Mechanized wood chips harvesting in the thinning of the forest culture of Weymouth pine (P<em>inus strob<em>us</em> L.)

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Introduction

• systematic work on increasing the proportion of conifers in the forest resources of Croatia began around the 1960s

• forest cultures were mainly established with the aim to ensure continuous supply of raw material for timber industry, especially for pulp and paper production

• timber harvesting issues showed to full extent in the period when most of the newly-established forest cultures came to the age of first thinning
  
  • the absence of complete mechanization of tree felling and processing work conditioned the unit costs which market price of the produced pulpwood could hardly offset
  
  • implementation of the first thinning was generally prolonged and forest cultures continued to develop spontaneously and the growing stock was accumulated on a large number of thin trees
Introduction

• due to the large initial number of plants, the lack of thinning and reached age forest cultures became unstable

• necessity to conduct silvicultural work coincided with the increased demand for energy wood and on the other hand with the introduction of high technologies in the Croatian forestry

• fully mechanized harvesting systems incorporating harvester for felling and processing of trees, forwarder for extraction and chipper for production of wood chips promise the acceptable cost of solid biofuel procurement

• it is expected that those new moments will be an incentive to carry out the necessary silvicultural work in the coniferous forest cultures with a certain financial gain, and that they will probably encourage the establishment of new cultures on available lands
Research goal

• determine the time consumption of the individual work elements in the working process of wood chips production; design a mathematical model for calculating productivity; calculate the costs of production

Materials and Methods

• state forest managed by the "Croatian Forests" Ltd., Forest Administration Gospić, Forest Office Perušić
• management unit "Ostrvica“
• sub-compartment 111 A (44°37' N, 15°15' E)
  • 44 years old Weymouth pine forest culture of an area of 21.85 ha situated on a flat terrain at an altitude of 570 m
  • before harvesting: 553 trees per hectare and the growing stock was 323.62 m³/ha
  • Weymouth pine (Pinus strobus L.) with the 517 trees per hectare and the growing stock of 320.32 m³/ha dominated the stand
  • average DBH of Weymouth pine trees was 31 cm, and average height was 15 m

• thinning was performed with the intensity of 14.14% (45.77 m³/ha) according to the prescription of the management unit plan
Materials and Methods

• Workflow of the wood chips production

- six-wheel harvester Timberjack 1270C (length 7,185 mm, width 2,680 mm, height 3,645 mm, mass 17,500 kg, power 163 kW@2,100 r/min) equipped with Timberjack 758 harvesting head
- eight-wheel FMG 280 ÖSA forwarder (length 9,705 mm, width 2,800 mm, height 3,970 mm, mass 18,000 kg, power 154 kW@2,000 r/min) equipped with hydraulic crane FMG 130 with declared net lifting torque of 110 kNm and the maximum reach of 7.2 m
- forest truck and trailer unit powered by Iveco Trakker 440 (324 kW@1,900 r/min) equipped with hydraulic crane Palfinger E110Z81 with declared net lifting torque of 101 kNm and the maximum reach of 8.1 m
- towed drum chipper Jenz Hem 561 DQ (mass 13,300 kg, power 360 kW, drum diameter 820 mm, screen size opening 35 × 35 mm)
Materials and Methods

• marking of sample trees and DBH measurement
• measurement of produced assortments per tree
• time and motion study – recording of time consumptions by digital camera
• analysis of records provided time consumption of individual work elements precisely divided by fixed points and enabled the establishment of effective time to output relation:
  • effective time of harvester: moving time \( (t_M) \), felling time \( (t_F) \) and processing time \( (t_P) \)
  • felling and processing time was regressed vs. DBH, and moving time was expressed as an average time consumption per tree
  • effective times of other machines were expressed as average consumptions per net volume
  • standard times for all machines were calculated
• machine rates were calculated by a modified FAO method
• produced wood chips were sampled and laboratory analyses were performed in order to determine the product quality (moisture content, particle size distribution and bulk density)
Results

• in total 47 trees were felled and processed into 28.192 m$^3$ of different wood assortments that were extracted in 3 cycles; of that amount all the pulpwood, 10.022 m$^3$, was transported to the terminal and chipped

• harvester productivity

\[
P_h = \frac{60}{f_{all} \times (t_M + t_F + t_P)} \times v_{net} \left[ \frac{m^3}{h} \right]
\]

\[v_{net} = 0.0006 \times DBH^{0.857}
\]

\[R^2 = 0.9326; \; N = 41\]

\[t_F = 0.056 \times e^{0.0419 \times DBH}
\]

\[R^2 = 0.4479; \; N = 40\]

\[t_P = 0.1269 \times e^{0.0487 \times DBH}
\]

\[R^2 = 0.5471; \; N = 40\]

• productivity of the harvester increases from 14.36 m$^3$/h for trees in the DBH class 22.5 cm to 26.29 m$^3$/h for the trees in the DBH class 47.5 cm
Results

• system productivity and costs

<table>
<thead>
<tr>
<th></th>
<th>Harvester</th>
<th>Forwarder</th>
<th>Truck&amp;trailer</th>
<th>Chipper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard time, min/m³</td>
<td>3.04</td>
<td>5.51</td>
<td>4.89</td>
<td>1.33</td>
</tr>
<tr>
<td>Machine rate, €/h</td>
<td>119.82</td>
<td>73.48</td>
<td>41.46</td>
<td>93.93</td>
</tr>
<tr>
<td>Productivity, m³/h</td>
<td>19.74</td>
<td>10.89</td>
<td>12.27</td>
<td>45.11</td>
</tr>
<tr>
<td>Unit cost, €/m³</td>
<td>6.07</td>
<td>6.75</td>
<td>3.38</td>
<td>2.08</td>
</tr>
</tbody>
</table>

• total unit cost of a mechanized wood chips production system was € 18.28/m³ of pulpwood

• wood chip quality
  • according to wood chip quality requirements (HRN EN 14961-1:2010) wood chips produced by the investigated system were classified in the particle size distribution class P16B, moisture content class M55+ (64), and bulk density class BD350
Conclusion

• use of mechanized harvesting system in the researched stand enables the thinning at the average cost of € 12.82 /m³

• additional € 5.46 /m³ are needed to transport and process the pulpwood to wood chips at the terminal

• wood chips produced in this way can be used either directly as a source of energy for heat and/or electricity production or as a raw material for wood pellet production
Thank You for your attention