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ASSESSMENT OF MECHANIZED CUTTING OPERATIONS IN THE SLOVENIAN STATE FORESTS

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Abstract: *In the past decade, the use of mechanized cutting has already become very common and almost an every day standard in Slovenian forest operation practice. A lot of mechanized cutting was carried out in thinning operations; a substantial part was also applied by final felling. It was largely made use of in clearing out storm-damaged forest, while its use in regular felling has mainly been limited by the size of the property, the availability of technology, and by the stand, terrain and floor conditions. The assessment of influential factors such as floor (soil) conditions and the degree to which the remaining stands are damaged after the forest maintenance is largely dependent on climatic conditions and the quality of work performance. On the other hand, terrain and stand conditions as influential factors are of a much more permanent character, and consequently the main focus of assessment in the following presentation. The results of worksite analyses in Slovenian state forests show that mechanized cutting was carried out mainly in coniferous stands and on a moderate slope, which is in accordance with the guidelines administered by the research institution and adopted by the Slovenian Public Forest Service. The cutting intensity in mechanized worksites does not exceed the national average. The higher competitiveness of the mechanized cutting operation that was expected in comparison to manual motor cutting and tractor skidding in thinning operations was not recorded to a greater extent, since mechanized cutting was applied in the majority of cases (75%) to stands dominated by an older phase of development (stands of mature trees) predominantly from the second expanded thickness class (30-50 cm) in the structure of breast-height diameter.*

1 Introduction and purpose of research

Modern forestry technology is increasingly being used in Slovenia. The first applications of Cut-To-Length (CTL) date back to demonstrations of foreign contractors in the 1990's (Marusic, 1998; Kosir, Robek, 2000; Magajna, 2002). They were associated primarily with salvage felling in storm-damaged forests. Since 2000, CTL has also been used increasingly by domestic contractors – first and foremost by private individuals. Soon, the forestry profession comes to an agreement that the best approach is the controlled introduction of modern technology into Slovenian forests. They hold workshops initiated by the Forestry Services (FS), as well as forestry companies and research institutions (Bled, Chamber of Commerce, Nazarje, Kočevje) (Beguš 2002).

Often we are faced with the dilemma of using CTL technologies and the need for mechanisms to regulate and control its operation. In addition to full mechanized harvesting (modern assortment method) together with the forwarding, we count at least a modern cable crane with a processor head in combination with the full-tree method and a modern technological chain for the production of wood chips among modern technologies. The amount of forestry work that is carried out with modern technologies, both around the world as well as in Slovenia, is rapidly increasing. The experience gained by forestry companies and the forestry profession is growing and the assortment of machines and technology solutions on the market is very diverse. Slovenian entrepreneurs are pragmatic in investing in more universal machines, which are

also larger and heavier. The purchase of heavy machinery from a business perspective is logical in at least two respects. The relatively large investment has a greater chance of effective depreciation (higher utilization rate of the machine) if the machine is more universal, while the forestry profession has not yet produced and adopted uniform standards that would restrict the use of less appropriate technological solutions.

The chance of potential conflicts among stakeholders who use the forest and forest land is relatively high in these circumstances of introducing modern technologies. Additionally, we have witnessed a rise in salvage felling, where modern technologies have proved to be very efficient in terms of ergonomics and work safety. Somewhat more indirectly, and when used appropriately, there are also advantages in terms of the ecological impact on the forest land (faster salvage operation and thus less likely potential of a bark beetle outbreak, preservation of the forest floor and skidding trails by concentrating forwarding on the roads, limiting the extent of the ecologically less desirable ground skidding) (Žlogar 2007). Greater effectiveness was also reflected in the wider range of appropriate times for carrying out salvage felling, making foresters more flexible in work scheduling since operation is faster and less stretched out into the seasons and weather conditions with less ground carrying capacity and vegetation periods when the trees are exposed to greater vulnerability.

The purpose of this study is to assess the use of modern forest operation technologies – especially Cut-To-Length (CTL) - in Slovenia. Past research, which was conducted in the initial period of introducing mechanized harvesting, showed a set of indicators that should be taken into account in assessing the appropriateness of the use of mechanized cutting (Krč, Kosir 2003, Krč 2004). The Forest Service (FS) records the location and quantities of felling in state owned forests, which is carried out by contractors in the case of regular felling. Forestry operations of regular felling where CTL was used will be compared using a set of criteria, and based on the comparisons an assessment of the implementation of mechanized cutting in Slovenia will be made.

2 Method

Data on the use of mechanized cutting was obtained from the FS and partly from forestry companies. We used two primary sources: first, data regarding regular cutting and second, simultaneous clean-up plans for storm-damaged forests, the consequences of which fell during the analyzed years of 2008 and 2009. From the records of regular cutting we obtained information on the locations of the working areas by the FS forest sections and the extent of the work in terms of size and net felling amounts, separated into coniferous and deciduous species. For the forest sections where CTL was applied, we obtained additional data on indicators that enable us to make an assessment of the appropriateness of the use of mechanized cutting (Table 1). Local values of the indicators used in assessment are taken from the Forest Information System. For each analyzed forest section, we obtained the original forest inventory data (Mikulic 1990) and made a new database with a set of primary and combined fields (Table 1).

Table 1. Set of data for assessment of mechanized cutting operation suitability

Code	Variables Description
GGO	Identification of the Forest Service regional unit
SECTION	Forest section identification
	area
F_AREA	rea
	Geographical coordinate X
	Geographical coordinate Y
	Slope in degrees
	Proportion of the section surface that is rocky
ETAT_CON	allowable cut, coniferous
ETAT_DEC	allowable cut, deciduous
SHARE_1DBH	Proportion of growing stock in the first extended DBH class (up to 30 cm DBH)
SHARE_2DBH	Proportion of growing stock in the second extended DBH class (from 30 to 50 cm DBH)
AREAF02	Area of younger pole stand development phase in forest section (from 10 to 20 cm DBH)
AREAF03	Area of older pole stand development phase in forest section (20 to 30 cm diameter breast)
AREAF04	Area of mature stand development phase in forest section (from 30 to 50 cm DBH)
Share_C	Proportion of conifers in growing stock of forest section
MC_CON	Net amount of conifers mechanically cut (m^3) by thickness classes
MC_DEC	Net amount of deciduous mechanically cut (m^3) by thickness classes
Share GS	Removal intensity expressed in percentage of growing stock [%]
Share ET	Removal intensity expressed in percentage of allowable cutting volume [%]
Share C_L	Proportion of conifers in the structure of removal
m3_ha	Removal intensity expressed in m3/ha/10 years
YEAR_MC	Year of mechanized cutting operation

3 Result

The analysis included 119 working sites, which we are able to connect to the forestry information system and consequently associate them with basic forestry information system data (Table 1). Altogether, we received complete information for 62 working sites in 2008 and 68 working sites in 2009. The data were summarized at the level of forest sections in which mechanized cutting was carried out. Basic information about the extent of working activity was given for all forest sections where mechanized cutting was recorded according to the regional FS Units by year.

Table 2. Extent of mechanized cutting for regular cutting operations in state owned forests in 2008

	Conifers [m^3]	Deciduous [m^3]	Area of Working Sites [ha]	Number of sections
Bled	3840.81	7.49	43.55	11
Postojna	3026.11	826.16	79.63	7
Kočevje	3468.54	41.62	77.35	5
Novo Mesto	899.32	135.73	60.71	1
Slovenj Gradec	3294.64	262.91	43.5	9
Maribor	8548.92	829.11	210.9	20
Total	23078.34	2103.02	515.64	53

Table 3. Extent of mechanized cutting for regular cutting operations in state owned forests in 2009

	Conifers [m ^{3}]	Deciduous [m ^{3}]	Area of Working Sites [ha]	Number of sections
Postojna	1134.09	61.28	23.93	3
Kočevje	5243.35	21.55	80.5	5
Novo mesto	6017.73	7266.54	167.4	9
Slovenj Gradec	1101.16	3.3	18	1
Maribor	17011.83	3812.17	388.36	48
Total	30508.16	11164.84	678.19	66

The spatial distribution of regular cutting operations for the years 2008 and 2009 using CTL technology (mechanized cutting) were also shown graphically (Figure 1).

Figure 1. Locations of forest sections by municipalities in which the Forest Service recorded regular felling carried out by CTL technology in the years 2008 and 2009

The data in Tables 1 and 2 shows the increase in forest operations which were carried out using CTL technology. This growing trend was recorded in terms of the quantity of cutting volume as well as the number of different locations. Only a slight decrease was recorded in the total area of forest sections where CTL was applied.

The real data of the extent of mechanized cutting in Slovenia is certainly quite different. The FS does not have systematic and uniform data collection for forest sections or basic production indicators at the working sites where CTL is used for salvage cutting operations of storm-damaged forests, or its operation in private forests. For example, in the FS regional unit Bled, the FS did not document regular felling by CTL in the year 2009 because there was such a large volume of salvage felling in the year 2009 that it was unable to perform the regular timber harvesting with CTL technology. According to the FS data for the FS unit Bled, salvage felling represented 60-80% of all cutting operations in the last period.
Data on the extent of salvage felling in storm-damaged forests in the year 2008, which were provided for in the salvage plan worked out by the FS, are summarized in Table 4.

Table 4. Extent of storm damaged forests in the year 2008, (source: FS salvage plan)

FS regional unit		Volumes [m^3 BTO]			Area [ha]			Technology	
	Date	Total	Conifers	Decidi-ous	Total	State	Private	Anticipated technology	Anticipated CTL [m^3]
Murska Sobota	13,14.7.	14140	2400	11740	3281	768	2513	95% motor manual+ tractor, 4% CTL, 1% Cable	15847
Sežana	13,14.7.	1697	11	1686	15	0	15		
Tolmin	13,14.7.	50000	17500	32500	179	179	0		
Kranj	13,14.7.	2320	1770	550	1678	29	1649		
Ljubljana	13, 14.7.	174635	102465	72170	8471	201	8270		
Nazarje	13,14.7.	153385	145251	8134	792	0	792		
Brežice and Celje	15.8.	93992	17562	76430	5436	1289	4147	motor manual+ tractor	
Bled	15-25.12.	49000	47800	1200	4900	1700	3200	motor manual+ tractor +Cable (30% CTL)	14700
Total		539169	334759	204410	24752	4166	20585		30547

The actual salvage cutting that is carried out in storm-damaged forests can often vary greatly from what was determined in the salvage plan. Salvage plans are worked out immediately after disasters, so in most cases at a time when the salvage work is just beginning. Data on realization, obtained subsequently, shows a greater extent of CTL operations in comparison to what was planned. An analysis of the FS units Ljubljana and Nazarje show that the extent of CTL forest operation was 32,400 m^3 in FS unit Kamnik and 62,864m^3 in FS unit Nazarje. These two units are predominantly private forests. This fact alone indicates a three-times greater use than the total planned use of CTL technology for salvage felling in all storm-damaged forests in the year 2008 (Table 4).

In the next part, we will focus on the available data for regular felling carried out by CTL technology in forest sections that was recorded by the FS. Research results dealing with the development and use of new technologies show that the harvesters are more flexible and consequently more suitable for operation in conifer stands (BIGOT et. al. 2003). Therefore, in the first step we analyzed the growing stock structure for the forest sections where CTL was applied (Figure 2).

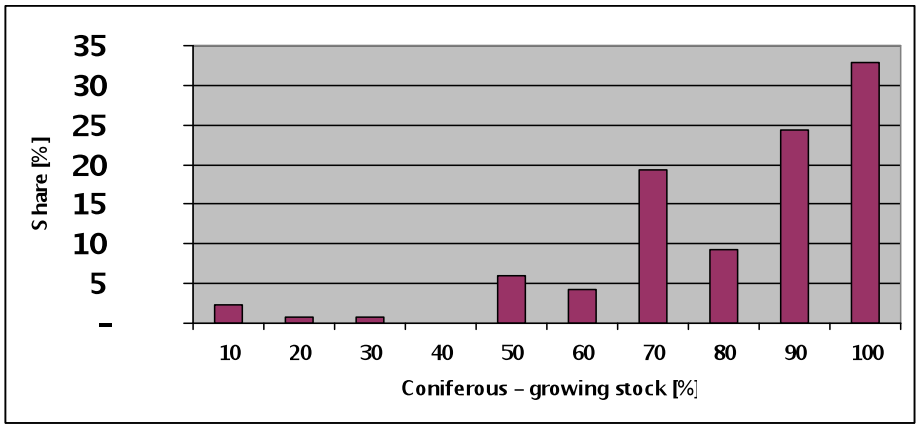

Figure 2. Distribution of analyzed forest sections according to the proportion of conifers in the growing stock

The analysis showed that almost 2/3 of working sites were located in stands where the growing stock consists of a minimum of 70% coniferous wood volume. We presume that the CTL recorded in these forest sections was used primarily where coniferous trees prevail. So we can assume with high probability that the sites with a strong predominance of conifers represent a major share of the working sites. This statement is supported by data analyzing the structure of the cutting volumes by working sites with CTL

technology. The coniferous share of cutting volume in the year 2008 was 92% and in the year 2009, the share was 73% (Tables 2 and 3).

We can explain the smaller proportion of coniferous stands in 2009 compared to 2008 by the expansion of working sites to deciduous stands - especially in younger developmental phases where the CTL technology is relatively efficient (Vranešič 2008). Another explanation of the greater proportion of deciduous stands among CTL working sites could be the large extent of salvage felling, which took place mainly in coniferous stands.

The second factor that was included among the most influential factors for assessing the suitability of CTL technology was the terrain slope. Slovenian forests greatly vary topographically. The data on the terrain slope, which assesses the average slope for the entire forest section, is relatively unreliable. The average size of a forest section in the database documenting CTL technology in forest operation for the years 2008 and 2009 is 17.52 ha. Data analysis on the frequency distribution of the forest sections with CTL technology in the years 2008 and 2009 according to the average terrain slope is shown in Figure 3.

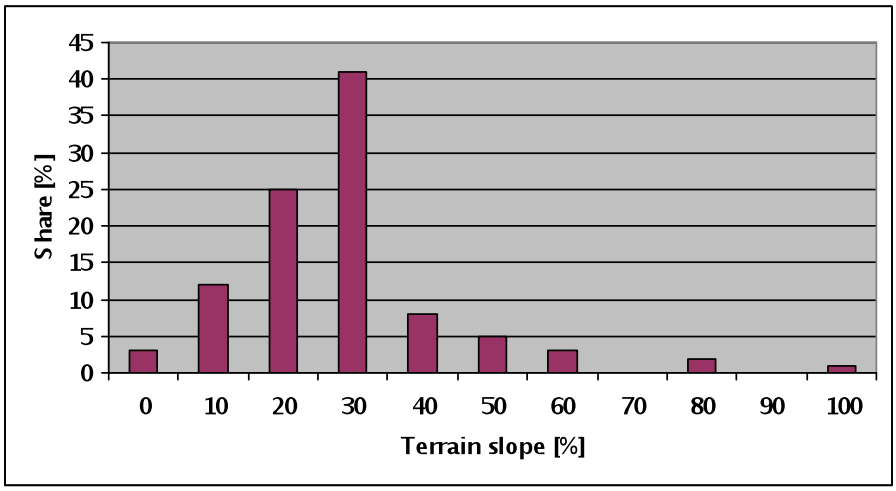

Figure 3. Frequency distribution of the analyzed forest sections according to the terrain slope (forest section with CTL working sites)

The data analysis shows a relatively small difference between the practice and the guidelines regarding terrain slope as an influential factor. The research results indicated that CTL technology is more suitable for less steep working sites. The majority of the time, CTL technology was used in forest operations (81% of working sites) on forest sections with a terrain slope of less than 30%. Over 60% of the average terrain slope is practically not documented on the regular working sites where CTL was used in the years 2008 and 2009.

The next influential factor that was used for suitability assessment of the application of CTL technology in Slovenia was the intensity of felling at the level of the forest section. Figure 4 shows the frequency distribution of the forest sections where CTL was applied, analyzed by its cutting intensity. We distinguish between (a) the cutting intensity expressed in the share of the forest section growing stock, which represents the mechanized cutting that has been carried out and (b) the cutting intensity which was calculated as a ratio (percentage) between the cutting volumes in 2008 and 2009 and the ten-year allowable cut in those forest sections.

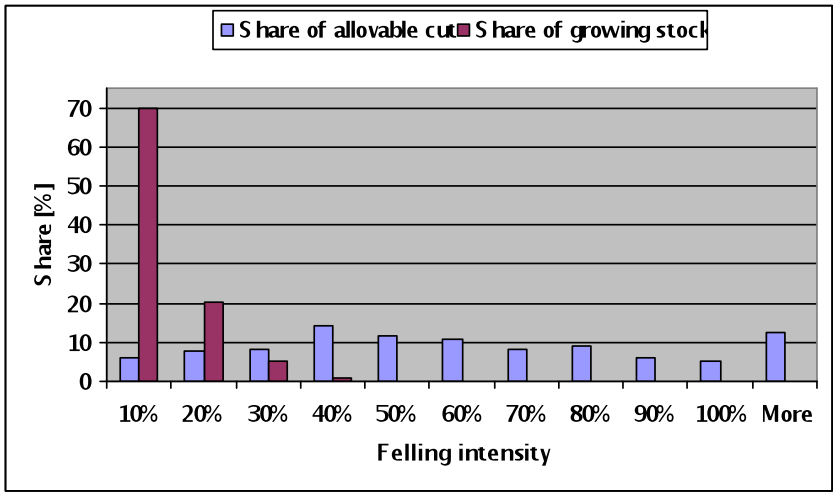

Figure 4. CTL cutting intensity, expressed as the share of growing stock and the share of the ten-year allowable cut in a forest section

The frequency distribution of the forest section shows a relatively low intensity of CTL felling, - of course in asmuch as we compare the felling with the growing stock of the forest section. The removal intensity only exceeds 15% of the growing stock of the forest section in just over ten per cent of the cases. We can assert that the cutting intensities (both the representation in the share of growing stock, as well as the share of allowable cut) are minimal among working sites that were located within the forest section. In extreme cases, where the working site area covered the entire forest section, the percentages shown are correct. Normally the cutting intensities are higher because the working site comprises in most cases only part of the forest section.

Comparing the CTL productivity and costs with an alternative technology, in our case cutting with a chainsaw, it is clear that the CTL technology has an advantage in the stands with the thinner /younger trees. Differences in productivity and costs are in favor of mechanized cutting in such working conditions, which leads us to believe that by increasing the share of mechanical harvesting there will also be an increased proportion of silviculture activities. In Figure 5, we analyzed the sites (forest sections) with mechanized cutting in regards to the DBH structure of the stands. The figures represent the percentage of the total number of sites (forest sections) in which the first extended DBH class represents a certain percentage of growing stock in the forest section.

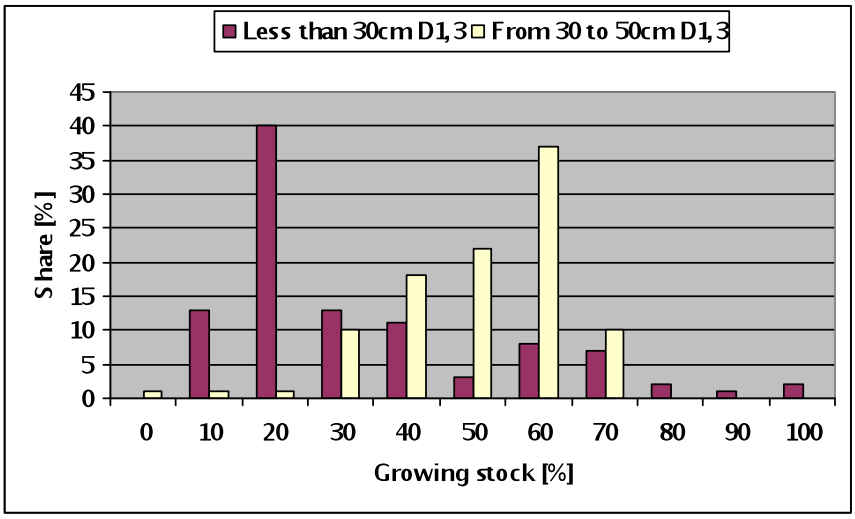

Figure 5. The structure of growing stock by DBH extended classes in the analyzed forest sections where CTL technology was applied

It is understandable that in variably aged stands a greater proportion of the growing stock is represented by larger trees, with a thicker DBH extended class (over 50 cm). Therefore, the relatively low proportion of the first and the second DBH extended class in the structure of the growing stock is logical. A more complete image can be obtained by additional analysis of the relationship between stand development phases. The sections were analyzed in regard to the structure of the area by forest development phase, from young pole stands to mature stands The development phase of a younger pole stand was not present in the analyzed forest sections with CTL technology, while the structure for development phases of older pole stand and mature stands are shown in Figure 6.

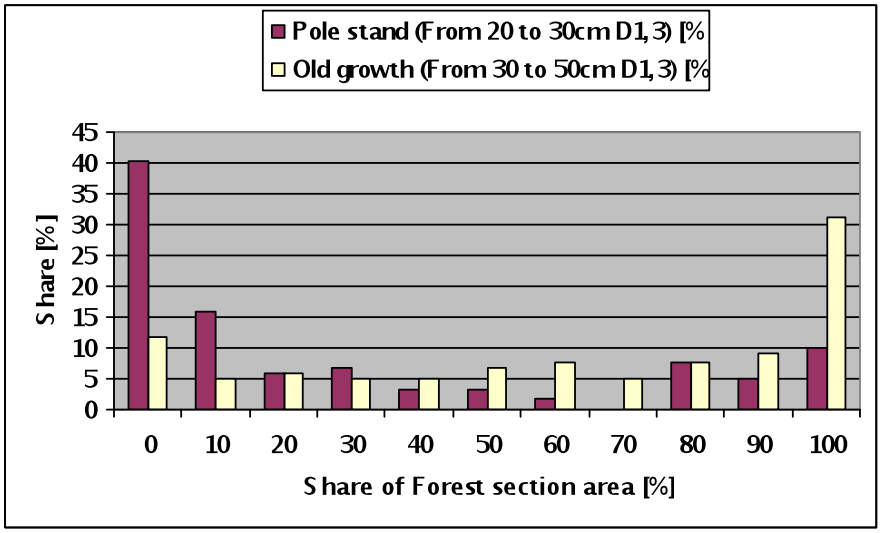

Figure 6. The structure of the analyzed forest sections by the stand development phases

The analysis showed that regular cutting operations are conducted more often with CTL technology in the forest sections with a higher proportion on average of older development phases (on average mature stands cover 2/3 of the forest section surface). This conclusion could be explained by the fact that regular felling is predominantly in older development phases and of course also with the predominant use of heavy machinery owned by domestic contactors, which allows for the use of CTL technology in older /thicker stands.

4 Discussion

On the basis of the data on the realization of regular felling in state forests for the years 2008 and 2009, which included various indicators (stands' tree structure with proportion of conifers in the growing stock of the forest section, terrain slope, intensity of felling, DBH removal structure and the size and quantity of felling on working sites), the assessment of the appropriateness of the use of mechanized harvesting in relation to the field and stand conditions could be done.

The analysis showed that regular cutting operations were carried out mainly in coniferous stands. More than 2/3 of working sites was inside forest sections with a strong domination of coniferous stands (over 70% of growing stock). Furthermore, we did an analysis of the dimensions and stand development phases of the trees inside the forest sections. We expected that the use of mechanized cutting would be primarily taking place in thinner stands, but this was not the case. The analysis showed that mechanized cutting was mainly carried out in the mature stand development phase (there is an average share of more than 75% in the mature stand development phase in forest sections where CTL was used).

New CTL technology has been mainly implemented on slightly sloping terrain. There were no working sites on steeper terrains and in that respect, less suitable sites were avoided. The results are particularly important from a timber skidding operation point of view, because the limitations regarding terrain slope for using the forwarders are stricter in comparison to those applied in practice for harvesters (Krč, Kosir 2004).

The efficiency of mechanized cutting is strongly dependent on the spatial concentration of working sites and cutting intensity (Krč, Kosir 2005). The spatial concentration of working sites can be visually assessed from Figure 1, and the intensity of felling was further analyzed (Figure 4). It showed that CTL was used inside forest sections where cutting intensity does not deviate greatly from usual ones. The felling intensity was expressed by the share of allowable cutting in the forest section growing stock. We also did an analysis of the forest inventory data. The results showed that the average cutting intensity in Slovenia is 16% (ratio between the total amount of the ten-year allowable cut and the total growing stock in stands with planned cutting operations). The assessment of the proportion of singe cutting operation compared to the ten-year allowable cut shows a prevalence of CTL cutting sites, representing one half of the total ten-year allowable cut The proportion of analyzed forest sections where CTL technology was used to do between 30 and 70% of the allowable cutting for ten years was 45%. In view of the domination of forest operations in older development phases, it would be reasonable to consider the rationalization of the number of cutting operations inside the ten-year period. The result would be increased cutting intensity, reduced logistical costs and consequently, a direct increase in the efficiency of mechanized cutting (Krč, Kosir 2005).

The assessment of the CTL working sites regarding the forest stands and the trees' dimensions was focused on the younger development phase of forest stands with smaller tree dimensions, where the CTL technology is more cost-efficient compared to cutting with a chainsaw. Despite the fact that in variably aged stand structures it is logical that the stand growing stock is dominated by thicker trees, the results show that there were relatively few working sites inside forest sections with predominantly smaller trees dimensions. Only 20% of forest sections where more than 50% of the growing stock was in the first expanded DBH class (up to 30 cm $D_{1.3}$) were documented.

The question about the appropriateness of the use of mechanized harvesting regarding the climatic conditions remains unanswered. The weather conditions and consequently soil moisture have a strong influence on the extent and severity of the ecological effects of CTL operations (especially damage to the floor and stand).

We can improve the assessment of the appropriateness of the use of mechanized cutting in Slovenia by applying unified methodology for data collection on all CTL working sites - not only the working sites with regular felling in state forests. A significant part of mechanized cutting is namely done in private forests, and CTL technology is used to an even larger extent for salvage cutting operations in storm-damaged forests, where the much-needed methodology for uniform data collection is also missing.

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