Current practices and efficiency gaps in logging operations from European mountain forests

Adrian Enache¹, Martin Kühmaier¹, Rien Visser², Karl Stampfer¹

¹ University of Natural Resources and Life Sciences, Institute of Forest Engineering, Vienna, Austria
² University of Canterbury – School of Forestry, Christchurch, New Zealand

* Corresponding author: adrian.enache@boku.ac.at
INTRODUCTION

European mountain forests

- forests cover 41% of the EU mountain areas
- multifunctional role - wide variety of ecosystem services
- high variability in timber harvesting intensity, machinery used, productivity, costs, etc.

Goals

- assess current logging practices
- highlight existing efficiency gaps
- identify opportunities for improving efficiency
## METHODS

- web-designed data collection protocol (questionnaire)
- 7 case study areas (CSA) in EU mountain ranges
- 632 operations: 290 thinning op., 342 regeneration felling op.

<table>
<thead>
<tr>
<th>CSA</th>
<th>Country</th>
<th>Forest area (ha)</th>
<th>Altitude (m)</th>
<th>Slope (%)</th>
<th>Tree species</th>
<th>FM System</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CSA 1</td>
<td>Spain</td>
<td>2654</td>
<td>1422±107</td>
<td>32±21</td>
<td>Scots pine, Pyrenean oak</td>
<td>59CO, 35EA, 6NO</td>
</tr>
<tr>
<td>CSA 2</td>
<td>France</td>
<td>5190</td>
<td>1310±189</td>
<td>36±25</td>
<td>Spruce, fir, beech</td>
<td>94UA, 6NO</td>
</tr>
<tr>
<td>CSA 3</td>
<td>Austria</td>
<td>579</td>
<td>1523±157</td>
<td>61±21</td>
<td>Spruce, beech, maple, fir</td>
<td>100UA</td>
</tr>
<tr>
<td>CSA 4</td>
<td>Slovenia</td>
<td>5016</td>
<td>973±201</td>
<td>22±14</td>
<td>Beech, fir, spruce</td>
<td>29EA, 65UA, 6NO</td>
</tr>
<tr>
<td>CSA 5</td>
<td>Sweden</td>
<td>10405</td>
<td>482±68</td>
<td>11±7</td>
<td>Scots pine, spruce, birch</td>
<td>100EA</td>
</tr>
<tr>
<td>CSA 6</td>
<td>Slovakia</td>
<td>5130</td>
<td>1057±166</td>
<td>29±14</td>
<td>Spruce, fir, beech</td>
<td>100EA</td>
</tr>
<tr>
<td>CSA 7</td>
<td>Bulgaria</td>
<td>1737</td>
<td>1580±176</td>
<td>56±52</td>
<td>Scots pine, black pine, fir, beech, spruce</td>
<td>70EA, 30NO</td>
</tr>
</tbody>
</table>
METHODS

- statistic analysis: t-test, ANOVA, correlation tests

<table>
<thead>
<tr>
<th>Road network</th>
<th>Transport method</th>
<th>Transport parameters</th>
<th>Accidents in logging operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density roads (m ha(^{-1}))</td>
<td>Single truck</td>
<td>Loading capacity (t)</td>
<td>Accident quote</td>
</tr>
<tr>
<td>Density skid trails (m ha(^{-1}))</td>
<td>Truck with trailer</td>
<td>Transport distance (km)</td>
<td>Frequency in harvesting</td>
</tr>
<tr>
<td>Construction costs (€ m(^{-3}))</td>
<td>Train</td>
<td>Fuel costs (€ litre(^{-1}))</td>
<td>Frequency in extraction</td>
</tr>
<tr>
<td>Maintenance costs (€ m(^{-3}))</td>
<td>Others</td>
<td>Transport costs (€ m(^{-3}))</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Harvesting method</th>
<th>Felling and processing</th>
<th>Extraction methods</th>
<th>Productivity</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole tree (WT)</td>
<td>Axe</td>
<td>Manual</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tree length (TL)</td>
<td>Saw</td>
<td>Animal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cut-to-length (CTL)</td>
<td>Chainsaw</td>
<td>Tractor</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Feller-buncher</td>
<td>Skidder</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Harvester</td>
<td>Forwarder</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>Cable yarder</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

10.12.2015 Institute of Forest Engineering (BOKU) Dr. Adrian ENACHE
Efficiency gaps analysis

- Scenarios:
  1. BAU – business as usual: current harvesting systems (HS) and road network
  2. Improved road network & BAU HS
  3. Improved road network & NEW HS

- Indicators:
  - road density, extraction distance, HS productivity, HS costs, transport, fuel consumption, CO2 emissions, number of accidents & mean damage stand index.
RESULTS – Current practices

Across CSA

Harvesting methods

- Tree length (TL): 40%
- Cut-to-length (CTL): 60%

Extraction methods

- Animal: 15%
- Forwarder: 1%
- Manual: 8%
- Skidder: 3%
- Tractor: 29%
- Cable Yarder: 44%
RESULTS – Current practices

Mechanization degree

a) Productivity (m³ h⁻¹)

<table>
<thead>
<tr>
<th>CSA 1 (SP)</th>
<th>CSA 2 (FR)</th>
<th>CSA 3 (AT)</th>
<th>CSA 4 (SLO)</th>
<th>CSA 5 (SWE)</th>
<th>CSA 6 (SK)</th>
<th>CSA 7 (BG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>20%</td>
<td>40%</td>
<td>60%</td>
<td>80%</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

Partly  Highly  Fully

11.5  24.0  13.7

6.4  8.2  16.2  16.5

Partly  Highly  Fully

b) Costs (€ m⁻³)

<table>
<thead>
<tr>
<th>CSA 1 (SP)</th>
<th>CSA 2 (FR)</th>
<th>CSA 3 (AT)</th>
<th>CSA 4 (SLO)</th>
<th>CSA 5 (SWE)</th>
<th>CSA 6 (SK)</th>
<th>CSA 7 (BG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.5</td>
<td>24.0</td>
<td>13.7</td>
<td>9.8</td>
<td>9.8</td>
<td>6.5</td>
<td></td>
</tr>
</tbody>
</table>

Partly  Highly  Fully
RESULTS – Current practices

Timber extraction

a) Productivity (m³ h⁻¹)

<table>
<thead>
<tr>
<th>Method</th>
<th>Productivity (m³ h⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal Forwarder</td>
<td>17.4</td>
</tr>
<tr>
<td>Manual</td>
<td>2.3</td>
</tr>
<tr>
<td>Tractor</td>
<td>8.1</td>
</tr>
<tr>
<td>Skidder</td>
<td>11.3</td>
</tr>
<tr>
<td>Cable Yarder</td>
<td>8.0</td>
</tr>
</tbody>
</table>

b) Costs (€ m⁻³)

<table>
<thead>
<tr>
<th>Method</th>
<th>Costs (€ m⁻³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal Forwarder</td>
<td>9.3</td>
</tr>
<tr>
<td>Manual</td>
<td>6.1</td>
</tr>
<tr>
<td>Tractor</td>
<td>9.3</td>
</tr>
<tr>
<td>Skidder</td>
<td>10.2</td>
</tr>
<tr>
<td>Cable Yarder</td>
<td>8.6</td>
</tr>
</tbody>
</table>

Animal □ Forwarder ■ Manual □ Skidder □ Tractor ■ Cable Yarder
RESULTS – Efficiency gaps

Road network

Road density (m ha\(^{-1}\))

- CSA1
- CSA2
- CSA3
- CSA5
- CSA6
- CSA7

18.5 m ha\(^{-1}\)
19.4 m ha\(^{-1}\)
20.2 m ha\(^{-1}\)

Scenario 1
Scenario 2
Scenario 3
Mean Scenario 1
Mean Scenario 2
Mean Scenario 3
RESULTS – Efficiency gaps

Extraction distance

- Scenario 1
- Scenario 2
- Scenario 3

Mean extraction distance (m)

- 501 m
- 338 m
- 307 m
RESULTS – Efficiency gaps

Productivity

Timber harvesting productivity (m$^3$ h$^{-1}$)

- CSA1
- CSA2
- CSA3
- CSA4
- CSA5
- CSA6
- CSA7

- Scenario 1
- Scenario 2
- Scenario 3

- Mean Scenario 1
- Mean Scenario 2
- Mean Scenario 3

- 14.6 m$^3$ h$^{-1}$
- 15.7 m$^3$ h$^{-1}$
- 23.3 m$^3$ h$^{-1}$
RESULTS – Efficiency gaps

Costs

Timber harvesting costs (€ m⁻³)

- 26,4 € m⁻³
- 22,9 € m⁻³
- 19,4 € m⁻³

Scenario 1
Scenario 2
Scenario 3
Mean Scenario 1
Mean Scenario 2
Mean Scenario 3

CSA1
CSA2
CSA3
CSA4
CSA5
CSA6
CSA7

10.12.2015
Institute of Forest Engineering (BOKU)
Dr. Adrian ENACHE
RESULTS – Efficiency gaps

CO₂ emissions

- Scenario 1
- Scenario 2
- Scenario 3
- Mean Scenario 1
- Mean Scenario 2
- Mean Scenario 3

CO₂ emissions (kg m⁻³)

<table>
<thead>
<tr>
<th>CSA1</th>
<th>CSA2</th>
<th>CSA3</th>
<th>CSA4</th>
<th>CSA5</th>
<th>CSA6</th>
<th>CSA7</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.6</td>
<td>4.8</td>
<td>5.4</td>
<td>5.6</td>
<td>4.8</td>
<td>5.4</td>
<td>5.6</td>
</tr>
</tbody>
</table>
RESULTS – Efficiency gaps

Timber transport (loading capacity)

- Efficiency gaps
- Timber transport (loading capacity)

- Total weight of loaded truck (t)
- Max. allowed weight (t)

CSA1 | CSA2 | CSA3 | CSA5 | CSA6 | CSA7
---|---|---|---|---|---
0.0 | 50.0 | 30.0 | 60.0 | 40.0 | 20.0

0.0 | 10.0 | 20.0 | 30.0 | 40.0 | 50.0 | 60.0

10.12.2015
Institute of Forest Engineering (BOKU)
Dr. Adrian ENACHE
RESULTS – Efficiency gaps

Timber transport (distance & costs)

Transport distance (km)

Transport cost (€ m⁻³)

CSA1  CSA2  CSA3  CSA5  CSA6  CSA7

Transport distance  Transport cost

0 50 100 150 200 250 300

0 2.0 4.0 6.0 8.0 10.0 12.0 14.0 16.0 18.0 20.0
CONCLUSIONS

Mountain Forests

- no influence of FM system, terrain topography on selection of HS
- availability and affordability of state-of-the-art HS
- quality of the road network (layout and trafficability)?
- mechanization degree
- transfer of knowledge to practical know-how
- capacity building & training of forest workers
THANK YOU!

Acknowledgments

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 289437 – ARANGE Project.