4th CASEE Conference
"Food and Biomass Production - Basis for a Sustainable Rural Development"

Mechanized wood chips harvesting
in the thinning of the forest culture of Weymouth pine (*Pinus strobus* L.)

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July 1 - 3, 2013, Zagreb, Croatia

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**
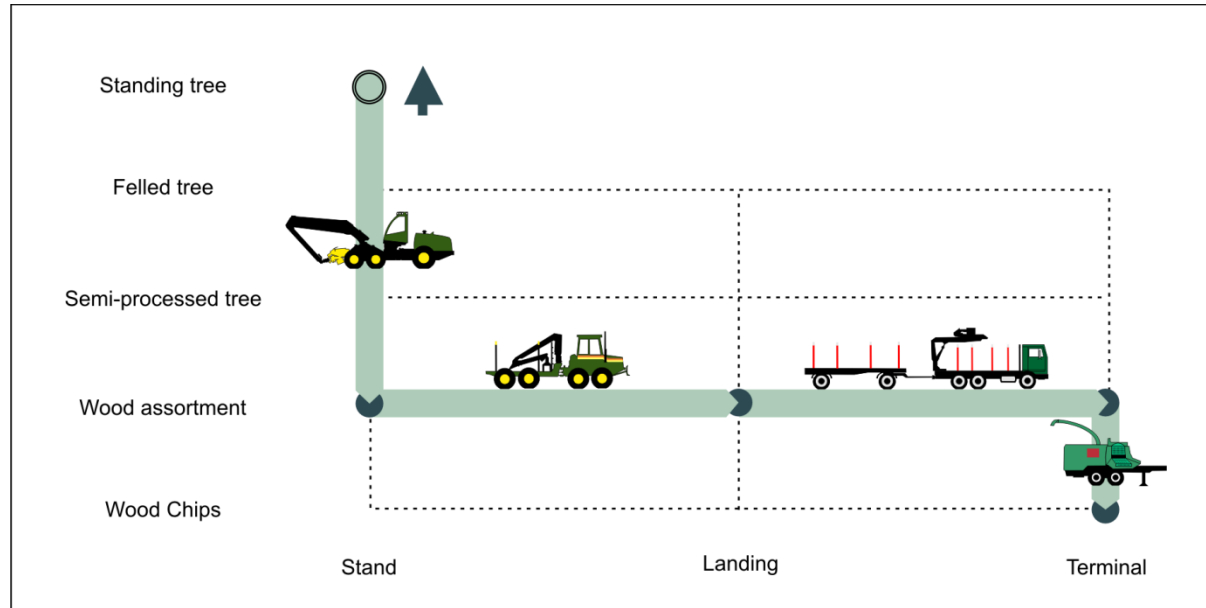
- six-wheel harvester Timberjack 1270C (length 7,185 mm, width 2,680 mm, height 3,645 mm, mass 17,500 kg, power 163 kW@2,100 r/min) equipped with Timberjack 758 harvesting head
- eight-wheel FMG 280 ÖSA forwarder (length 9,705 mm, width 2,800 mm, height 3,970 mm, mass 18,000 kg, power 154 kW@2,000 r/min) 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)
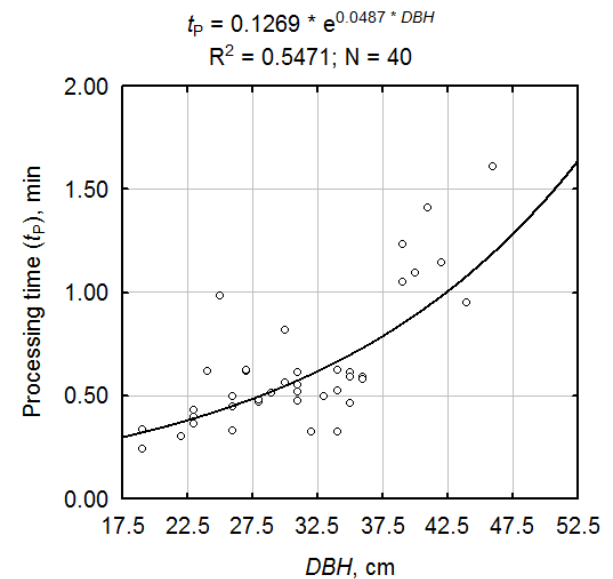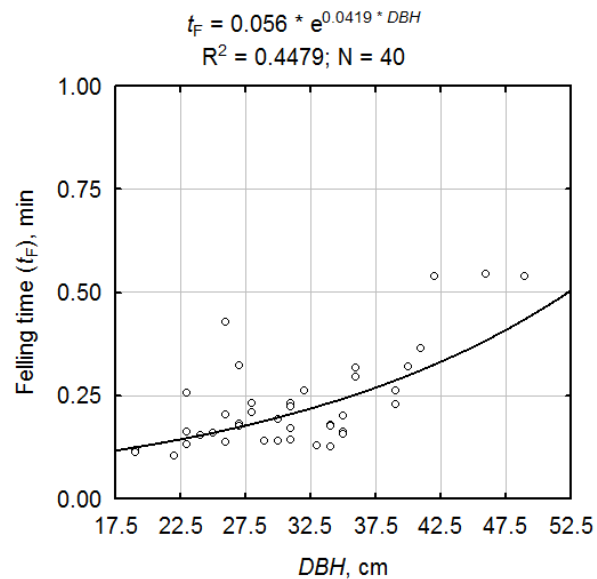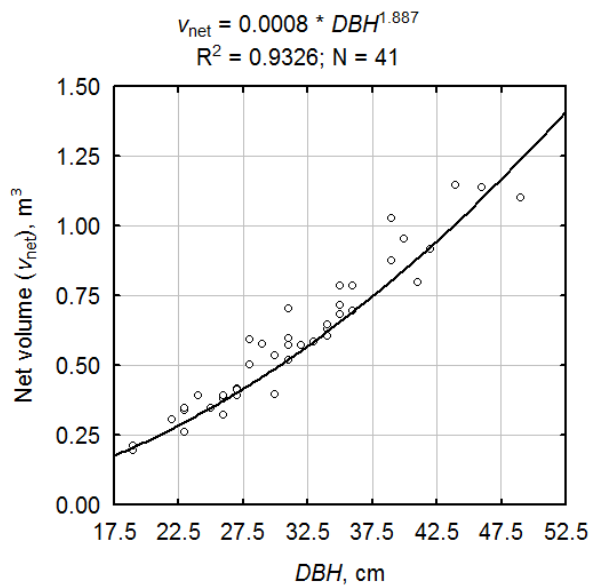
Materials and Methods

- 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)
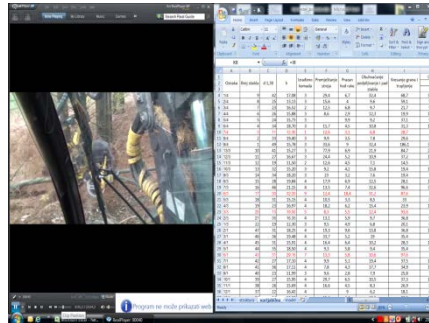
Results

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

$v_{net} = 0.0008 * DBH^{1.887}$
$R^2 = 0.9326; N = 41$

$t_F = 0.056 * e^{0.0419 * DBH}$
$R^2 = 0.4479; N = 40$

$t_P = 0.1269 * e^{0.0487 * DBH}$
$R^2 = 0.5471; N = 40$

- 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**

	Harvester	Forwarder	Truck&trailer	Chipper
Standard time, min/m^3	3.04	5.51	4.89	1.33
Machine rate, €/h	119.82	73.48	41.46	93.93
Productivity, m^3/h	19.74	10.89	12.27	45.11
Unit cost, €/m^3	6.07	6.75	3.38	2.08

- total unit cost of a mechanized wood chips production system was € 18.28/m^3 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