- Origin soil density: 212 kg/m²
- Soil density after passing: 1153 kg/m³ → 1365 kg/m³
  ~ 118% increase

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**Soil density before and after passing with constant speed [5 km/h] with WLCS**

- Origin soil density: 136 kg/m³
- Soil density after passing: 1246 kg/m³ → 1382 kg/m³
  ~ 111% increase
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Results: **Scientific verification of the wheel load control system: Prepared field site**

**Soil density before and after passing with Stop&Go maneuvers without WLCS**

- Origin soil density (n=81)
- Soil density after passing (S&G) without WLCS (n=81)

278 kg/m²
1260 kg/m³ → 1538 kg/m³ 
~ 122 %

124 kg/m³
1212 kg/m³ → 1336 kg/m³ 
~ 110 %
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**Results:** Scientific verification of the wheel load control system: Forest site

For the forest site:

<table>
<thead>
<tr>
<th>Soil Density (kg/m³)</th>
<th>Before)</th>
<th>After)</th>
</tr>
</thead>
<tbody>
<tr>
<td>122 kg/m²</td>
<td>1011 kg/m³</td>
<td>1133 kg/m³</td>
</tr>
<tr>
<td>90 kg/m³</td>
<td>1083 kg/m³</td>
<td>1173 kg/m³</td>
</tr>
</tbody>
</table>

- 122 kg/m²
- 1011 kg/m³ → 1133 kg/m³ ~ 112%
- 90 kg/m³
- 1083 kg/m³ → 1173 kg/m³ ~ 108%
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**Results:** Scientific verification of the wheel load control system: Forest site

![Soil density before and after passing with Stop&Go maneuvers without WLCS](image)

- **Origin soil density:** 151 kg/m²
- **Soil density after passing S&G without WLCS:** 1161 kg/m³
- **~ 115%**

![Soil density before and after passing with Stop&Go maneuvers with WLCS](image)

- **Origin soil density:** 78 kg/m³
- **Soil density after passing S&G with WLCS:** 1090 kg/m³
- **~ 108%**
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Results: Scientific verification of the wheel load control system: Resume

### Classification of varying percentage

<table>
<thead>
<tr>
<th></th>
<th>&lt;110%</th>
<th>110-120%</th>
<th>&gt;120%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field with WLCS</td>
<td>119</td>
<td>43</td>
<td>0</td>
</tr>
<tr>
<td>Field without WLCS</td>
<td>93</td>
<td>33</td>
<td>36</td>
</tr>
<tr>
<td>Forest with WLCS</td>
<td>125</td>
<td>37</td>
<td>0</td>
</tr>
<tr>
<td>Forest without WLCS</td>
<td>107</td>
<td>42</td>
<td>13</td>
</tr>
</tbody>
</table>
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Conclusion:

→ significant change of the static wheel load distribution caused by traction force

→ dynamic effects have to be considered if effective ground pressure is calculated!

→ WLCS can be a contribution to improve soil protection

~ 35 % (min.) lower soil compaction on our practice conditioned forest site
Thank you for your attention

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