Bulletin of the *Transilvania* University of Braşov, Special Issue
Series II: Forestry • Wood Industry • Agricultural Food Engineering • Vol. 10 (59) No.1 - 2017

COMPARISON OF DIFFERENT SCALING METHODS OF HARVESTER-PROCESSED TIMBER

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Abstract: *Annually, harvester technology in the Czech Republic processes 38% of the wood yield, which represents 6.1 mil m^3. At the same time, there is the open issue on the possibility of electronic scaling and grading of timber from harvesters as the quality of grading must be supported by correct methods of timber scaling in forest stands. The primary aim of this paper was to develop a methodology able to compare the differences between the timber scaling by harvester production-management software and by manual means within the stands. The differences are expected to range from 1.5 to 5% in electronic calculation of timber volume as compared with the "Recommended Rules for the Measurement and Grading of Timber in the Czech Republic".*

Key words: *harvester technology, scaling, assortment.*

1. Introduction

The harvester technology represents an important step forward as, apart from the possibility of harvesting and handling of timber, it offers a major added value, by its "individual" electronic timber scaling, performed along with delimbing and timber handling [2]. This fact would be particularly important for forest management if the outputs of the measurement and control system were accepted by the forest owners. However, with sporadic exceptions, the reality in Czech forest management is quite the opposite. Initial scaling and scaling control of produced assortments are done manually at the roadside landings, as forest owners are suspicious on service providers as well as on to the credibility of harvester data. The Czech Republic still lacks a unified control procedure able to provide a methodological system for measurement control and equipment calibration, as well as the access to such systems for forest owners or representatives of independent organizations to allow them to check the settings of a number of parameters in the measurement and control systems (*e.g.* settings for allowance, bark deductions etc.).

This is due to the ignorance of most forest managers in relation to the harvester measurement and control systems and due

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to an insufficient knowledge on these systems from the part of forest district managers employed by the State Enterprise of Forests from the Czech Republic, which in turn limits the application of an already approved internal regulation into practice [4], as well as the reluctance and inability of forest owners to apply legal mechanisms enabling the entering of third parties into measurement and control systems (*e.g.* by including this provision in work contracts) of harvesters owned by other persons providing harvesting and forwarding services to forest owners.

The above-mentioned issue is a reality even at present, when the ratio of cut-to-length logging in the Czech Republic is estimated at almost 38% [5]. The number of harvesters in the country also remains debatable. The Central Register of Motor Vehicles of the Czech Republic lists 81 vehicles [6], while statistics of the Ministry of Agriculture list a total of 494 machines [5]. Considering the annual timber volume of 4.5 mil m^3 produced by the cut-to-length method, the actual number will probably be somewhere in the middle. The Central Register data are undeniably incomplete, as owners are not obliged to register the harvesters if they are not used on public and private roads. Numbers released by the Ministry of Agriculture, on the other hand, can be considered overrated with respect to the data collection method applied and the real usability of the owned harvesters.

2. Objectives

The aim of the study was to point out differences between the timber volume outputs obtained from harvesters, manual measurements and standing timber grading. The study follows up on research conducted in 2016 [3]. Conclusions of this report will serve as a complementary material for the *"Recommended Rules for Electronic Scaling of Timber in the Czech Republic"*.

3. Material and Methods

The primary task of the study was to verify the proposed methodology in a specific case study prior to launching system data processing from harvesters deployed in various production conditions. Owing to this, an analysis has been conducted at two workplaces so far. The procedure is outlined in the following points.

3.1. Specification of Production Conditions

Planned in advance felling was analysed in forest stands 2A4b and 73A6 managed by the Military Forests and Farms, State Enterprise, the Hořovice division. The research task follows up the results published at the FORMEC 2016 conference. Timber harvesting was done by a John Deere 770D harvester having installed the production-management software TimberMatic 300, version CDM 2.3. Detailed technical parameters can be found on www.deere.com. The field conditions of the forest stand can be classified as terrain type 11, *i.e.* flat bearing terrain without obstacles, with inclination which does not exceed 8%. Only spruce was harvested in the stand. The surveying parameters of the forest stand are shown in Table 1.

3.2. Specification of CTL-Method in the Forest Stand

Cut-to-length logging was done according to the customer specifications, in seven assortments (Table 2).

Table 1

Surveying parameters of the studied forest stands according to the Forest Management Plan

Tree species	Proportion [%]	Mean tree volume [m^3]	Height [m]	Diameter at breast height [cm]	Yield class	Standing volume [m^3/ha]
stand 2A4b						
Spruce	100	0.15	16	16	28/3	243
stand 73A6						
Spruce	100	0.29	20	20	28/3	339

Table 2

Entered production and "price types" for volume calculation

Assortment	Price type	Minimum top diameter [cm]	Nominal log length [m]	Specified quality	Quality class
Round timber	m3toDE	20	4.00	1,2,3,4	III.
Aggregate	m3toDE	12	4.00 / 2.45	1,2,3,4,5	III.
Saw logs (KPZ)	m3toDE	17 (18)	4.00	6	III.
Pole timber	m3toDE	6	2.55	1,2,4	IV.
Mechanical wood pulp	m3fm	8	2.00	1,2,4	IV.
Selection pulpwood	m3toDE	12	2.45	1,2,3,8	V.
Pulpwood	m3fm	5	2.00	1,2,3,4,7	V.
„Waste“	m3fm	4	0.01	1,2,3,4,5,6 7,8	-

The described production encompasses classes III, IV and V of the six classes according to which timber is classified in the Czech Republic [1]. Six assortments were produced in each stand and the production was virtually identical. Only in stand 2A4b pole timber was produced on top of the regular production and mechanical wood pulp was produced in stand 73A6. The last (eighth) assortment is classified as "waste" and represents the harvesting residue which does not conform to the metric requirements of the produced assortments, therefore is left on the ground in the stand. Round timber, aggregate and saw logs are intended for production of sawn timber (classified as quality class III).

The mechanical wood pulp (work term "ROTO") is classified in quality class IV.

According to their qualities, selection pulpwood and pulpwood, are used for production of paper, pulp industry, or as a material for the production of compressed or glued boards (quality class V).

In case of John Deere harvesters, the log parameters are entered in the production-planning software SilviA together with „price matrices" and "price types". Prior to production launching, the respective "price type" must be entered for each assortment, based on which the proposed grading and consequent calculations of the assortment volumes are done. At present, the Standard for Forest Data and Communication (StanForD) includes fourteen "price types" [8]. To calculate the volume of produced assortments, the two following price types are used **m3toDE** and **m3f** [3]. The TimberMatic 300 system has an additional setting for entering every processed trunk and the assortments produced from it in the *.STM format (for those harvesters using the StandForD 2010 system files have the

*.HPR format). The data saving must be setup individually and it does not come preset by the harvester supplier. As a standard, the measurement and control system saves only comprehensive information on the production within a forest stand or a production block as files in *.PRD format (for those harvesters using the StandForD 2010 system the files have a *.THP format) [8].

3.3. Specification of "price types" and method of volume calculation by the measurement and control system

Prior to production launching, the respective "price type" must be entered for each assortment, based on which the proposed grading and consequent calculations of assortment volumes are done. At present, the Standard for Forest Data and Communication (StanForD) includes fourteen "price types" [7]. For calculation purposes of the produced assortment volume the two following price types are used:

- **m3toDE**. The price type was included in the production-planning software following the requirements from Germany. Volume calculations draw on the mid-diameter of the given assortment and nominal log length. The mid-diameter is rounded down to full centimetres and the volume is calculated from this value. The measurement procedure is prescribed by the Decree of the German Federal Ministry for Food, Agriculture and Forests issued in 1969. The assortment is classified based on the minimum top end diameter and entered nominal log length. The same method of volume calculation is required in the Czech Republic [1];
- **m3f**. The volume of whole-stem log or assortment is calculated from the real (non-rounded off) section diameter which is set at a 10-cm interval. The assortment is classified based on the top end diameter and the diameter is measured in mm.

3.4. Method of calculating the assortment volume in accordance with the Recommended Rules for the Measurement and Grading of Timber in the Czech Republic from 2008

Over bark volume calculations according to the "Recommended Rules for the Measurement and Grading of Timber in the Czech Republic 2008" [1] are done according to Equation 1. The mid-diameter is measured in centimetres in the middle of the nominal log length. For mid-diameters over 20 cm, the diameter is measured on two perpendicular directions from which the average is calculated. The decimals are rounded down.

$$V_{bk} = \frac{\pi}{4} * (d_{bk} - 2k)^2 * l * 10^{-4} \qquad (1)$$

where:

V_{bk} is the log volume inside bark (m^3);
d_{bk}- log mid-diameter measured over bark (cm);
l - log length (m);
k - bark thickness (cm).

Bark thickness of the spruce is calculated according to Equation 2:

$$2k = 0{,}57723 + 0{,}006897 * d_{sk}^{1{,}3123} \qquad (2)$$

where:

d_{sk} is the mid-diameter over bark (cm).

4. Results and Discussions

Six assortments of quality classes III and V were produced in the forest stand 2A4b.

696 of the total 3,258 items produced were classified as "waste" and 54 items were not classified in the production-recording software (Table 3). Pole timber represented 37% of produced assortments in the planned in advance felling, which was the highest share. Assortment volume was also calculated in quality class III assortments. For selection pulpwood it was calculated according to the "m3toDE" price type, while for other logs it was calculated according to the "m3fm" price type.

Six assortments of quality classes III and V were produced in the forest stand 73A6. 103 of the total 3,410 produced items were classified as "waste" and 13 items were not classified by the production-management software (Table 3). Pulpwood represented 62% of produced assortments in the planned in advance felling, which was the highest share. Assortment volume was also calculated in quality class III assortments. For selection pulpwood it was calculated according to the "m3toDE" price type, while for other logs it was calculated according to the "m3fm" price type.

The production-management software calculates the volumes separately for each assortment. The total production volume derived from *. STM files according to the entered "price types" was of 69.843 m^3 in the stand 2A4b and of 97.260 m^3 in the stand 73A6. Calculations of timber volume according to the Recommended Rules for the Measurement and Grading of Timber in the Czech Republic from 2008 (hereinafter "recommended rules") [1] estimated the total timber volume at 71.123 and 98.112 m^3 respectively.

Compared to the recommended rules the production management software underestimated the volume of saw logs (round timber, aggregate, saw logs - KPZ) in stand 2A4b by up to 0.45% and by up to 1.1% in stand 73A6. Selection pulpwood was underestimated in both stands by 1.1 and 0.3% respectively.

The harvester's production-management system overestimated the pole timber produced in the first stand by 0.92%.

Table 3

*Produced timber volume according to the harvester operation-recording software (from *. STM files)*

Assortment	**Price type**	**Number [pc]**		**Mean volume of assortment, including bark [m^3/pc]**			
				According to set price type		**Calculation by sections**	
		2A4b	**73A6**	**2A4b**	**73A6**	**2A4b**	**73A6**
Round timber	m3toDE	2	20	0.159	0.167	0.171	0.179
Aggregate	m3toDE	154	622	0.074	0.045	0.082	0.049
Saw logs (KPZ)	m3toDE	12	20	0.147	0.157	0.157	0.175
Pole timber	m3toDE	1208	---	0.018	---	0.018	---
Mechanical wood pulp	m3f	---	29	---	0.016	---	0.016
Selection pulpwood	m3toDE	529	158	0.030	0.052	0.034	0.054
Pulpwood	m3f	607	2445	0.026	0.022	0.026	0.022
Waste	m3f	692	103	0.003	0.003	0.003	0.003
Unclassified	m3f	54	13	0.015	0.197	0.013	0.170
Total	**-**	**3258**	**3410**	**-**	**-**	**-**	**-**

Similarly, pulpwood in the stand 73A6 was overestimated by 0.6% by the production-management system, while in 2A4b, a stand with smaller dimensions of mean stem diameter, the amount of produced pulpwood was electronically underestimated by 0.4%. The total estimation difference between *.STM files and the recommended rules was of - 1.3% in stand 2A4b (Table 4) and -0.9% in stand 73A6 (Table 5). Therefore, the production volume was slightly underestimated by the production-management software.

Compared to the already analysed stand, where the mean stem volume was of 0.72 m^3 [3], we can detect a clear trend towards underestimation by the production management system upon decreasing the mean stem volume and vice versa.

Table 4

Comparison of assortment volume according to selected methods - stand 2A4b

Assortment	**Volume, including bark [m^3]**			**Volume difference between columns (3) and (1), expressed in [m^3], respectively [%]**	
	From *.STM files		**RRMGT 2008 (Huber's formula)**		
	According to set price type	**Calculation by sections**			
	1	2	3	4	5
Round timber	0.318	0.342	0.319	-0.001	-0.313
Aggregate	11.452	12.553	11.902	-0.450	-3.781
Saw logs (KPZ)	1.763	1.884	1.779	-0.016	-0.899
Pole timber	21.842	21.842	20.922	0.920	4.397
Selection pulpwood	15.791	17.645	16.872	-1.081	-6.407
Pulpwood	15.913	15.913	16.306	-0.393	-2.410
Waste	1.961	1.961	2.343	-3.382	-16.304
Unclassified	0.803	0.683	0.68	0.123	18.088
Total	**69.843**	**72.823**	**71.123**	**-1.28**	**-1.800**

Table 5

Comparison of assortment volume according to selected methods - stand 2A4b

Assortment	**Volume, including bark [m^3]**			**Volume difference between columns (3) and (1), expressed in [m^3], respectively [%]**	
	From *.STM files		**RRMGT 2008 (Huber's formula**		
	According to set price type	**Calculation by sections**			
	1	2	3	4	5
Round timber	3.349	3.577	3.368	-0.019	-0.569
Aggregate	27.956	30.180	29.075	-1.119	-3.849
Saw logs (KPZ)	3.137	3.498	3.183	-0.046	-1.445
Pole timber	0.454	0.454	0.441	0.013	2.948
Selection pulpwood	8.207	8.568	8.497	-0.290	-3.413
Pulpwood	53.657	53.657	53.015	0.642	1.211
Waste	0.303	0.303	0.359	-0.056	-15.599
Unclassified	0.197	0.170	0.174	0.023	13.218
Total	**97.260**	**100.407**	**98.112**	**-0.852**	**-0.868**

There is no legal norm in the Czech Republic which would stipulate the maximum allowable deviation from the recommended rules. The acceptable deviation is specified by an internal guideline or by an agreement between the forest owner and the service provider. For the largest forest owner in the country (Forests of the Czech Republic, State Enterprise) the allowable tolerance is 2% [4]. The commonly tolerated deviation is up to 5% of the volume measured and calculated according to the recommended rules.

5. Conclusions

This study presents the results of different methods of calculating the processed timber volume with respect to the set "price type" in harvesters as well as the recommended rules for timber scaling and calculating standing timber volume prior to harvesting. At this point, it must be noted that if we want to use harvester software outputs on the volume of processed timber in the Czech Republic, it is necessary to set clear rules and control systems. This process starts by resetting the key factors, such as the price type, bark thickness, allowance and others, and encompasses the calibration of measurement systems.

The obtained results reveal differences in the outcome of two methods of calculating the same timber volume by the production-management software (the pre-setting for each assortment can be selected from 14 formulas). The difference is primarily related to the manual calculations based on Huber's formula which is required by the recommended rules. When calculating timber volume according to the pre-set price type, the difference in volume was of 1.8% and 0.9% (harvester's data underestimates). With the growing mean stem diameter, the trend reverses [3]. It may be due to the fact that the harvester measures and calculates timber volume with the accuracy of three decimal places, while the manual calculations involve rounding down to a whole number and volume calculation with an accuracy of two decimals. Different methods of bark deductions used by the harvester and in by the manual calculations account for this difference as well. However, differences of up to 5% can be considered operationally acceptable (excepting the requirements of Forests of the Czech Republic, State Enterprise, which are set to a maximum difference of up to 2%).

The future task of grading simulations by a harvester should be to determine whether it would be possible to achieve production of higher quality classes and thus better recover and commercialize the timber. It must be said beforehand that implementation of this objective in harvesting practice will probably always face two major obstacles: requirements of local purchasers of timber and the low volume of produced assortments of quality classes I or II whose production will be ineffective with respect to the consequent transport costs.

Acknowledgements

This paper is supported by the National Agency for Agricultural Research of Czech Republic under the project no. QJ1520005: "*Optimization of cut-to-length logging and grading of harvester-processed timber and proposed control procedures of timber volume measurements accuracy with the objective to enhance the production function of forests and maintain stand stability with respect to harmful agents*."

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