Timber Harvesting Methods in Eastern European Countries: a Review

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Abstract

The social and economic changes that began over 25 years ago in post-communist Eastern Europe and the countries of the former Soviet Union also affected the forestry sector. Forested areas were privatised in many countries, and timber harvesting, also in state-owned forests, was contracted out to private sector logging companies. An analysis was conducted of the following countries: Belarus, Bulgaria, Czech Republic, Estonia, Latvia, Lithuania, Poland, Romania, Slovakia, and Ukraine. The basic parameters of forestry, like the characteristics of forest resources, the volume of harvested timber and logging processes used, were given for each country. Special attention was paid to the methods of timber harvesting. The main findings of the study are that various methods are used in Eastern Europe depending on site and forest conditions. In some countries, especially the wealthier ones, a dynamic increase in the cut-to-length method is observed, with the use of harvesters and forwarders.

Keywords: forests privatisation, cut-to-length method, tree-length method, timber harvesting costs, work productivity

1. Introduction

Forest utilization, including timber harvesting, has been part of human life since the dawn of time. Throughout this period, however, the ways humans have impacted the forest have been constantly changing. This applies particularly to the period after World War II, when various types of technologies have been introduced on a large scale in forestry to achieve partial or full mechanization of work.

The systemic transformation that followed the collapse of communist regimes in the early 1990s in European countries of the so-called Eastern Bloc affected virtually all areas of the economy, including forestry (Zālītis 2015).

The changes that shaped the new political and economic systems, as well as the social changes, had their own characteristics and their own pace in each country of Eastern Europe. This was conditioned by many different factors, including geographic location and the degree of dependence on the Soviet Union.

The concept »Eastern European countries« is not completely unequivocal. Generally, it is used to define European countries with common cultural and historical roots. Various classifications are used for this area (according to the United Nations Group of Experts on Geographical Names, United Nations Statistics Division and political classification during the Cold War). Since the 1980s, the concept of Central and Eastern European (CEE) countries has been more commonly used.

All of the countries share a history of having been socialist countries between 1948–1990, when private forests were nationalized or used by the state. More than 20 years ago, these countries began transitioning from communist regimes with centrally planned economies and one-party political systems to democratic rule and market economies. Today, most of them (except Belarus and Ukraine) are full members of the European Union, meeting all its requirements and conforming to its policy developments. These changes in the political system also stimulated new phenomena, which changed the forestry sectors of these countries: restitution of forest land, privatisation of forest industries, formation of a liberalized timber market, an increased level of timber exports, and new models of forest management, i.e. private businesses, logging companies (Sarvašová et al. 2015, Weiss et al. 2011).

In terms of the forest economy, the breakthrough of the 20th and 21st centuries, especially in Europe, is the attempt to manage forests with continuous and sustainable development. This concept coincides with the contemporary multifunctional forestry model. It should be noted that forest utilization and harvesting, as the main sector of forestry, comprises the most important part of the multifunctional forest economy (Moskalik 2004).

The aim of this study is to present the state of forestry in the countries of Eastern Europe, with particular emphasis on forest utilization, in the context of socio-economic changes that have occurred in the last 25 years. This also reflects the diversity of natural conditions affecting the structure of the timber and the techniques and technologies used for its harvesting.

2. Methods

On the basis of their similar history, ten Eastern European countries were selected for the analysis of aspects of forest utilization: Belarus, Bulgaria, the Czech Republic, Estonia, Latvia, Lithuania, Poland, Romania, Slovakia, and Ukraine.

In order to achieve the intended aim, it was necessary to analyse a large amount of data on, among others, the characteristics of forest resources in a given country (its size, indicator of forest cover, ownership structure, species structure), the volume of harvested timber and logging processes used. While obtaining information on general indicators of individual countries is relatively easy (though the indicators provided by FAOSTAT, EUROSTAT and Statistical Yearbooks are often inconsistent), it is difficult to obtain current data on the technologies used in logging. These data are often not available in the literature, or dated, due to the rapid pace of changes primarily caused by the mechanization of processes. For this reason, the survey method addressed to experts, mainly the authors of this paper, on the forest utilization in a given country was used.

The survey included questions about the degree of mechanization of harvesting and skidding, with special emphasis on providing the number of working harvesters and forwarders, technological processes used and costs of timber harvesting and extraction.

Nine methods of obtaining shortwood timber were distinguished, assortments under 6 m in length, and five methods of obtaining tree-length timber (over 6 m). These methods differ in the degree of mechanization of work and distance of skid trails. Respondents were asked to indicate the extent to which methods were used in their country: very often, often, rarely or never. The exact characteristics of the processes are presented in Table 3. The descriptions in the table also includ explanations of the abbreviations used for the machine systems listed. A short analysis of the state of timber harvesting for each individual country was also made.

3. Results

3.1 Characteristics of forest resources

The forest resources of Eastern European countries are relatively diverse in terms of size. As shown in Table 1, the largest areas of forest among those analysed are found in three countries: Ukraine, Poland, and Belarus. Significantly smaller areas, at a level of 1.9–2.5 million ha, are found in Slovakia, the Czech Republic and the Baltic countries (Adamczyk at al. 2015, Ambrušová at al. 2015, Jarský at al. 2015).

An important indicator is the forest cover, showing the proportion of the forested area to the total area of the country. In this respect, the best situation is in Estonia and Latvia (50%). The lowest proportion of the forest cover, 16.7%, is in Ukraine. It should be noted, however, that these resources are very heterogeneous, so the distribution of forests across countries is often uneven. In Ukraine, for example, the forest cover varies from 3.7% in the Zaporozhye region to 51.4% in Transcarpathia (Teder at al. 2015a, 2015b, Vilkriste and Zālīte 2015). Most of the countries have more forest cover than the average in Europe of 32.2% (excluding Russia) (EUROSTAT 2016). A very positive feature of

Table 1 Forest area and cover in the studied Eastern European countries

Country	Forest area 1000 ha	Forest area available to supply wood, %	Forest cover in 2015, %	Change in forest cover from 1990 to 2015, %
Belarus	8633.50	75.0	42.5	10.7
Bulgaria	3774.70	57.9	37.4	16.9
Czech Republic	2597.18	86.3	34.5	1.5
Estonia	2231.95	89.3	52.7	1.3
Latvia	3356.00	93.9	54.0	5.9
Lithuania	2180.00	88.3	34.8	12.3
Poland	9197.90	87.7	29.4	6.2
Romania	6520.00	67.4	29.8	7.2
Slovakia	1941.52	92.0	41.0	0.7
Ukraine	9657.00	54.1	16.7	4.4

all countries, in contrast to the global trend, is the new afforestation that has been underway for the last 25 years. The greatest progress in this respect was recorded in Bulgaria, Lithuania, and Belarus (Mizaraite at al. 2015, Stoyanov at al. 2015).

The domination of state forest ownership, state capital goods and a centrally planned economy characterised Eastern European countries until 1990 (Teder et al. 2015a). One of the most important factors influencing the current state of the forestry sector and ownership structure in these countries was the restitution of land rights that were lost during the communist regime. This process started in the 1990s and faced many problems. New, the so-called »non-state« owners (a term that includes individual owners, cooperatives, private companies, churches, environmental groups and municipalities) lacked sufficient knowledge about how to manage their forests to achieve financial and ecological sustainability. Properties returned to private individuals were often too small for viable independent management and highly fragmented in their location. New forest owners also lacked financial capital, technological know-how, and the necessary equipment and tools (Kocel 2010).

Fig. 1 presents the structure of forest ownership. It shows that the process of reprivatisation has not yet been completed, as there are still areas of forest whose ownership has not been settled in Estonia, Lithuania, and Slovakia. To date, forests have not been returned to private ownership in three countries: Belarus, Ukraine, and Poland. According to the forest policies presented, their reprivatisation is not foreseen in the coming years. In the future of course, the policy system can change over and privatisation can be implemented more efficiently (Adamczyk at al. 2015).

A very important feature of Eastern European forests is their economic function as a raw material for the wood products industry. The structure of obtained assortments largely depends on the specific conditions of the stands. Undoubtedly, one of the most important factors in this regard is the share of each tree species. Fig. 2 shows a very large variation among the countries. In the case of Poland and Belarus, pine stands prevail; in the Baltic countries, there is far more spruce, birch or alder. In the southern part of the region, with mostly upland and mountainous forests (Bulgaria, Romania, Slovakia), there are mixed deciduous forests dominated by beech trees and various oak species (Nichiforel at al. 2015).

In the past, the region was dominated by native forests. However, due to intensive logging in the late 19th and 20th century, native forests were replaced with spruce monocultures in some countries. Today these forests are often destroyed by the bark beetle.

3.2 Roundwood production and trade

Wood is harvested within final felling, thinning, sanitary and other cuttings. A limit of timber harvest-

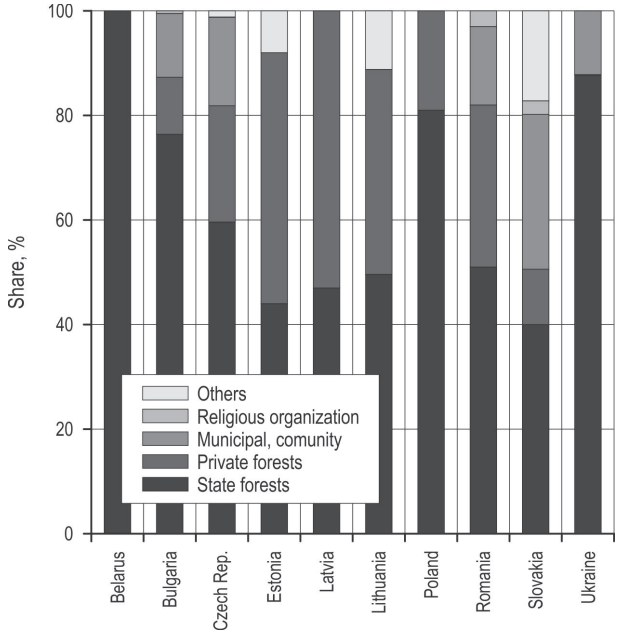

Fig. 1 Forest ownership structure in Eastern European countries under analysis

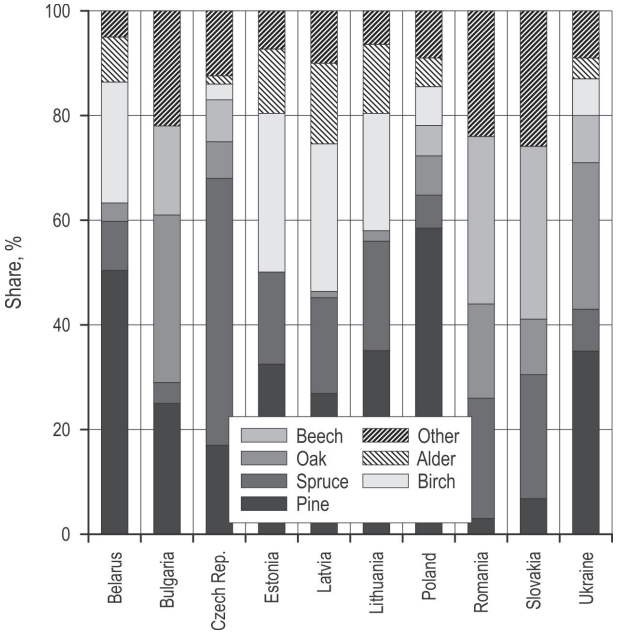

Fig. 2 Tree species structure in Eastern European countries under analysis

Table 2 Roundwood production and the timber trade in Eastern European countries under analysis (FAO 2016)

Country	Production 1000 m^3	Production per capita m^3/person	Export, % of production	Import, % of production
Belarus	19,550	2.10	11.1	0.1
Bulgaria	5570	0.76	9.7	0.6
Czech Republic	15,476	1.47	31. 9	15.8
Estonia	12,600	9.57	21.9	1.8
Latvia	12,597	6.29	30.4	10.3
Lithuania	7351	2.49	23.2	4.6
Poland	40,565	1.05	6.6	6.5
Romania	15,068	0.75	2.2	6.7
Slovakia	9417	1.73	31.1	8.2
Ukraine	18,300	0.43	18.8	0.1

ing within the final felling is provided by allowable cuts, which should be approved taking into account the principles of continuity and sustainability of the use of forest resources.

Table 2 shows the volume of roundwood production in the analysed countries. These values are varied, amounting from 5.5 million m^3 (Bulgaria) to just over 40 million m^3 in Poland. Of course, the determining factors here are the size of the forest area of the country, the type of forest management and the age and species structure of the stands.

Large differences are observed in production per capita. The largest number of timber per person is harvested in the two Baltic countries – Estonia and Latvia, where the ratio is at the level of 9.6 and 6.3 m^3, respectively. Less than 1 m^3 per person is obtained in Ukraine, Bulgaria, and Romania.

Countries exporting significant quantities of roundwood are the Czech Republic, Slovakia, and Latvia. The share of exports, compared to the amount harvested, is just over 30%. The smallest amount of timber is exported from Romania (2.2%). The Czech Republic and Latvia also import wood, in amounts of 15.8% and 10.3%, respectively. There is practically no import of wood in Ukraine and Belarus. This is because of the prices offered on the European wood market. For example, the average amount of the price for pine ranges from 50 €/m^3 (Ukraine, Belarus) to 83 €/m^3 in Romania (Fordaq 2014). The prices can be much higher, reaching up to 500 €/m^3, when most valuable wood is under a special offer (Zastocki at al. 2012, 2015).

3.3. Timber harvesting processes and work productivity

Different methods of logging are used in the countries of Eastern Europe. Their selection depends on site conditions, silvicultural treatments, species composition, tree sizes, stand density and the economic condition of each country. The degree of mechanization of work also differs. According to Asikainen et al. (2009), the proportion of mechanization varies greatly among European countries. The percentage is close to 100% in the Nordic countries, United Kingdom and Ireland, and notably smaller in Eastern Europe.

Currently, most European countries use two methods of harvesting wood: the tree-length method (TL) and cut-to-length method (CTL). These methods refer to the form in which wood is delivered to the road. In the TL method, trees are felled, delimbed and topped in the cut-over or bucked. In this analysis, the minimum length of timber was 6 m. Delimbing and crosscutting are done at the stump. Trees are mainly skidded to roadside by using skidders or agricultural tractors equipped with winches. In the CTL method, also called the shortwood method, trees are felled, delimbed and bucked to various assortments directly at the stump. Harvesting can be fully mechanized or motor-manual. Off-road transport is usually done by forwarders or agricultural tractors equipped with self-loading trailers.

Table 3 shows the most common timber harvesting methods applied in each analysed country. Certain trends in particular regions are clearly visible. In the Baltic countries, a significant proportion of timber is harvested using the CTL method by harvesters and forwarders. A clear increase in this type of machinery has also taken place in Poland, the Czech Republic, and Belarus. Long wood is still harvested in considerable quantities in all countries but not the Baltic ones. In Ukraine, tree-length timber is extracted, but processed into lengths of 2–4 m at the landing located directly by haul roads. Horse skidding is used primarily in Bulgaria, Romania and Slovakia. Cable yarding is used in all countries, where the forests are located in mountainous areas.

Important aspects influencing the effectiveness of the processes used are the condition and age of the technical equipment. Malinen at al. (2016) conducted interesting research in this area, which showed that among the machines being used in Europe, the oldest harvesters were in Eastern Europe (8.2 years). The average age of forwarders was 9.9 years. In comparison, the average age of harvesters and forwarders in Nordic countries is 6.5 and 6.1 years, respectively.

Table 3 Timber harvesting methods applied in each country under analysis

Harvesting method	Average distance between skid rails m	Mechanization degree	Transported wood	Belarus	Bulgaria	Czech Republic	Estonia	Latvia	Lithuania	Poland	Romania	Slovakia	Ukraine
H–F	20	Fully mechanized	Short wood <6m										
C–H–F	>20	Highly mechanized											
C–F	20												
C–TT	20												
H–CC	20												
C–H–CC	>20												
C–O–H–F	>30	Partially mechanized											
C–OT	20												
C–O–F/TT	>20												
H–TW/S	20	Highly mechanized	Long wood >6m										
C–TW/S	>20												
C–CC	>40												
C–O–TW/S	>20	Partially mechanized											
C–O	>20												
Frequency of usage:					Very often			often			rarely		

Explanation of abbreviations: H – Harvester; F – Forwarder; C – Chainsaw; O – Horse; OT – Horse with a trailer; S – Skidder; TW – Agricultural tractor with a winch; TT – Agricultural tractor with a trailer; CC – Cable crane

Table 4 Work productivity of timber harvesting in different forest conditions depending on the level of mechanization

Cutting category	Volume of cut trees m^3	Work productivity, m^3/h			
		Technological operations (Felling-delimbing-bucking)		Extraction 300 m	
		Tree-length method (TL) Chainsaw	Cut-to-length method (CTL) Harvester	Tree-length method (TL) Skidder	Cut-to-length method (CTL) Forwarder
Early thinning	0.06–0.08	0.5–1.1	4.4–5.6	4.2–5.3	4.6–5.4
Late thinning	0.18–0.32	0.7–1.5	8.6–16.1	6.3–14.2	8.8–15.1
Clear cut	0.32–0.57	1.8–4.3	19.8–32.1	13.7–16.3	16.5–17.9

The significantly high capital investment in CTL machines requires high productivity and high annual use of machines. Factors affecting productivity include machine size and properties, equipment configuration, stand and site conditions, forest management objectives, and operator capabilities. The effects of these factors have been studied widely over the last 25 years (Malinen at al. 2016, Mederski at al. 2016a, Moskalik 2004, Nurminen et al. 2006, Oikari et al. 2010, Stankić at al. 2012).

Table 4 presents the average work productivity of various operational logging processes, depending on cutting category, method applied, and chosen machine. The productivity can, of course, increase or decrease considerably as a result of a slight change in any of these factors.

Individual data on timber harvesting for each analysed country is presented below.

3.3.1 Belarus

Tree-length (TL) and cut-to-length (CTL) methods are applied in Belarus to harvest wood. These methods differ in relation to the technology used. The typical TL system employs chainsaws for felling and delimbing, and a cable skidder for extraction; the typical CTL system employs chainsaws for felling, delimbing and cross-cutting, and a forwarder for extraction. The fully mechanized »harvester and forwarder« CTL system is becoming a common practice in Belarus (Gerasimov and Karjalainen 2010).

In the last 10–15 years, the Belarus Ministry of Forestry has upgraded its enterprises, moving in the direction of the mechanized harvesting (Baginsky 2015, Fedorenczik at al. 2013). The forestry enterprises of Belarus have about 160 harvesters, and in 2016, another 72 Vimek harvesters and 52 forwarders for thinning will be supplied (BelTA 2016).

In 2014, the amount of timber harvested by machines was 41%. The prognosis is that this number will increase to 80–85% by 2030. It is also planned that by this year, about 30% of harvested timber will be cut by external companies. The cost of wood harvesting using the government's resources is 2.7–3.45 €/m³, while this cost is 10% lower with external contractors.

3.3.2 Bulgaria

Bulgaria's forest areas are divided among six state-owned logging companies that hire private firms to perform the harvesting. Cutting and delimbing are done with chain saws. There are only single harvesters, forwarders and cable cranes (about 10 skylines are still in use). There is no accurate statistics about wood extraction, but about 60% of timber is extracted mainly by horses and mules; oxen are rarely used; 40% of the wood is extracted by skidders, agricultural tractors and military trucks. The average logging cost paid by the state forest enterprises to private logging companies, which deliver wood to the roadside was 15.10 €/m³ at the end of 2015.

3.3.3 Czech Republic

The tree-length method dominates in the Czech Republic (71%), with the use of chainsaws for felling and delimbing, as well as skidders and agricultural tractors fitted with winches. National cable yarding system »Larix« is used in mountainous areas. About 120,000 m³ of timber is extracted in this way. 29% is harvested in a fully mechanized manner with the use of harvesters and forwarders. It is estimated that there are about 500 harvesters and 850 forwarders (MZe 2015). The cost of felling and extracting timber is 17.1 and 8.3 €/m³, respectively.

Municipal forests and private owners take an individual approach to logging operations. They either do it by themselves or through outsourced services – depending on the economic efficiency.

3.3.4 Estonia

Wood is harvested by private companies in Estonia. The distinctive feature of the 1990s was the rapid growth of harvesting volumes and the transition from the tree-length method to the cut-to-length method. The share of mechanized harvesting also started to grow. In 1995 there were only approx. 20 modern forwarders and 10 harvesters in Estonian forests (Muiste at al. 2006). Today, mechanized harvesting dominates. Over 95% of final fellings are made by harvesters (up to 100% in state forests), as are over 80% of thinning operations.

The estimated total number of machines of cut-to-length technology is: 220–250 harvesters, 300–350 forwarders and 1000 agricultural tractors with self-loading trailers.

3.3.5 Latvia

Timber is harvested by private companies. Several thousand companies declared forest operations as one of their business activities; however, most of the felling operations are carried out by less than 50 companies. There is no accurate statistics about harvesting methods, but it is estimated that about 70% of wood is cut by using the fully mechanized CTL method; 30% (mostly for thinning and low valued deciduous stands) is cut by chainsaws. The distribution and number of forest machines (estimated) is: 312 harvesters, 1024 forwarders (some of them are agriculture tractors with trailers, which cannot be distinguished in the statistics), and 281 skidders.

The average cost in 2015 was 16.54 €/m³ for final felling, including harvesting, off-road transport and delivery to customer (CSB 2015). For specific operations, the costs were 5.70, 4.94, and 5.90 €/m³ respectively; the average cost of thinning was 21.6 €/m³ (9.39, 6.14, and 6.07 €/m³, respectively). Harvesting costs are mostly affected by the type of felling (thinning or final

felling) and forwarding conditions (soil bearing capacity and forwarding distance). Species do not have a significant impact on harvesting costs.

3.3.6 Lithuania

Private logging companies dominate in Lithuanian forests. Contractors harvested 90% of timber procured in state forest enterprises. Chain saws, forwarders or agricultural tractors with self-loading trailers are used in the highly mechanized harvesting of the CTL method in Lithuania. Recently, timber harvesting by chainsaws is being replaced with harvesters (Mizaras at al. 2008).

In accordance with the data provided by the Register of Tractors, self-propelled agricultural machines and their trailers, 47 harvesters were registered in Lithuania in 2008 (Steponavičius and Zinkevičius 2010). It is estimated that nowadays there are about 90 harvesters and 170 forwarders operating in Lithuanian forests.

3.3.7 Poland

Despite the fact that most forests belong to the state, a private forestry services sector has developed in Poland since the beginning of the 1990s. At this time, about 98% of the work associated with harvesting and extracting timber is carried out by such firms. The tree-length method continues to dominate in mature stands, with the use of chain saws for cutting trees and skidders or agricultural tractors for wood extraction. The number of operational skidders is estimated to about 1500 machines. In younger stands, the CTL method is partially used, as well as agricultural tractors with self-loading trailers.

In 2004, there were about 15 harvesters operating in Poland. The level of mechanization in forestry was then relatively low (Moskalik 2004). In recent years, rapid changes related to forest operations have been observed in Poland. A growing number of harvesters, an increased volume of harvested timber and a larger proportion of broadleaved species are considered the most important. There were 368 harvesters reported in the survey in early 2014, although at the end of 2015, this number rose to 530 machines (Mederski et al. 2016b). With such a number of machines, the level of mechanization with the harvester-forwarder system should be estimated to about 20%.

On average, last year the cost of wood harvesting was 6.5 €/m³ for cutting-delimbing-bucking and 5.65 €/m³ for extraction. Special tender auctions are organized each year in every forest district and there is one cost of logging, which is not dependent on the cutting category, tree species or extraction distance.

3.3.8 Romania

Romanian timber harvesting operations still rely heavily on the use of motor-manual tree felling and processing followed by skidding, carried out mostly by Romanian-produced wheeled winch skidders (Borz 2015, Sbera 2007, Sbera 2012). About 98% of the work is done with chainsaws and only 2% by feller-bunchers and harvesters. In 2012, Romania had about 35 harvesters and forwarders (Sbera 2012),

There are some reasons for this particular situation. While the Romanian Forest Code states that preference should be given to cable yarding in mountainous and hilly forests to protect the soil, there is a lack of cable yarding operators at the national level (Oprea 2008). The transition to a market economy left the Romanian timber harvesting industry with a serious lack of qualified personnel for cable yarding operations. The number of existing cable yarders was estimated to about 135 in 2012 (Sbera 2012).

In 96% of cases, wood extraction is done using Romanian and foreign tractors, including forwarders, and only in 4% of cases by other equipment, such as cable yarders.

The most often used harvesting methods are the tree-length and cut-to-length methods, with intermediary adaptations depending on the equipment used and operational conditions. The tree-length method is usually implemented in mountainous and hilly regions when extracting the wood by skidders. The cut-to-length method is used in lowland forest areas when procuring firewood directly from the stump. It is also used in mountainous forests in the process of aligning the cable yarding capabilities to the size of extracted wood or to the spatial limitations of the cable yarding corridors (Borz at al. 2015). The full tree method is forbidden by law (MO 2011) in order to limit the environmental impact of logging.

3.3.9 Slovakia

In Slovakia, wood is mostly harvested by subcontractors. There is only one state-owned enterprise, which harvests and transports timber – Forestry Mechanization of the Forests of the Slovak Republic, a state enterprise. This enterprise harvests about 5% of the annual cut. It owns 3 harvester-forwarder units, and 20 cable cranes.

The exact number of mechanized units used in the harvesting process and their exploitation in the annual harvest of timber are not known today because of the lack of data. Chainsaw work is still most commonly used in felling operations – about 95% of annual felling is done this way. The rest is performed by the three state-owned harvesters and private ones (the

actual number is unknown, but most probably it is less than 10).

The estimated percentages of individual mechanized means of extraction, based on the latest data available from 2006 (Green Report 2007) were: horses (8%), cable cranes (8%), agricultural tractors with winches (37%), skidders (45%), and forwarders (2%).

The average costs of individual operations of timber harvesting are as follows: felling – 10.79 €/m^3, transportation from the stand to the forest landing (mainly by skidding) – 7.89 €/m^3, log bucking – 2.52 €/m^3.

3.3.10 Ukraine

To perform certain types of work, including logging, state forest enterprises use their own workers or private contractors that have the appropriate licence. In 2015, about 83% of logging operations were performed with own technical equipment.

Practically, all harvested timber is obtained using the chainsaw. Only a few harvesters are encountered (9 machines in 2015). Two methods of harvesting dominate: in lowlands – chainsaw and agricultural tractor with a trailer/winch or skidder; in the Carpathians – chainsaw-cable system-skidder). Wood is transported to the customer mainly as logs of 2–4 m in length (82–87%).

4. Discussion

One of the primary functions of sustainable forest management, among others, is the broadly understood concept of the forest utilization, which also includes logging. Logging carried out in accordance with the rational planning of silviculture and forestry work, taking into account the protective functions of forests and socio-economic needs, is an activity that helps in forming stable and sustainable ecosystems. However, this field has been undergoing profound transformation in recent years. In practice, it must strive for profound harmony in reconciling environmental requirements, ergonomics and work safety and the appropriate effectiveness of performed tasks, using specialized techniques and technologies (Paschalis and Moskalik 2000).

In Eastern European countries, at the beginning of the economic transformation, when the private forestry services sector was being established, the equipment acquired was of low technical quality. Enterprises owned mainly chainsaws and small numbers of archetypal forest machines, such as tractors with grapples or winches; they rarely had forwarders. Additionally, some of the companies kept horses, especially for use in mountainous regions.

Increasing competition in the forestry services set off a search for new technological solutions to decrease labour costs and increase work efficiency. Many entrepreneurs invested in specialised machinery for timber harvesting despite growing financial difficulties and other challenges. Some forest service companies were able to obtain subsides from EU funds (Kocel 2010).

With each year, also in the analysed region, the level of mechanization in logging is increasing, but the variation between countries is great due to the availability of personnel, fear of unemployment and the rate of investment capability. The rate of investment for mechanization also depends on the regional availability of skilled workers. The complexity of operating high-end forest machines demands a long training period for operators before the person-machine unit can reach its full productivity (Asikainen et al. 2011). In terms of this issue, there is very much to be done in Eastern European countries.

Mechanized forest logging processes using harvesters and forwarders have vastly increased in some parts of the region, especially in the Baltic countries. 60% of Eastern European harvesters are mainly small and medium class machines. In terms of forwarders, the most popular size class is final felling forwarders (Malinen at al. 2016). In the remaining countries, chainsaws and agricultural tractors with trailers are still used to a great extent to harvest shortwood.

Introducing modern technologies is linked to the need to gain access to tree stands (Stereńczak and Moskalik 2015, Pentek at al. 2008). However, the area of strip roads should not exceed 20% of the stand area. This limitation mainly affects thinning operations and generally no regulations exist for the final felling. Considering the average width of a strip road (4 m), the standard distance between strip roads is 20 m.

5. Conclusions

The social and economic changes, which began in the countries of Eastern Europe in the early 1990s, also led to the restitution or privatisation of forests. Of the countries under analysis, only Belarus, Ukraine and Poland have not introduced such changes. It should be noted that, except for Belarus and Ukraine, the analysed countries are currently members of the European Union.

All of the analysed countries have public companies that manage national forests. These companies entrust most of the field work of harvesting and extraction to private contractors. This work is carried out

by the state only in Ukraine. The owners of private forests harvest timber primarily with their own equipment.

In recent years, we have seen a dynamic growth in the use of the cut-to-length method using a harvester and forwarder to obtain wood. This applies especially to the Baltic countries. The leader in this respect is Estonia, where over 95% of final felling and over 80% of thinning operations are performed by harvesters. The lowest level of mechanization of logging processes is seen in Bulgaria, Romania, Slovakia and Ukraine.

The tree-length method is still dominant in all countries of Eastern Europe, with the exception of the Baltic countries. This method is based, in most cases, on using chainsaws and skidders or agricultural tractors with self-loading trailers. In mountainous regions, cable yarding systems are also used.

While the total productivity of the work methods used to obtain wood is comparable to the results obtained in other EU countries, unit costs, particularly with the less mechanized technologies, are at a lower level. This is mainly due to the availability of relatively cheaper labour.

6. References

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