Industrial Round-Wood Losses Associated with Harvesting Systems in Russia

Yuri Gerasimov, Alexander Seliverstov

Abstract – Nacrtak

A field-based study was performed to broaden our knowledge of industrial round-wood (IRW) losses associated with most applicable motor-manual (MM) and fully mechanized (FM) harvesting systems in Russia. Observations were made for five harvesting systems, namely cut-to-length (MM CTL and FM CTL), full-tree (MM FT and FM FT), and tree-length (MM TL), during the felling, skidding/forwarding, processing, sorting, and loading operations. Damage to IRW was examined in 15 logging companies in Karelia. There were about 23 400 measured logs in 17 harvesting sites during summer and winter seasons. The damages detected were broken down into four groups: mechanical damage, processing defects, contamination with dirt, and deviations from the desired log dimensions. The results were then compared with the effective quality requirements in a given logging company, and the IRW volume loss was determined in terms of the reject rate and value loss per unit volume in the context of a harvesting system. Mechanical damage (torn and loosened grain, cuts in stemwood, and gouges made by grapples), processing defects (branches, log end splits and cracks) and contamination with dirt were the most frequent types of damage. The MM CTL and FM CTL systems provided the minimum losses (the reject rate was 2% of observed logs and 0.5–0.6 € per m^3 of total industrial wood). The FT systems resulted in somewhat lower but still acceptable quality (MM: 4% and € 1.1; FM: 3% and € 0.9). The quality of wood harvested with the MM TL system turned out to be the lowest (5 % and € 1.4), especially in the summer season. The total annual losses in IRW value at the companies studied were estimated as 1.0 € per IRW m^3 or € 1.8 million.

Key words: volume loss, value loss, sawlog, pulpwood, pine, spruce, birch, cut-to-length, tree-length, full-tree

1. Introduction – *Uvod*

The use of fully mechanized (FM) systems is increasing in wood harvesting operations globally. The increase in the use of mechanized harvesting systems has led to problems of log damage, including butt pull, log splitting during handling, and bucking and crushing of the log. Damage to a harvested log can occur during the felling, delimbing, bucking, skidding or forwarding, piling, loading, and hauling functions of wood harvesting. Several studies have reported log damages during harvesting operations. Greene and McNeel (1987, 1989) and Faust and Greene (1989) studied log damage by feller-bunchers with shear and saw heads. Volume losses of up to 4.5% were found when using a shear head, while losses of only 0.25% were found when using a saw head. Egan (1999) and Unver and Acar (2009) studied the log damage caused by ground based skidding. The contamination of the logs with dirt was highlighted. Brunberg et al. (2006), Jonsson and Hannrup (2007), and Nuutinen et al. (2010) studied the log damage caused by the harvester. They found that feed rollers equipped with steel spikes caused the greatest damage, leading to a 3% reduction in value.

According to Hamish et al. (2006), on average mechanical log-making systems lose 18% of the potential value compared to 11% for motor-manual (MM) systems. However, Connell (2003) and Spinelli et al. (2010) reported that some mechanized harvesting operations have reduced the incidence of log damage due to mechanical handling. In addition, log damage and value loss associated with tree-length (TL) and full-tree (FT) harvesting systems were reported by Wang et al. (2004). The MM TL system

Table 1 Basic data about conditions for sites and number of measured logs during summer and winter seasons (MM – moto-manual, FM – full mechanized)

Tablica 1. *Osnovni podaci o uvjetima na radilištima te broju izmjerene oblovine tijekom ljetne i zimske sječe (MM – djelomično mehanizirani sustavi, FM – potpuno mehanizirani sustavi)*

Site – *Radilište*	Company – *Poduzeće*	Technology – *Tehnologija rada*			Conditions – *Radni uvjeti*						Total logs sampled, pieces *Ukupan broj trupaca, kom.*					
							Species composition, % *Udio vrsta, %*				Pine *Bor*		Spruce *Smreka*		Birch *Breza*	
		System – *Sustav*	Equipment used *Korištena oprema*	Experience, years *Radno iskustvo, god.*	Season/soil *Godišnje doba/tlo*	Stem volume, m^3 *Obujam stabla*, m^3	Pine – *Bor*	Spruce – *Smreka*	Birch – *Breza*	Other – *Ostalo*	Sawlog – *Trupci*	Pulp-wood – *Celuloza*	Sawlog – *Trupci*	Pulp-wood – *Celuloza*	Sawlog – *Trupci*	Pulp-wood – *Celuloza*
1	7	MM CTL	Husqvarna 254XP John Deere 1110D	7 1	Winter *Zima*	0.257	30	20	50	–	300	300	300	300	300	300
2	8	MM CTL	Husqvarna 254XP John Deere 1110D	12 1	Summer/Clay loam *Ljeto/glinovita ilovača*	0.313	10	30	40	20	300	300	–	–	300	300
3	9	MM CTL	Husqvarna 254XP John Deere 1010D	>5 1	Summer/Clay loam *Ljeto/glinovita ilovača*	0.300	20	20	40	20	–	–	300	300	–	–
4	1	FM CTL	John Deere 1270D John Deere 1410D	2.5 1.5	Winter *Zima*	0.303	40	50	10	–	300	300	300	300	–	300
5	1	FM CTL	John Deere 1270D John Deere 1410D	2,5 0.5	Winter *Zima*	0.130	70	–	30	–	–	–	–	–	–	300
6	3	FM CTL	Volvo EC210BLC Timberjack 1110D	4 3.5	Winter *Zima*	0.356	10	80	10	–	300	300	300	300	–	300
7	5	FM CTL	John Deere 1070D John Deere 1010D	1 1	Summer/Silt loam *Ljeto/praškasta ilovača*	0.328	10	50	20	20	300	–	300	300	–	–
8	5	FM CTL	John Deere 1270D John Deere 1410D	1 0.5	Summer/Silt loam *Ljeto/pjeskovita ilovača*	0.270	60	20	20	–	300	300	300	300	–	300
9	1	FM CTL	Timberjack 1270D Timberjack 1410D	5 2.5	Summer/Silt loam *Ljeto/pjeskovita ilovača*	0.266	40	10	50	–	300	300	300	300	–	300
10	2	FM CTL	Valmet 911.3 Valmet 840.3	1 8	Summer/Clay loam *Ljeto/glinovita ilovača*	0.270	60	20	20	–	300	300	300	–	–	300
11	10	MM TL	Husqvarna 254XP Axe TDT-55A	14 >5 30	Winter *Zima*	0.641	20	30	30	20	300	300	300	300	300	300
12	11	MM TL	Husqvarna 256XP Axe TDT-55A	>5 >5 >5	Summer/Clay loam *Ljeto/glinovita ilovača*	0.267	10	40	30	20	300	300	300	300	300	300
13	12	MM TL	Husqvarna 254XP Husqvarna 254XP TDT-55A	>5 >5 >5	Summer/Clay loam *Ljeto/glinovita ilovača*	0.230	30	10	60	–	300	300	300	300	–	–
14	15	MM FT	Husqvarna 254XP TDT-55A LP-30B PL-1	16 19 16 >5	Winter *Zima*	0.254	50	30	20	–	300	300	300	300	300	300
15	15	MM FT	Husqvarna 254XP TDT-55A LP-30B PL-1	16 19 16 >5	Summer/Clay loam *Ljeto/glinovita ilovača*	0.254	50	30	20	–	300	300	300	300	300	300
16	1	FM FT	Timberjack 850 ML-136 Hitachi Zaxis 230	7 23 5	Winter *Zima*	0.276	50	40	10	–	300	300	300	300	–	300
17	14	FM FT	Timberjack 850 Timberjack 460D Hitachi Zaxis 230LC	3 0.5 5	Summer/Silt loam *Ljeto/pjeskovita ilovača*	0.234	40	50	10	–	300	300	300	300	–	300

with chain-saws and skidders and the FM FT system with feller-bunchers and skidders were studied. Volume losses of up to 6.1% and 1.1% were found and value losses of up to 6.0 US $/m^3 and 1.5 US $/m^3 were found when using MM TL and FM FT systems, respectively. The majority of the value loss was caused during the felling function when using an MM TL system.

The world's best harvesting operations using the modern cut-to-length (CTL) machinery – many of them in Nordic countries – are currently losing 4–5% of the wood value of forests at harvest (Murphy 2005). However, wood harvesting operations in many countries, such as Russia, using a number of different harvesting systems, such as MM FT, FM FT, MM CTL, FM CTL, and MM TL, have shown losses of 11–18% of the wood value at harvest (Marshall et al. 2006). Certainly, the influence of wood quality on industrial round-wood (IRW) value cannot be ignored when comparing different technologies. This is determined by evaluating it in accordance with the quality specifications in the customer contracts as well as other quality requirements. To remain competitive, logging companies should minimize the wood loss at the time of harvest by using a more advanced harvesting technology. The major objective of this study was to identify the major sources of damage to IRW arising from applied harvesting systems in Russia to minimize this damage loss.

2. Methods and data – *Metode i podaci*

The Republic of Karelia was selected as the study region, because its territory is very representative in terms of a wide range of harvesting methods, systems, and equipment used and in terms of nearly all harvesting technologies being employed in different natural conditions typical for northwest Russia. The

Fig. 1 Measurement of logs in MM CTL harvesting (chainsaw + forwarder)
Slika 1. *Izmjera oblovine pri djelomično mehaniziranom pridobivanju drva sortimentnom metodom (motorna pila i forvarder)*

study was performed in 2007–2009 and involved 15 logging companies that provide approximately 35% of the total harvesting volume in Karelia (2.2 million m^3 per year). The selected companies perform harvesting operations across the whole territory of Karelia in different conditions and apply MM CTL, FM CTL, MM FT, FM FT, and MM TL harvesting systems using both Russian and foreign machinery (Gerasimov and Sokolov 2009).

A common approach was used for field data collection directly at harvesting sites in the actual working conditions (Table 1). The harvested stands were not managed or thinned before the final felling. A typical study stand was mixed in terms of tree age and species. The tree species composition included spruce (31% on average), pine (35%), birch (28%), and aspen (6%). The average stem volumes of the harvesting sites varied between 0.13 and 0.64 m^3 with the average value 0.29 m^3. The average growing stock of stands in the studied regions was 150 m^3 per ha with tree density of approximately 520 trees per ha. The typical soils in the test areas were silt loam, clay loam, and sandy loam. The harvesting sites were on flat terrain.

According to the methodology used, the required number of logs to be measured equals 300 both for each species and for each assortment per harvesting site separately in the winter and summer seasons. The total number of observed logs was 23 400, and the number of observed harvesting sites was 17 including 7 in winter and 10 in summer (Table 1).

All the measurement results were registered on checklists using a data collector. In CTL harvesting systems, the logs were measured at the felling site and at the road-site landing (Fig. 1 and 2).

In TL harvesting, the logs were measured both at the felling site before skidding and at the road-site landing after skidding and piling. In addition, the logs were measured at the bucking and sorting line of the central processing yard (Fig. 3).

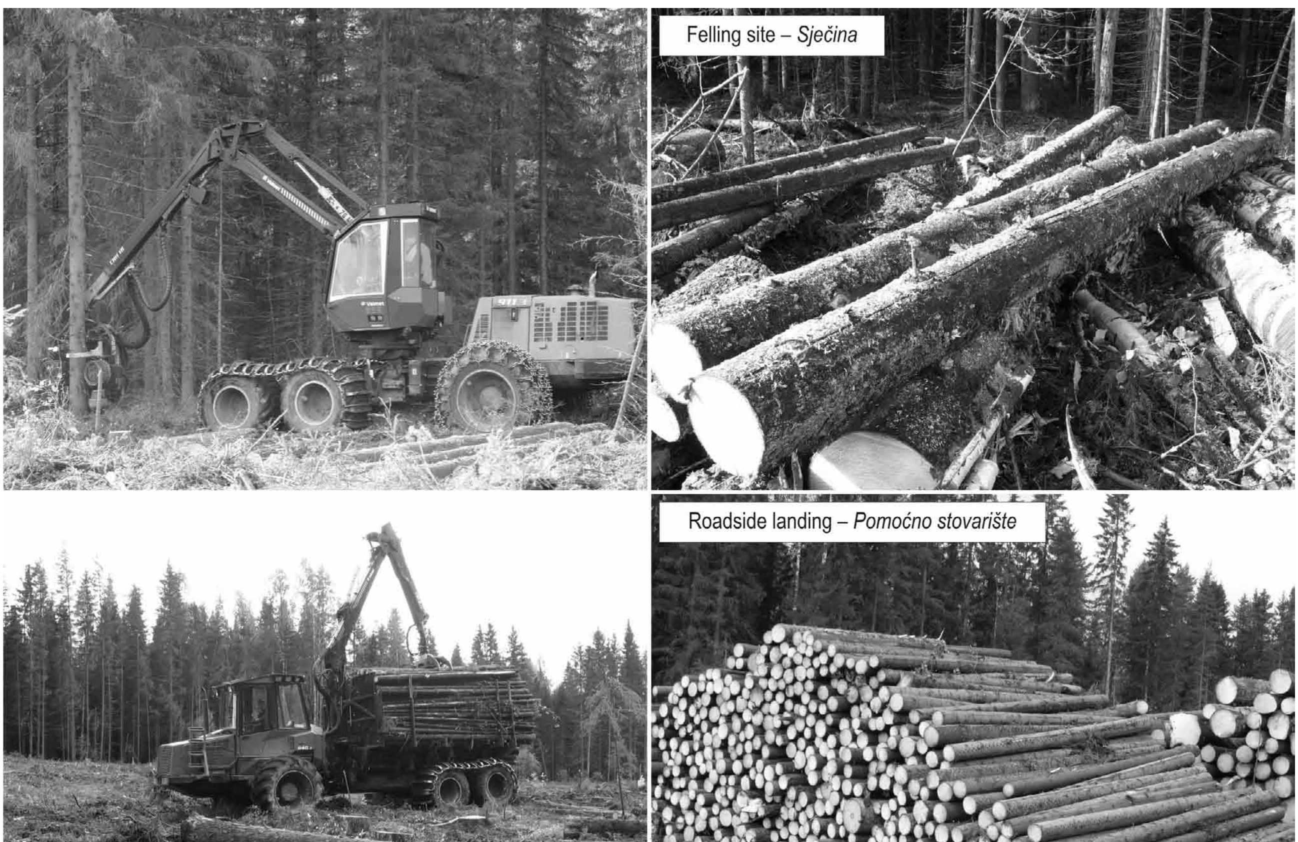

Fig. 2 Measurement of logs in FM CTL harvesting (harvester + forwarder)
Slika 2. *Izmjera oblovine pri potpuno mehaniziranom pridobivanju drva sortimentnom metodom (harvester i forvarder)*

Fig. 3 Measurements during MM TL (chainsaw + skidder)
Slika 3. *Izmjera pri djelomično mehaniziranom pridobivanju drva deblovnom metodom (motorna pila i skider)*

In FT harvesting, the logs were measured at the road-site landing and logs at the cross-cutting and sorting line of the central processing yard (Fig. 4 and 5).

The IRW damage evaluation was based on a number of damage indicators, which are regulated by relevant national standards and forest industry specifications, as follows (Fig. 6).

⇒ mechanical damage, which occurs during skidding, sorting, piling, and transportation of timber; there are the following types of damage: torn and loosened grain, barked stem, cuts (damage by chainsaw, skidder cable), and gouges made by grapples,

⇒ processing defects, including unprocessed branches and defects caused by improper tree-felling and cross-cutting, namely: log end (butt and top) splits, cracks, log splitting, and snipes,

⇒ contamination with dirt,

⇒ deviation of IRW dimensions, including log-length allowances and tolerances, as well as the grades and the maximum butt and minimum top diameters of assortments.

The results were then compared with the effective quality requirements in a given logging company and the percentage of rejected logs was determined. The obtained estimates for all the measured parameters were integrated into one indicator – the so-called reject rate.

The quality requirements for IRW of various species, grades, and end-uses (sawlog, pulpwood, etc.) were determined in the contract between the logging company and the IRW buyer, that is, in the technical specifications. The specifications include the following: tree species, harvesting schedule, dimensions, requirements for processing and quality requirements, such as compliance with relevant na-

Fig. 4 Measurements during MM FT (chainsaw + skidder + delimber)
Slika 4. *Izmjera pri djelomično mehaniziranom pridobivanju drva stablovnom metodom (motorna pila, skider, procesor)*

tional standards, for example the national technical specifications for export (TU 13-2-12-96, TU 13-2-1-95), the national standards for the domestic market (GOST 9462-88, GOST 9463-88), or other technical specifications used in trade contracts, or by using internal log quality specifications of the given logging company in the case where the logs were to be used within the company. Where contamination of dirt was not acceptable according to the contractual specifications, logs were rejected if more than 15% of the log side surface area or 50% of the log end was contaminated. Logging companies also develop their own additional specifications for grading and piling logs, defining the length and diameter of piles, as well as the most preferable log length. Quality requirements of the measured logs of various species and end-uses are shown in Tables 2 and 3.

If a log complies with both the quality and dimension requirements, it is accepted. If a log does not comply with the above-mentioned requirements, it is rejected or transferred to another grade according to its quality: sawlog to pulpwood, pulpwood to fuel wood.

The IRW damage was analysed in terms of value losses. The losses in IRW value in the context of a logging company and a harvesting system were estimated as follows:

$$
\begin{aligned}
L = {} & R_{psl} \times P_{psl}(C_{psl} - C_{ppw} - C') + \\
& + R_{ssl} \times P_{ssl} \times (C_{ssl} - C_{spw} - C') + \\
& + R_{bsl} \times P_{bsl} \times (C_{bsl} - C_{pbw} - C') + \\
& + R_{ppw} \times P_{psl} \times (C_{ppw} - C_{pfw} - C') + \\
& + R_{spw} \times P_{spw} \times (C_{spw} - C_{sfw} - C') + \\
& + R_{pbw} \times P_{bpw} \times (C_{pbw} - C_{bfw} - C')
\end{aligned}
$$

Where:

- L value losses due to IRW damage at harvest, €/m^3
- R average reject rate of the IRW assortment

P proportion of the assortment production in the total volume of industrial wood at the given logging company

C average EXW (ex works) price of the IRW assortment at the road-site or central processing yard, €/m^3

C′ additional expenses associated with load, unload and transport of rejected wood, €/m^3

psl, ssl, bsl indexes for pine, spruce, and birch sawlogs

ppw, spw, bpw indexes for pine, spruce, and birch pulpwood

fw index for fuel wood

A log pricing system was developed based on IRW market prices from the Karelia timber market reports (Timber Prices 2010). A monetary value was assigned to the IRW based on its tree species, assortment, and delivery terms.

3. Results – *Rezultati*

To summarize, Table 4 shows the distribution of reject rates by assortment in 17 studied harvesting sites.

The results include all harvesting systems and apply to both the winter and summer seasons. A rejected log sometime had two or more types of damages. In that case the log was rejected with several reasons. The difference between results in Table 4 and Tables 5 – 7 (original tables by damage type for coniferous sawlogs, birch veneer logs, and pulpwood) shows a common fact that a rejected log had more than one type of damage.

The MM TL system caused the highest reject rate both for sawlogs (7% of observed logs in winter and 9–10% in summer) and for pulpwood (3% in winter and 7–8% in summer). The lowest reject rate for sawlogs was provided by the FM CTL system (3%). The

Fig. 5 Measurements during FM FT harvesting (feller buncher + skidder + delimber)
Slika 5. *Izmjera pri potpuno mehaniziranom pridobivanju drva stablovnom metodom (feller buncher, skider, procesor)*

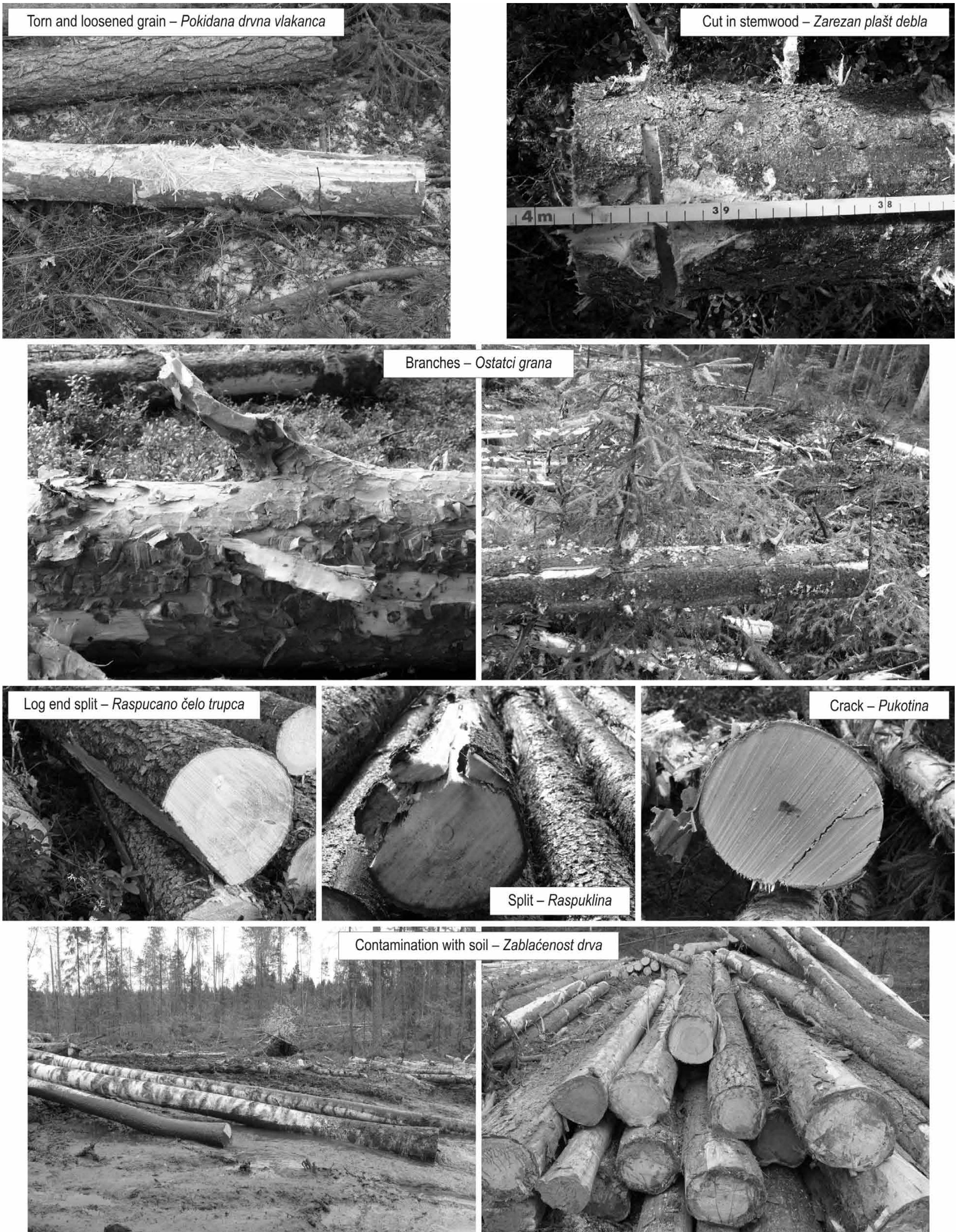

Fig. 6 Typical IRW damages regulated by relevant national standards and log quality specifications
Slika 6. *Tipična oštećenja oblovine propisana važećim nacionalnim normama*

Table 2 Quality requirements for saw and veneer logs in domestic and export markets

Tablica 2. *Zahtijevi za kakvoćom pilanskih i furnirskih trupaca za domaće i inozemno tržište*

Damage type *Vrsta oštećenja*	Sawlogs – *Pilanski trupci*				Birch veneer logs *Brezovi furnirski trupci*
	Pine – *Bor*		Spruce – *Smreka*		
	Export *Izvoz*	Domestic *Domaće tržište*	Export *Izvoz*	Domestic *Domaće tržište*	Export *Izvoz*
1. Mechanical damage – *Mehanička oštećenja*	TU 13-2-12-96 Not acceptable 🗐 *Nije prihvatljivo* 🗐	GOST 9463-88	TU 13-2-12-96 Not acceptable 🗐 *Nije prihvatljivo* 🗐	GOST 9463-88	TU 13-2-8-96
2. Processing defects – *Greške pri izradbi drva*					
Branches *Ostatci grana*	TU 13-2-12-96 *l* < 10/20 mm 🗐 *d* <50/60 mm 🗐	GOST 9463-88	TU 13-2-12-96 *l* < 10 mm 🗐 *d* <50 mm 🗐	GOST 9463-88	TU 13-2-8-96
Log end splits, cracks *Raspucano čelo, pukotine*	Not acceptable 🗐 *Nije prihvatljivo* 🗐	GOST 9463-88	Not acceptable 🗐 *Nije prihvatljivo* 🗐	GOST 9463-88	TU 13-2-8-96
Log end splinters *Raspukline*	Not acceptable 🗐 *Nije prihvatljivo* 🗐	Not acceptable 🗐 *Nije prihvatljivo* 🗐	Not acceptable 🗐 *Nije prihvatljivo* 🗐	Not acceptable 🗐 *Nije prihvatljivo* 🗐	Not acceptable 🗐
Butt trimming *Obrada čela*	Not acceptable 🗐 *Nije prihvatljivo* 🗐	GOST 9463-88	Not acceptable 🗐 *Nije prihvatljivo* 🗐	GOST 9463-88	TU 13-2-8-96
3. Contamination with dirt – Zablaćenost drva	Not acceptable 🗐 *Nije prihvatljivo* 🗐	Not acceptable 🗐 *Nije prihvatljivo* 🗐	Not acceptable 🗐 *Nije prihvatljivo* 🗐	Not acceptable 🗐 *Nije prihvatljivo* 🗐	Not acceptable 🗐 *Nije prihvatljivo* 🗐
4. Dimension non-compliance – *Neodgovarajuće dimenzije*					
Length, m (allowance, cm) *Duljina*, m (*nadmjera*, cm)	4.9; 5.5 (0 / +6) 4.0 (0 / +6) 4.3; 4.6; 6.1 (+5 / +8)	5.0; 5.5; 6.0; 6.1 (0 / +10) 6.1; 4.0; 3.1 (+3 / +5) additional – *dodatno* 4.0; 4.3 (+3 / +10)	5.5 (+3 /+6) 5.5 (0 / +6) 4.05 (0 / +6)	5.0; 5.5; 6.0; 6.1 (0 /+10) additional – *dodatno* 4.0; 4.3; 5.2 (+3 /+10)	3.3; 6.0 (0 / +10) 4.4; 5.0 (0 / +5) 3.3 (0 / +5)
Maximum diameter of the butt end without bark, cm *Najveći promjer na debljem kraju bez kore*, cm	55.0* 34.0	75 42.0*	55.0* 40.0* 14.9	75 52.0* 36.0 56.0	65.0* 55.0* 50.0*
Minimum diameter of the butt end without bark, cm *Najmanji promjer na debljem kraju bez kore*, cm	18.0* 15.0 15.0*	16.0 14.0 11.0	18.0* 17.0* 16.0* 12.0	16.0 14.0	25* 18.0*

🗐 – Quality requirements in contractual specifications – *Ugovorni zahtjev za kakvoćom drva*

* – Diameter over bark – *Promjer s korom*

l – Max. acceptable branch length – *Najveća prihvatljiva duljina čaprlja (grane)*

d – branch diameter – *promjer grane*

lowest reject rate for pulpwood (2%) was registered with the MM CTL system (Table 4).

The study of the quality of IRW harvested with the MM CTL system demonstrated that log end splits and cracks (up to 3% of observed logs), as well as cuts by chainsaws and gouges by forwarders' grapples during loading operations (up to 2%), were the most common types of processing defects (Tables 5-7). The reject rate was about 5% in winter and 4% in summer for coniferous sawlogs and about 1% for pulpwood regardless of the harvesting season (Table 4).

The FM CTL system, in both winter and summer, was mostly associated with the following types of defects (Tables 5 and 7): unprocessed branches (2% of observed logs), log end splits and cracks during felling and bucking (2%), and log surface damage. The latter appeared in the form of damage by delimbing and feeding mechanisms of the harvester head during delimbing, that is, torn and loosened grain (2%). This damage was accompanied by barked stems or even lost layers of stemwood. Logs damaged by harvester head saws (cuts) or forwarders' grapples were rare (about 1%).

Table 3 Pulpwood quality requirements for domestic and export markets

Tablica 3. *Zahtjevi za kakvoćom celuloznoga drva za domaće i inozemno tržište*

Damage type *Vrsta oštećenja*	Pine – *Bor*		Spruce – *Smreka*		Birch – *Breza*
	Export *Izvoz*	Domestic *Domaće tržište*	Export *Izvoz*	Domestic *Domaće tržište*	Export *Izvoz*
1. Processing defects (branches) – *Greške pri izradbi (grane)*	GOST 9463-88; TU 13-2-10-96	GOST 9463-88	GOST 9463-88; TU 13-2-10-96	GOST 9463-88; TU 13-2-10-96	TU 13-2-1-95; TU 13-2-10-96; TU 13-2-11-96. *l* <20mm 🗐
2. Contamination with dirt – Zablaćenost drva	Not acceptable 🗐 *Nije prihvatljivo* 🗐	Not acceptable 🗐 *Nije prihvatljivo* 🗐	Not acceptable 🗐 *Nije prihvatljivo* 🗐	GOST 9463-88; TU 13-2-10-96	Not acceptable 🗐 *Nije prihvatljivo* 🗐
3. Size non-compliance – *Neodgovarajuće dimenzije*					
Length, m (allowance, cm) *Duljina*, m (*nadmjera*, cm)	3.0; 4.0; 6.0 (0 / +10)	3.0–6.0 (–20 / +20)	3.0; 4.8. 6.0 (0 / +10)	2.4; 3.6; 4.8; 6.0 (–5/+15); 4.0; 5.5 (–5/+15); 1.2 (–2 /+ 2); 2.4 (–2 /+ 2); 3.6 and 4.8 (–15 / 15); 4.0 and 5.5 (–10 / +10); 2.4 and 3.6 (+3 / +5)	4.0; 5.5 (0 / +10); 3.0; 4.0; 6.0 (–10 / +10)
Maximum diameter of the butt end without bark, cm *Najveći promjer na debljem kraju bez kore*, cm	60.0	40.0	40.0	60.0; 50.0; 36.0	60.0
Minimum diameter of the butt end without bark, cm *Najmanji promjer na debljem kraju bez kore*, cm	8.0; 6.0	6.0	8.0*	16.0; 6.0	16.0; 6.0

🗐 – Quality requirements in contractual specifications – *Ugovorni zahtjev za kakvoćom drva*

* – Diameter over bark – *Promjer s korom*

l – Max. acceptable branch length – *Najveća prihvatljiva duljina čaprlja (grane)*

Table 4 Reject rates of round-wood (% of observed logs) at the studied harvesting sites by harvesting system and season

Tablica 4. *Stopa odbacivanja oblovine (% od oblovine uzorka) na istraživanim radilištima s obzirom na sustav pridobivanja drva i sezonu radova*

System *Sustav*	Pine sawlog *Borovi trupci*		Spruce sawlog *Smrekovi trupci*		Pine pulpwood *Borova celuloza*		Spruce pulpwood *Smrekova celuloza*		Birch veneer logs *Brezovi furnirski trupci*		Birch pulpwood *Brezova celuloza*	
	Winter *Zima*	Summer *Ljeto*	Winter *Zima*	Summer *Ljeto*	Winter *Zima*	Summer *Ljeto*	Winter *Zima*	Summer *Ljeto*	Winter *Zima*	Summer *Ljeto*	Winter *Zima*	Summer *Ljeto*
MM CTL	4.0	3.7	5.3	4.0	1.0	1.3	1.0	1.3	2.7	3.0	1.7	1.3
FM CTL	2.7	3.3	3.0	3.3	2.0	2.0	1.7	1.7	n/a	n/a	2.0	2.1
MM TL	7.3	9.0	7.0	10.3	2.7	8.3	2.7	8.0	6	8.3	2.3	7.3
MM FT	4.7	7.7	6.3	7.3	2.1	6.0	1.8	6.3	3.3	7.0	1.7	5.0
FM FT	5.3	5.0	5.0	5.3	2.3	2.0	2.7	2.3	n/a	n/a	2.3	2.3

When harvester operators followed all work requirements and instructions, the reject rate was less than 3% for coniferous sawlogs harvested with the FM CTL system, and less than 2% for coniferous pulpwood, regardless of the season. The FM CTL system also ensured efficient cross-cutting of the stems with the required length allowance, normally +(0–4) cm, which maximized the amount of received IRW assortments, unlike the MM CTL system, where the allowance was mostly +(5–10) cm.

For the MM TL and MM FT systems, regardless of the season, the following types of damage were typical (Tables 5-7): torn and loosened grain (2–3% of observed logs) and cuts in stemwood and gouges made by grapples (2–3%). Less frequent were unprocessed branches (1%) and log end splits and cracks

Table 5 Losses of coniferous sawlogs volume (% of observed logs) at the studied harvesting sites by harvesting system and damage type (PSL – pine, SSL – spruce)

Tablica 5. *Gubitci obujma pilanskih trupaca četinjača (% od oblovine uzorka) na istraživanima radilištima s obzirom na sustav pridobivanja drva i vrstu oštećenja (PSL – bor, SSL – smreka)*

System *Sustav*	Mechanical damage – *Mehanička oštećenja*								Processing defect – *Greške pri izradbi drva*								Contamination with dirt *Zablaćenost drva*	
	Torn *Pokidana drvna vlakanca*				Cuts, gouges *Zarezan plašt, odlupljeno drvo*				Unprocessed branches *Neokresane grane*				Splits, cracks *Raspukline, pukotine*					
	Winter *Zima*		Summer *Ljeto*		Winter *Zima*		Summer *Ljeto*		Winter *Zima*		Summer *Ljeto*		Winter *Zima*		Summer *Ljeto*		Summer *Ljeto*	
	PSL	SSL	PSL	SSL	PSL	SSL	PSL	SSL	PSL	SSL	PSL	SSL	PSL	SSL	PSL	SSL	PSL	SSL
MM CTL	2.0	2.3	0	0	0	0	1.7	2.0	0	0	0	0	2.3	2.7	2.0	1.3	0	0
FM CTL	0.7	0.7	1.5	1.7	1.3	1.7	1.0	1.0	1.7	2.1	1.7	1.7	1.7	2.1	1.5	1.7	0	0
MM TL	2.0	2.7	2.7	3.0	2.3	2.7	2.0	2.1	0.9	1.0	1.1	1.3	1.0	0.9	1.0	1.3	8.1	7.3
MM FT	2.0	2.7	2.0	2.7	2.3	2.0	1.7	1.7	1.0	1.3	1.1	1.3	1.0	1.1	1.3	1.0	5.0	4.3
FM FT	3.0	3.1	1.7	1.3	1.3	1.7	1.3	1.3	1.3	1.3	1.3	1.7	2.1	1.9	1.7	1.3	0	0

Table 6 Losses of birch veneer logs volume (% of observed logs) at the studied harvesting sites by harvesting system and damage type

Tablica 6. *Gubitci obujma brezovih furnirskih trupaca (% od oblovine uzorka) na istraživanim radilištima s obzirom na sustav pridobivanja drva i vrstu oštećenja*

System *Sustav*	Mechanical damage – *Mehanička oštećenja*				Processing defect – *Greške pri izradbi drva*				Contamination with dirt *Zablaćenost drva*
	Torn *Pokidana drvna vlakanca*		Cuts, gouges *Zarezan plašt, odlupljeno drvo*		Unprocessed branches *Neokresane grane*		Splits, cracks *Raspukline, pukotine*		
	Winter *Zima*	Summer *Ljeto*	Winter *Zima*	Summer *Ljeto r*	Winter *Zima*	Summer *Ljeto*	Winter *Zima*	Summer *Ljeto*	Summer *Ljeto*
MM CTL	0	0	1.8	1.7	0	0	1.7	1.7	0
MM TL	2.7	3.0	2.7	2.0	1.0	1.1	1.1	1.3	8.3
MM FT	1.7	1.7	2.3	2.0	1.3	1.3	1	1.3	6.0

Table 7 Losses of pulpwood volume (% of observed logs) at the studied harvesting sites by harvesting system and damage type (PPW – pine, SPW – spruce, BPW – birch)

Tablica 7. *Gubitci obujma drva za celulozu (% od oblovine uzorka) na istraživanim radilištima s obzirom na sustav pridobivanja drva i vrstu oštećenja (PPW – bor, SPW – smreka, BPW – breza)*

System *Sustav*	Unprocessed branches – *Neokresane grane*						Contamination with dirt – *Zablaćenost drva*		
	Winter – *Zima*			Summer – *Ljeto*			Summer – *Ljeto*		
	PPW	SPW	BPW	PPW	SPW	BPW	PPW	SPW	BPW
MM CTL	0.7	0.7	0.7	0.7	0.7	1.0	0	0	0
FM CTL	1.7	1.3	1.7	1.7	1.7	2.0	0	0	0
MM TL	0.9	1.0	0.9	1.0	1.3	1.0	9.1	8.3	8.0
MM FT	1.0	1.0	0.7	1.0	0.9	0.9	5.0	5.7	4.0
FM FT	1.3	1.7	1.3	1.3	1.7	1.7	0	0	0

(1%). In summer, contamination with dirt was also found (up to 9% for the MM TL and 6% for the MM FT). For spruce and pine sawlogs, the following reject rates were registered (Table 4): 6–7% for spruce and 5–7% for pine in winter, and 7–10% for spruce and 8–9% for pine in summer. The maximum reject rate was registered for the sawlogs intended for the export market. For birch pulpwood, this figure reached 2% in winter and up to 7% for the tree-length system and 5% for the MM FT system in summer. For

Table 8 Losses of industrial round-wood volume and value at the studied companies by harvesting system
Tablica 8. *Gubitci obujma i vrijednosti obloga drva za istraživana poduzeća s obzirom na sustave pridobivanja drva*

System *Sustav*	Company *Poduzeće*	Annual harvest – *Godišnji etat*, 1000 m^3			Volume loss *Gubitak obujma*		Value loss *Gubitak vrijednosti*	
		Total *Ukupno*	Fuel round-wood *Ogrjevno drvo*	Industrial round-wood *Tehnička oblovina*	%	1000 m^3	€/m^3	1000 €
MM CTL	2, 3, 7, 8, 9	363.0	56.2	306.8	1.8	5.64	0.51	156.6
FM CTL	1, 2, 3, 4, 5,6	503.0	64.8	438.2	2.3	9.98	0.65	286.2
MM TL	1, 5, 10, 11, 12 13, 14	935.4	155.6	779.8	5.0	39.14	1.38	1074.9
MM FT	15	67.1	6.7	60.4	4.2	2.52	1.04	62.7
FM FT	1, 14	318.2	31.8	286.4	3.3	9.56	0.86	247.4
Total *Ukupno*		2186.7	315.1	1871.6	3.6	66.84	0.98	1827.8

pine and spruce pulpwood, the reject rates were up to 3% and 2% in winter, respectively, and 3% in summer.

FM FT harvesting in both winter and summer was mostly associated with the following types of timber defects (Tables 5 and 7): cuts in stemwood and gouges made by grapples (2% of observed logs), log end splits and cracks (2%), torn and loosened grain (2–3%), and unprocessed branches (2%). The reject rate for spruce and pine sawlogs (Table 4) was about 5%, regardless of the season. For birch, pine, and spruce pulpwood, this figure was about 3% in winter and up to 2% in summer.

The seasonality of harvesting operations has a negative impact on the quality of harvested wood; this pertains to the MM CTL, MM TL, and MM FT systems.

In 15 studied companies, volume losses of IRW (in terms of the reject rate as a percentage of total IRW on average per year) were found by harvesting system as follows: MM CTL: 1.8%; FT CTL: 2.3%; MM TL: 5.0%; MM FT: 4.2%; and FM FT: 3.3% (Table 8).

The total average volume loss of IRW in the studied companies was 3.6% or around 67 000 m^3 of IRW per year. Value losses of IRW (in terms of value loss per unit volume of IRW) were found by harvesting system as follows: MM CTL: € 0.51; FT CTL: € 0.65; MM TL: € 1.38; MM FT: € 1.04; and FM FT: € 0.86. The total average value loss of IRW in the studied companies was € 0.98 per m^3 of IRW or around € 1.8 million per year.

4. Conclusion and recommendations –*Zaključci i preporuke*

The analysis of the obtained results indicates that CTL harvesting can ensure the highest quality of harvested wood (reject rate below 3% of observed logs) in all the studied companies, with different species composition. The FT harvesting systems demonstrated acceptable IRW quality (reject rate about 3–5%). The quality of wood in TL harvesting was low (reject rate over 6%), particularly in summer (reject rate up to 10%).

Over 50% of the harvesting sites in Russia are on wet and soft soil terrain and the proportion of sandy soils is small in Russian forests in comparison with loams and clays (Gerasimov and Katarov 2010). The MM TL system causes the highest reject rate due to the fact that debranched tree-length logs are bunched and skidded by a cable skidder in this type of terrain, which leads to contamination with dirt and other damages. The MM FT has the same reason for high reject rate, particularly in summer season, but branches in some extend protect stemwood from damages. The FM FT is largely free from this disadvantage due to bunching by a feller-buncher and skidding by a grapple skidder. Regardless of the season, the CTL systems show the lowest rejection rate due to using forwarding (round-wood is carried out on a trailer) instead of skidding (logs are dragged out of the forest over soft soils). Therefore, the selection of the harvesting system has to be adapted to the most common soil terrains in order to reduce wood losses.

Mechanical damage (torn and loosened grain, cuts in stemwood, and gouges made by grapples), processing defects (branches, log end splits and cracks), and contamination with dirt were the most frequent types of damage. On the whole, damage to IRW in terms of volume loss did not differ much from what is obtained with FT systems in the USA (Wang et al. 2004) and CTL systems in Finland and Russia (Eronen et al. 2000, Syunev and Seliverstov 2006).

Certainly, the improvement of harvesting operations is needed for the reduction of IRW losses even in the same harvest system. Loggers (operators and lumberjacks) need to pay more attention to value, rather than volume alone: this could be accomplished by the development of a payment system and harvesting instructions for utilizing the forest resources better by not damaging valuable logs. The seasonality could be taken into account: the reject rate is higher for the MM CTL system in winter and for MM TL and MM FT systems in summer. Bed logs under piles should be used for IRW piling at roadsite landings, depending on the dirt conditions. Operators need to perform the maintenance of harvesting machines properly (e.g. adjustment of the delimbing and feeding mechanisms of harvester heads, sharpening the delimbing knives, cleaning the rollers to remove bark and timber residue, etc.). A harvester head must match both the base machine and the site conditions (species composition, tree size). The development of new guidelines and corresponding training to minimize IRW damage occurring during wood harvesting are needed as well (Syunev et al. 2008). However, prior to specializing in operating sophisticated machines, as a harvester, a forwarder, and a feller-buncher, an operator is required to have a relevant vocational education.

The potential improvement of rejection rate was roughly estimated from the best practices in the studied logging companies in comparison with the common practices. If all the discovered shortcomings typical for FM CTL and FM FT harvesting were eliminated, it should be possible to decrease the reject rates by approximately 20% and 25%, respectively. It should be noted that bucking optimization of the FM CTL harvesting system allows an increase in the amount of received IRW assortments. Improvements made to the MM CTL system would enable the reject rate to be reduced by approximately 15%. In MM TL and MM FT, the potential reductions in the amount of damaged logs could reach 20% and 15%, respectively.

The IRW damage in terms of value loss per unit volume in the studied companies may not seem important. This is especially true when looking at the lack of difference between FM CTL and MM CTL systems. However, the switch from the traditional motor-manual TL to CTL gives an average savings value of € 0.8 per m^3 of industrial wood, or around € 100 000 per year for an average size logging company. With the initial investment cost in CTL machines of several hundred thousand euros (a forwarder costs over € 200 000, a harvester over € 300 000), the switch from motor-manual TL and FT systems to an FM CTL system might be worth it in the long run, but the switch to an MM CTL system might be justified in the medium run. Additional analysis is needed before the system selection is made, taking into account that the efficiency of a particular harvesting system depends on a number of criteria. The economic benefits, which are the most applicable in practice, are evaluated by productivity and costs (Adebayo et al. 2007, Konovalov and Seliverstov 2008). Special attention has been paid to comfortable and safe working conditions in felling operations. This will make harvesting work more attractive to young people and employment in a logging company more desired (Gerasimov and Sokolov 2009). Environmental criteria and terrain conditions include dirt damage, damage to undergrowth or remaining trees, and so on (Syunev et al. 2009).

This study has been focused on various quality requirements and wood harvesting practices at the logging companies in Karelia. This fact might limit the application of obtained results in other regions in Russia. Moreover, further research is needed to determine the influence of different quality requirements (for the domestic market, export, individual customers) and bucking on IRW volume and value losses. Improper bucking might not damage the log in a physical sense, but could damage the potential value gained from bucking correctly (Wang at al. 2004, Marshall et al. 2006). Taking into account natural and production conditions in Russia, it is necessary to improve the design of the harvester head delimbing and feeding mechanism, in order to ensure its higher efficiency in the processing of trees with crooked trunks and tapering of large branches of deciduous trees. More in-depth analysis of birch veneer log degradation in fully mechanized CTL and FT systems is also needed due to substantial increases in the demand for veneer products.

Acknowledgements – *Zahvala*

The work was carried out for the project »Wood Harvesting and Logistics», financed by the European Union through the Finnish Funding Agency for Technology and Innovation (TEKES), and for the project »Comparison of Wood Harvesting Methods in the Republic of Karelia», funded by the EU-Russia programme »Euregio Karelia Neighbourhood«.

5. References – *Literatura*

Adebayo, A. B., Han, H., Johnson, L., 2007: Productivity and cost of cut-to-length and whole-tree harvesting in a mixed-conifer stand. Forest Products Journal 57(6): 59–69.

Brunberg, T., Hofsten, H., Jonsson, M. 2006: Kartlägging och värdering av dubbskador (Stud damage to logs – research and evaluation). Skogsforsk Resultat 2006(18), 4 p.

Connell, M. J., 2003: Log presentation: log damage arising from mechanical harvesting or processing. CSIRO Forestry and Forest Products. Victoria, 62 p.

Egan, A. F., 1999: Residual stand damage after shovel logging and conventional ground skidding in an Appalachian hardwood stand. Forest Products Journal 49(6): 88–92.

Eronen, J., Asikainen, A., Uusitalo, J., Sikanen, L., 2000: Control of log end checks during bucking with a modified single-grip harvester. Forest Products Journal 50(4): 65–70.

Faust, T. D., Greene, W. D., 1989: Effects of felling head type on tensile strength of southern pine dimension lumber. Forest Products Journal 39(11–12): 82–84.

Gerasimov, Y., Katarov, V., 2010: Effect of Bogie Track and Slash Reinforcement on Sinkage and Soil Compaction in Soft Terrains. Croatian Journal of Forest Engineering 31(1): 35–45.

Gerasimov, Y., Sokolov, A., 2008: Ergonomic characterization of harvesting work in Karelia. Croatian Journal of Forest Engineering 30(2): 159–170.

GOST 2292-88, 1990: State standard. Roundwood: marking, transportation, methods of measurement and acceptance. Moscow. Gosstandart, 12 p.

GOST 9463-88, 1990: State standard. Roundwood of coniferous species. Moscow. Gosstandart. 14 p.

Greene, W. D., McNeel, J. F., 1987: Productivity, costs, and levels of butt damage with a Bell Model T feller-buncher. Forest Products Journal 37(11–12): 70–74.

Greene, W. D., McNeel, J. F., 1989: Potential costs of shear damage in a southern pine chip-n-saw mill. Forest Products Journal 39 (5): 12–18.

Jonsson, P., Hannrup, B., 2007: Virkesvardestest 2006 – virkesskador (Timber-value tests 2006 – timber damage and defects). Skogsforsk Resultat 2007(7), 4 p.

Konovalov, A. P., Seliverstov, A. A., 2008: Logging technologies: an assessment of techno-economic factors. Forestry Expert 1(2008): 76–81.

Marshall, H., Murphy, G. E., Boston, K., 2006. Evaluation of the economic impacts of length and diameter measurement error on mechanical processors and harvesters operating in pine stands. Canadian Journal of Forest Research 36: 1661–1673.

McNeel, J. F., Czerepinski, F., 1987: Effect of felling head design on shear-related damage in southern yellow pine. Southern Journal of Applied Forestry 11(1): 3–6.

Murphy, G. E, 2005: Technology Aids Value Recovery. Focus on Forestry 18(2): 12.

Murphy, G., Twaddle, A. A., 1985: Techniques for the assessment and control of log value recovery in the New Zealand forest harvesting industry. In: Proceedings of the 9th Annual Meeting of Council on Forest Engineering, Mobile, AL, September 29 – October 2, 1985.

Nuutinen, Y., Väätäinen, K., Asikainen, A., Prinz, R., Heinonen, J. 2010. Operational efficiency and damage to sawlogs by feed rollers of the harvester head. Silva Fennica 44(1): 121–139.

Pickens, J. B., Lee, A., Lyon, G. W., 1992: Optimal bucking of Northern hardwoods. Northern Journal of Applied Forestry. 9(4): 149–152.

Sessions, J., 1988: Making better tree-bucking decisions in the woods. Journal of Forestry (10): 43–45.

Spinelli, R., Magagnotti, N., Nati, C., 2010: Comparison between mechanized and manual log-making in Italian poplar plantations. In: Forest Engineering Meeting the Needs of the Society and the Environment. Proceedings of 43 International Symposium on Forestry Mechanisation, July 11–14, 2010, Padova, Italy, 8 p.

Syunev, V., Seliverstov, A., 2006: The influence of assortment of logging on the quality of wood raw material. In: Actual Problems of Forest Industry. Volume 14. Bryansk, BSETA, 68–71 p.

Syunev, V., Sokolov, A., Konovalov, A., Katarov, V., Seliverstov, A., Gerasimov, Y., Karvinen, S., Välkky, E., 2009: Comparison of wood harvesting methods in the Republic of Karelia. Working Papers of the Finnish Forest Research Institute 120, 117 p.

Syunev, V., Sokolov, A., Seliverstov, A., Konovalov, A., Katarov, V., Gerasimov, Y., Välkky, E., Karvinen, S., 2008: Training needs analysis for operators of harvesters. Finnish Forest Research Institute, 11 p. <http://www.idanmetsatieto.info/rus/cfmldocs/document.cfm?doc=show&doc_id=1200> (Accessed 1 July 2010).

Timber Prices, 2010: Average contract prices for major products of forest and woodworking industries, established in the Republic of Karelia. Official site of the Government of Karelia <http://www.gov.karelia.ru> (Accessed 1 July 2010).

TU 13-2-12-96, 1996: Technical specifications. Coniferous saw logs delivered to Finland. Khimki. TsNIIME, 20 p.

TU 13-2-1-95, 1995: Technical specifications. Pulpwood delivered to Finland. Khimki. TsNIIME, 15 p.

Unver, S., Acar, H. H., 2009: A damage prediction model for quantity loss of skidded spruce logs during ground base skidding in north eastern Turkey. Croatian Journal of Forest Engineering 30(1): 59–65.

Wang, J., LeDoux, C., Vanderberg, M., McNeel, J., 2004: Log damage and value loss associated with two ground-based harvesting systems in central Appalachia. International Journal of Forest Engineering 15(1): 61–69.

Sažetak

Gubitci obloga drva u sustavima pridobivanja drva u Rusiji

Terenska su istraživanja provedena radi proširivanja spoznaja o gubitcima obloga drva za najčešće korištene djelomično (MM) i potpuno (FM) mehanizirane sustave pridobivanja drva u Rusiji. Praćenja su obuhvatila pet sustava pridobivanja drva s obzirom na sortimentnu (MM CTL i FM CTL), deblovnu (MM TL) i stablovnu (MM FT i FM FT) metodu izradbe drva, tijekom sječe, privlačenja/izvoženja, izradbe, uhrpavanja (razvrstavanja) i prihvata (utovara) drva. Istraživanje je provedeno u Republici Kareliji zbog širokoga raspona različitih sustava pridobivanja drva i uporabe vozila na tom području, što je ujedno i primjerni uzorak za područje sjeverozapadne Rusije, u razdoblju od 2007. do 2009. godine te je uključivalo 15 poduzeća za pridobivanje drva koja godišnje sijeku i izrađuju oko 35 % od ukupnoga etata u Kareliji (2,2 milijuna m^3/god.). Odabrana poduzeća pridobivaju drvo u cijeloj Republici Kareliji te primjenjuju različite sustave pridobivanja drva (MM CTL, FM CTL, MM FT, FM FT i MM TL) i koriste vozila ruskih i stranih proizvođača.

Istraživanje je obuhvatilo 23 400 komada obloga drva na 17 radilišta, a osnovni podatci o uvjetima na radilištima te broju izmjerene oblovine tijekom sječa prikazani su u tablici 1. Pri sortimentnoj metodi pridobivanja drva trupci su mjereni u sječini i na pomoćnom stovarištu (slike 1 i 2). Pri deblovnoj metodi pridobivanja drva trupci su mjereni u sječini prije privlačenja drva, na pomoćnom stovarištu nakon privlačenja i uhrpavanja drva te naknadno na glavnom stovarištu prilikom trupljenja i razvrstavanja drva (slika 3). Pri stablovnoj metodi pridobivanja drva trupci su mjereni na pomoćnom stovarištu te na glavnom stovarištu prilikom prerezivanja i razvrstavanja drva (slike 4 i 5).

Gubitci su obloga drva procijenjeni na temelju broja oštećenja. Oni su propisani odgovarajućim državnim normama i propisima šumarske industrije, kako slijedi (slika 6): a) mehanička oštećenja, b) greške pri izradbi drva, c) zablaćenost drva i d) odstupanja od odgovarajućih veličina (dimenzija). Rezultati su potom uspoređeni s važećim zahtjevima kakvoće u pojedinim poduzećima te je dobiven postotak odbijenih trupaca. Zahtjevi kakvoće za trupce i celulozno drvo prema raznim vrstama drveća te ciljano tržište prodaje prikazani su u tablicama 2 i 3. Dobivene procjene za sve mjerene veličine povezane su u jedan pokazatelj, tzv. stopu odbacivanja. Ako je trupac u skladu i s kakvoćom i s veličinama (dimenzijama) traženih zahtjeva, označuje se kao prihvatljiv. Nadalje, ako trupac nije u skladu bilo s kakvoćom bilo s izmjerenim veličinama, odbija se ili se upućuje za drugu namjenu, na primjer trupci postaju celulozno drvo, celulozno drvo postaje ogrjevno drvo.

Gubitci su obloga drva prikazani kao gubitci tržišne vrijednosti drva pomoću formule 1, dok su cijene drva preuzete s drvnoga tržišta Republike Karelije. Tablica 4 prikazuje stopu odbacivanja oblovine na 17 istraživanih radilišta pri svim sustavima pridobivanja drva tijekom zimske i ljetne sječe drva. Odbijeni trupac može sadržavati dva oštećenja i više njih, što je i prikazano u tablicama 5–7. Najviša se stopa odbacivanja oblovine javlja pri deblovnoj metodi i djelomično mehaniziranom sustavu pridobivanja drva. Tako je stopa odbacivanja za pilanske i furnirske trupce iznosila 7 % pri zimskoj sječi i 9–10 % pri ljetnoj sječi drva, dok je za celulozno drvo iznosila 3 % pri zimskoj sječi i 7–8 % pri ljetnoj sječi drva. Najniža je stopa odbacivanja za pilanske i furnirske trupce pri potpuno mehaniziranom sustavu pridobivanja drva i sortimentnoj metodi te iznosi 3 %, dok je za celulozno drvo najniža stopa odbacivanja pri djelomično mehaniziranom sustavu pridobivanja drva i sortimentnoj metodi te iznosi 2 % (tablica 4). Gubitci obujma i vrijednosti obloga drva za istraživana poduzeća s obzirom na sustave pridobivanja drva prikazani su u tablici 8.

Analiza dobivenih rezultata pokazuje da sortimentna metoda pridobivanja drva osigurava najvišu kakvoću oblovine u svim ispitivanim poduzećima pri različitim vrstama drveća. Stablovna metoda pridobivanja drva upućuje na zadovoljavajuću kakvoću oblovine odnosno stopu odbacivanja trupaca, dok se deblovna metoda pokazala kao najmanje zadovoljavajuća metoda, posebice pri ljetnoj sječi drva. Mehanička oštećenja drva (iskidana drvna vlakna, oštećenja debla, rezovi drva hvatalima), greške pri izradi drva (djelomično okresane grane, raspucano čelo i pukotine na drvu) te zablaćenost drva bila su najčešća oštećenja na oblovini.

Zbog privlačenja oblovine skiderom za vrijeme male nosivosti tla i velike vlage u tlu deblovna metoda s djelomično mehaniziranim sustavom pridobivanja drva ima najvišu stopu odbacivanja trupaca što zbog zablaćenja, što zbog drugih grešaka. Pri stablovnoj metodi s djelomično mehaniziranim sustavom pridobivanja drva isti je razlog visoke stope odbacivanja, međutim grane na deblu ipak pružaju kakvu-takvu zaštitu debla prilikom privlačenja. Sortimentna se metoda, bez obzira na vrijeme sječe, pokazala kao najbolja jer se drvo izvozi na *forvarderu i nema izravni doticaj s tlom. Odabir odgovarajućega vozila za privlačenje drva treba se zasnivati na terenskim uvjetima, odnosno na trenutačnom stanju tla.*

Da bi se smanjili gubitci obloga drva pri raznim sustavima pridobivanja drva, potrebno je obratiti više pozornosti na vrijednost i kakvoću drva, a ne samo na količinu odnosno drvni obujam. Stoga je potrebno razviti platni sustav te upute za sječu drva, što će omogućiti bolju iskoristivost drva te izbjeći oštećivanja vrijednih sortimenata. Također treba voditi računa o vremenu sječe (viša stopa odbacivanja za MM CTL pri zimskoj sječi, te za MM TL i MM FT pri ljetnoj sječi). Da bi se izbjeglo dodatno zablaćivanje drva prilikom uhrpavanja na pomoćnom stovarištu, potrebno je koristiti se potpornim trupcima. Radnici trebaju redovito održavati vozila (podešavanja harvesterske i procesorske sječne glave, oštrenje noževa, čišćenje valjaka i dr.). Vozila trebaju odgovarati sastojinskim uvjetima te svakako treba voditi računa o tome da su radnici osposobljeni za rad na pojedinim vozilima odnosno za vrhunske načine pridobivanja drva.

Gubitci obloga drva u smislu gubitaka novčane vrijednosti po jedinici obujma u pojedinim poduzećima možda se ne čine značajnim, posebice ako se usporede gubitci pri sortimetnoj metodi potpuno i djelomično mehaniziranoga sustava pridobivanja drva. Ipak, primjena sortimentne metode nasuprot tradicionalnoj deblovnoj metodi donijet će uštedu od 0,8 €/m^3 odnosno oko 100 000 €/god. prosječnomu poduzeću. Početna ulaganja od nekoliko stotina tisuća eura za prelazak iz MM TL u FM CTL isplativa su za duže razdoblje, dok je prelazak iz MM TL u MM CTL isplativiji u kraćem razdoblju. Potrebna su daljnja istraživanja koja će također uključiti proizvodnost sustava, troškove, ergonomske uvjete i zaštitu na radu, te svakako sastojinsku i okolišni pogodnost.

Key words: gubitak obujma, gubitak vrijednosti, pilanski trupci, celulozno drvo, bor, smreka, breza, sortimentna, deblovna i stablovna metoda izradbe drva

Authors' address – *Adresa autorâ*:

Yuri Gerasimov, PhD.
e-mail: yuri.gerasimov@metla.fi
Finnish Forest Research Institute
Joensuu Research Centre
Box 68
FIN-80101 Joensuu
FINLAND

Alexander Seliverstov, PhD.
e-mail: alexander@psu.karelia.ru
Petrozavodsk State University
Forest Engineering Faculty
A. Nevsky av., 58
185030, Petrozavodsk
Republic of Karelia
RUSSIA

Received (*Primljeno*): August 12, 2010
Accepted (*Prihvaćeno*): November 22, 2010