



Analysis of Forest Machinery in the Area of Una-Sana Canton B&H

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Abstract – Nacrtak

This study analyzes the state of mechanization and productivity in forest operations conducted by the Public Forestry Company »Unsko-Sanske Šume« Ltd. Bosanska Krupa (PFC) and private contractors in the Una-Sana Canton (Bosnia and Herzegovina). Data were collected through structured questionnaires targeting both the public company and eight private enterprises involved in felling, skidding, forwarding, and timber transport. Findings indicate that felling and processing are exclusively performed using chainsaws, without the integration of harvesters or modern mechanized systems. The average age of chainsaws is relatively low (2.44 years), reflecting routine replacement, particularly within private enterprises. In contrast, skidders and trucks demonstrate significant technical obsolescence, averaging 26.1 and 17.8 years, respectively. Forwarders constitute the most modern segment of mechanization, with an average age of 12.75 years and daily productivity between 100 and 135 m³. Skidders, primarily Timberjack and LKT models, achieve daily outputs ranging from 24.1 to 35 m³, while newer forwarders, including John Deere and Ponsse models, exhibit substantially higher productivity. Trucks, used for long-distance transport, display consistent outputs of 28–30 m³/day. Comparative productivity analysis reveals that the performance of locally used machinery is in some cases competitive with, but often inferior to, international benchmarks due to challenging terrain and outdated equipment. Despite partial modernization efforts, the overall mechanization level remains modest, particularly in the public sector. Regulatory constraints, limited capital investments, and aging equipment continue to hinder the technological advancement and economic viability of forestry operations in the region.

Keywords: forest mechanization, productivity, skidders, forwarders, chainsaws, Bosnia and Herzegovina

1. Introduction – Uvod

Tree felling and processing in forestry operations in the region are predominantly performed using chainsaws, while timber extraction is generally mechanized and transport is conducted by trucks. Selecting appropriate work technology remains a significant challenge throughout these processes. Long-term planning, grounded in sustainability principles and income continuity, informs the selection of machinery appropriate to specific conditions. The assortment method is commonly applied in timber harvesting and processing in the region, with the choice of method determined by stand conditions and the technical and technological capacities of extraction machinery (Marčeta et al. 2014). Following post-war sociopolitical changes

in Bosnia and Herzegovina, the forestry sector experienced a partial and uncoordinated privatization process, leading to modest outcomes. Nevertheless, the number of private forestry companies continues to increase, with many striving to enhance mechanization levels. Effective utilization of forest machinery requires comprehensive knowledge of new equipment, as well as machines modified through adaptation, reconstruction, or upgrading. Assessing the environmental acceptability of mechanization necessitates an understanding of technical characteristics and the establishment of ecological criteria, which are crucial for evaluating forest machinery and certifying forest operations. A fundamental objective of mechanization is to alleviate the human burden of physically demanding and hazardous forest work (Krpan and Poršinsky 2004). Mechaniza-

tion in primary timber transport serves as a means to replace manual labor, improve efficiency, and support optimal forest management (Horvat 1993).

The mechanization of forestry operations in general began nearly two and a half centuries ago, paralleling the formal development of forestry as a profession (Matić 2011). Mechanized tools in local region were first introduced in the 1950s, starting with two-operator chainsaws, which were soon replaced by more efficient single-operator models by the early 1960s. The 1970s marked the introduction of specialized forest machines for timber skidding (Bedžula and Slabak 1974). Formal mechanization in Croatia commenced in 1948 with the adoption of chainsaws and agricultural tractors, reducing physical labor though initially lacking fully adapted forest-specific machinery (Sever 1993, Horvat and Tomašić 2003). Timber harvesting methods, including mechanization levels and felling techniques, are primarily influenced by stand composition and terrain conditions (Krpan et al. 2003). Felling and processing, along with skidding, constitute the two principal phases of wood utilization, and their technological evolution has been shaped by regional forest management practices and terrain features (Tomašić 2012).

Contemporary forest work technologies integrate tools, techniques, and organizational systems adapted to production goals and site conditions (Kulušić 1977). Timber harvesting methods vary and include assortment-based systems, roadside processing, and centralized mechanized depots. The cut-to-length (CTL) system, particularly suited to hilly terrains and selective cutting, remains prevalent (Rebula 1988, Nikolić 1993, Krpan and Poršinsky 2004). FAO's classification identifies five harvesting systems, each offering varying mechanization and ecological compatibility (Pulkki 1997). Mechanization development is categorized into partial mechanization, full mechanization, and full mechanization with partial automation (Kulušić 1977).

Equipment selection of primary timber transport depends on geographical and climatic factors, tree morphology, assortment ratios, terrain slope, distance, and load dimensions (Sever 1980). Skidders, equipped with articulated steering, four-wheel drive, and protective safety cabins (ROPS, OPS, FOPS), are specialized for log skidding and exhibit superior mobility under forest conditions (Šušnjar et al. 2010, Šušnjar 2005, Horvat 1990). In lowland forests, forwarders dominate final cut operations, while skidder-based systems are typical for thinning. Forwarders offer environmental advantages, reduced soil damage, and enhanced operational safety (Pandur et al. 2014, Poršinsky 2005).

The transition from manual labor to mechanization has reshaped forestry operations, with the structure of mechanization, comprising machine types, ages, and models, playing a decisive role in harvesting performance. Modern systems vary in mechanization degree: motor-manual systems employ chainsaws and tractors or skidders; semi-mechanized systems combine manual and mechanized methods; and fully mechanized systems utilize harvesters and forwarders or skidders without manual felling (Labelle and Lemmer 2019). Fully mechanized systems achieve significantly higher productivity than motor-manual approaches (Moskalik et al. 2017).

Chainsaws remain versatile and essential in difficult terrains but offer lower productivity compared to mechanized felling, with performance heavily influenced by operator skill and equipment design (Moskalik et al. 2017). Skidder productivity varies by machine power, terrain, skidding distance, and log size, with larger, modern skidders delivering higher outputs and reduced downtime (Kluender et al. 1997, Moskalik et al. 2017, Ghaffariyan 2020, Holzleitner et al. 2011). Forwarders, integral to CTL systems, demonstrate high efficiency and minimal environmental impact, with productivity influenced by forwarding distance, load volume, and machine capacity (Ghaffariyan 2022, Moskalik et al. 2017).

Logging trucks complete the harvesting process, transporting timber from roadside landings to processing facilities. Truck fleet characteristics, including age, capacity, and configuration, significantly impact transport efficiency and safety (Dowling 2010, Jankovský et al. 2019, Smith and Tse 1977).

Machine age and condition critically affect performance and productivity. Older machines often experience increased maintenance requirements and reduced reliability, whereas newer models offer improved efficiency and safety features (Malinen et al. 2016). The optimal alignment of machine type, age, and technological capabilities is essential for achieving high productivity, operational safety, and environmental sustainability in modern forestry operations.

In the area managed by the Public Forestry Company »Unsko-Sanske Šume« Ltd. Bosanska Krupa, the assortment method is used for timber harvesting and processing. The choice of method depends on stand conditions and the technical and technological capabilities of the extraction machinery. Current forest exploitation practices in Bosnia and Herzegovina operate under conditions of relatively low labor costs and limited investment capacity. Forest infrastruc-

ture remains poor in both entities, and most contractors are small-scale to medium operators.

The aim of this research is to analyze the state of mechanization and work technologies used in the area of the Una-Sana Canton (USC) and to determine the machinery available for forest exploitation during the stages of felling and processing, skidding, and transport in the Public Forestry Company »Unsko-Sanske Šume« Ltd. Bosanska Krupa (PFC in further text) and private enterprises performing operations in the area of Una-Sana Canton.

The study hypothesizes that the level of technological development and forest utilization in the researched area is significantly lower than in developed countries and that substantial differences exist between private entrepreneurs and the state-owned company regarding mechanization development, workforce structure and productivity.

2. Materials and methods – *Materijal i metode*

Forests represent one of the greatest natural resources of the Una-Sana Canton (Fig. 1). The total forest area covers 190,880 ha, of which 85,899 ha consist of high forests, 86,234 ha consist of low forests, while barren land occupies 18,747 ha. The PFC operates through a central directorate and several organizational units, including forest management units, a nursery, and a construction and maintenance unit, distributed across six municipalities: Bihać, Bosanska Krupa, Bosanski Petrovac, Cazin, Ključ, and Sanski Most.



Fig. 1 Una-Sana Canton in B&H

Slika 1. Unsko-sanski kanton u BiH

The data used in this research was collected through a survey questionnaire distributed to the PFC and the owners of private companies engaged in logging, processing, and extraction. The questionnaire consists of 29 questions. A sample of 5 questionnaires was collected from PFC (5 forest administrations), and 8 questionnaires were collected from private entrepreneurs operating in the area studied. The data for the PFC, although collected separately for each management unit, are presented in aggregate for the entire PFC.

3. Results and discussion – *Rezultati i rasprava*

3.1 Analyzed companies – *Analizirana poduzeća*

The survey, beside PFC, covered eight private forestry contractors engaged in logging, processing, skidding, and timber transport: d.o.o. LELIĆ – KOMERC, KH – JAVOR Bihać, LOZIĆ d.o.o., Lonić – Comp d.o.o., FF – HS d.o.o. Bihać, d.o.o. Mele – Company Bosanski Petrovac, MUŠANOVIĆ d.o.o. Bosanski Petrovac, and S.M.A invest Hadžipašić. These enterprises are based in Bosanska Krupa, Bihać, and Bosanski Petrovac. According to the data based on the response, the founding years of these companies range from 2001 to 2020, with KH – JAVOR Bihać and d.o.o. LELIĆ – KOMERC being the oldest established.

PFC employed 741 workers with varying qualifications, the majority holding secondary education (SE), while 137 employees had higher education (HE). Most of the workforce was aged between 50 and 65, with the fewest employees in the 18 to 30 age group. In contrast, the private companies surveyed employed a total of 153 workers, including 104 permanent and 49 temporary staff. Most private sector employees also had secondary education, with only two holding higher education degrees. The largest private employer was d.o.o. Mele – Company Bosanski Petrovac, while d.o.o. LELIĆ – KOMERC had the smallest workforce. The age distribution in the private sector showed most workers aged between 30 and 50, differing from the public company's older workforce.

The total average annual output of all surveyed companies, including the public enterprise and private contractors, amounts to approximately 701,271 m³. The PFC contributes the largest share with 413,271 m³, while among private companies, d.o.o. Mele – Company Bosanski Petrovac has the highest output at 80,000 m³. Most private enterprises report

outputs ranging from 10,000 to 50,000 m³, reflecting their smaller operational scale compared to the public company. The methods of work vary, with some performing the entire technological process, while others focus solely on felling, processing, and skidding without loading or transport (Table 1).

Table 1 Employees and annual output

Tablica 1. Zaposlenici i godišnja proizvodnja

Company name <i>Ime poduzeća</i>	Number of employees, N <i>Broj zaposlenika, N</i>	Average ann. output, m ³ /year <i>Prosječan godišnji učinak, m³/god.</i>	Forest utilization operations <i>Operacije iskorištavanja šuma</i>
PFC	741	413,271	Felling and processing, skidding, timber transport with loading.
d.o.o. LELIĆ – KOMERC	12	10,000 - 12,000	
KH – JAVOR Bihac	17	20,000	
Lonić – Comp d.o.o.	23	30,000 - 35,000	<i>Sječa i izrada, privlačenje te prijevoz drva s utovarom.</i>
LOZIĆ d.o.o.	20	50,000	Felling and processing with skidding, without loading and without timber transport.
FF – HS d.o.o. Bihac	16	40,000 - 45,000	
d.o.o. Mele – Company Bosanski Petrovac	37	80,000	
MUŠANOVIĆ d.o.o. Bosanski Petrovac	15	40,000	<i>Sječa i izrada s privlačenjem,</i>
S.M.A invest Hadžipašić	13	13,000 - 15,000	<i>bez utovara i bez prijevoza drva</i>

In Croatia, for example, the majority of forestry contractors are small-scale enterprises, where most entrepreneurs meet only the minimum legal and technical requirements, typically engaging in low-volume harvesting activities (up to 8,000 m³ of net volume per year) (Šporčić et al. 2017). These small businesses often lack advanced mechanization and rely on modest technical resources, although they collectively perform a substantial share of forest operations, particularly in state-owned forests where they conduct about 26% of felling, 41% of skidding and forwarding, and 82% of log transportation (Šporčić et al. 2017). Kronholm et al. (2021) concluded that most enterprises in Sweden were small, often consisting of sole proprietorships or small limited liability companies, with a strong dependence on a limited number of clients and long-term contracts. Similarly, in Finland, Jylhä et al. (2020) observed that small contractors (< 0.6 million EUR turnover) generally demonstrate lower profitability and reduced mechanization levels, with a median workforce of three to five employees. In Slovakia, studies have identified that most forestry contractors are micro-enterprises, frequently

relying on family labor or a minimal external workforce (Štěrbová and Kovalčík 2020).

3.2 Felling and processing – *Sječa i izrada*

The research results revealed that felling and processing operations are performed exclusively with chainsaws, with no harvesters or other modern mechanized equipment in use. According to survey data, the PFC owns a total of 50 chainsaws, with the highest concentration in the Bosanski Petrovac and Sanski Most branches (20 chainsaws), while the Cazvin and Ključ branches have the fewest (14 chainsaws). In contrast, private companies collectively own 95 chainsaws. The largest number is held by d.o.o. Mele – Company Bosanski Petrovac (19 chainsaws), while d.o.o. LELIĆ – KOMERC has the fewest (8 chainsaws). Among private entrepreneurs, the most common model is the Stihl 440, representing 27% of all chainsaws, followed by Husqvarna 365 and 372, each accounting for 17% (Fig. 2). The Stihl 462 is the least common (1%). Stihl chainsaws dominate in number, accounting for approximately 70% of the total chainsaws, while Husqvarna models represent around 30%. Overall, private enterprises possess significantly more chainsaws than the public company, largely due to the higher number of workers involved in felling and processing operations in the private sector.

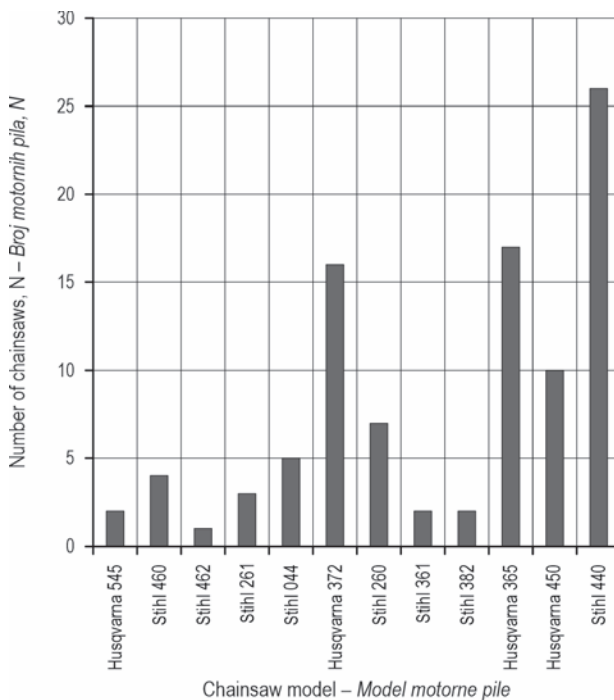


Fig. 2 Number and models of chainsaws in private companies
Slika 2. Broj i modeli motornih pila u privatnim poduzećima

The analysis of chainsaw age among private forestry companies revealed that 14% of chainsaws are less than one year old, 60% are between one and two years old, 16% are between two and three years old, and only 10% are older than three years. In contrast, 54% of chainsaws in the PFC are older than three years, with no chainsaws less than one year old. The average age of chainsaws used across both the public company and private enterprises is approximately 2.44 years, indicating relatively frequent replacement and good equipment maintenance practices, particularly in the private sector. These results indicate that private entrepreneurs regularly renew their chainsaw fleets, prioritizing technological advancement and worker safety. Modern chainsaws offer improved ergonomics, reduced weight, lower noise and vibration levels, and decreased exhaust emissions, contributing to safer and more efficient operations. According to Halilović et al. (2015), a comprehensive survey covering public forest companies and private contractors identified a total of 506 chainsaws in active use, with 328 owned by forest companies and 178 by private contractors. The age structure of the chainsaws indicated a relatively modern fleet: 47.5% of all chainsaws were between one and two years old, resulting in an average age of 2.35 years. The relatively young age structure of chainsaws in the private sector reflects a proactive approach to equipment modernization and occupational health, unlike the PFC, where aging equipment may pose operational and safety challenges (Table 2).

Table 2 Age of Chainsaws**Tablica 2.** Starost motornih pila

Company name <i>Ime poduzeća</i>	Age, year <i>Starost, god.</i>			
	0 - 1	1 - 2	2 - 3	3 <
PFC		23		27
d.o.o. LELIĆ – KOMERC		4		4
KH – JAVOR Bihac	2	5	2	3
LOZIĆ d.o.o.	2	5		3
Lonić – Comp d.o.o.	1	13	2	
FF – HS d.o.o. Bihac	2	7	2	
d.o.o. Mele – Company Bosanski Petrovac	5	9	5	
MUŠANOVIĆ d.o.o. Bosanski Petrovac		7	2	
S.M.A invest Hadžipašić	1	7	2	
Total – <i>Ukupno:</i>	13	80	15	37

The average number of operating hours per working day (h/day) with chainsaws varies slightly

among the surveyed companies, ranging from 5.27 h in the public company »Unsko – sanske šume« to 6.33 h at d.o.o. LELIĆ – KOMERC. Private companies generally report slightly longer operating hours, reflecting potentially higher workloads or different organizational practices compared to the public company. The variability in chainsaw use was influenced by factors such as the complexity of the tasks, species being cut, and the requirement for additional manual tools in certain treatments (Marchi et al. 2017). These findings underscore that while an official shift may last between 6 and 8 hours, actual chainsaw operation typically ranges between 3 and 5 h/day, with the remainder spent on preparatory, auxiliary, or delay tasks. Regarding average fuel consumption (l/m³), the values range from 0.25 l/m³ (the lowest, recorded by the public company) to 0.32 l/m³ (the highest, recorded by d.o.o. LELIĆ – KOMERC). Most private companies report fuel consumption between 0.26 and 0.31 l/m³. Overall, the results suggest that private companies achieve slightly longer daily operating times and slightly higher fuel consumption (Table 3). Popovici (2013) determined average consumption rates of 0.42 l/m³. Pandur et al. (2015) 0.34 l/m³ and Halilović et al. (2019) conducted a study in the Forest Office »Zavidovići« to evaluate fuel consumption rates of two chainsaw models – Husqvarna 365 and Dolmar PS-7310 and indicated that the average fuel consumption was 0.306 l/m³ for the Husqvarna 365 and 0.264 l/m³ for the Dolmar PS-7310.

Table 3 Operating hours and fuel consumption**Tablica 3.** Radni sati i potrošnja goriva

Company name <i>Ime poduzeća</i>	Operating hours, h/day <i>Radni sati, h/dan</i>	Fuel consumption, l/m ³ <i>Potrošnja goriva, l/m³</i>
PFC	5.27	0.25
d.o.o. LELIĆ – KOMERC	6.33	0.32
KH – JAVOR Bihac	5.6	0.29
LOZIĆ d.o.o.	5.5	0.31
Lonić – Comp d.o.o.	5.4	0.26
FF – HS d.o.o. Bihac	6	0.27
d.o.o. Mele – Company Bosanski Petrovac	5.83	0.31
MUŠANOVIĆ d.o.o. Bosanski Petrovac	6.25	0.28
S.M.A invest Hadžipašić	5.75	0.31

Both the PFC and private enterprises organize their felling and processing work using teams con-

sisting of one chainsaw operator and one assistant worker, a system well-suited to the cut-to-length method applied in the region. Chainsaw operations in European forestry are generally recommended to be performed by a team consisting of the operator and at least one assistant, as working alone has been associated with significantly higher accident rates (Robb and Cocking 2014).

3.3 First transport phase – *Prva faza transporta*

The research results show that the first phase of timber transport in both the PFC and private enterprises relies exclusively on the use of skidders and forwarders. The PFC operates a total of 10 skidders, and private sector owns a total of 40 skidders and forwarders, with the highest concentration (8 units) held by d.o.o. Mele – Company Bosanski Petrovac, and the lowest (3 units) by d.o.o. LELIĆ – KOMERC. The organization of work during timber skidding is uniformly based on the formula 1 + 0, where a single operator performs all tasks, including driving, winch operation, and load handling.

The analysis shows that both the public and private companies predominantly use skidders of the Timberjack and LKT brands, along with several John Deere and Hittner EcoTrack models. The most commonly used skidders in the private sector are various Timberjack models (240 A, B, C, D), which belong to the medium-heavy and heavy categories. The PFC primarily relies on the LKT 81 T and HITTNER EcoTrack models (Table 4). In terms of age, the majority of skidders in both the public and private sectors are quite old, often exceeding 25 years. The oldest are found in the public company, with the LKT 81 T models averaging 28 years, while the private sector shows a similar trend, with most Timberjack skidders being between 26 and 30 years old. An exception is the HITTNER EcoTrack (6 years) and John Deere 540 G (17 years). Skidders show a significantly high average age of 26.1 years, reflecting the continued use of older machinery, especially in the public company. Halilović et al. (2015) established that the majority of skidders were significantly aged, with 76% of public sector and 57% of private sector exceeding ten years of service. Halilović et al. (2015) also stated that adapted agricultural tractors were also in use in B&H, albeit representing a minor share (3%), primarily among private operators. In this study, the companies did not report using adapted agricultural tractors. The average daily productivity of skidders varies between 24.1 m³ and 35 m³ per working day, with private enterprises gener-

ally achieving slightly higher outputs compared to the public company. In their investigation, Marčeta et al. (2024) achieved a daily productivity of 55.7 m³/day with Timberjack 350A 46.38 m³/day, surpassing the performance of the Ecotrac 120V reported by Horvat et al. (2007), where productivity was 35.54 m³/day. The Timberjack 240C achieved an average productivity of 11.6 m³/h, as reported by Sabo and Poršinsky (2005), and Porter and Strawa (2006) reported a productivity of 7.15 m³/h for the LKT 81T in mountainous conditions.

Table 4 Skidders structure and productivity

Tablica 4. *Struktura i proizvodnost skidera*

Company name <i>Ime poduzeća</i>	Models <i>Model</i>	Age, year <i>Starost, god.</i>	Productivity, m ³ /day <i>Proizvodnost, m³/dan</i>
PFC	LKT 81	28	24.1
	HITTNER EcoTrack	6	28
d.o.o. LELIĆ – KOMERC	Timberjack 240A	30	25 - 30
KH – JAVOR Bihac	Timberjack 240 A	26	30
	Timberjack 240 C	28	30
LOZIĆ d.o.o.	Timberjack 240 A	28	30 - 35
	Timberjack 240 C	26	30 - 35
Lonić – Comp d.o.o.	Timberjack 240 A	28	30
	Timberjack 240 B	27	30
	Timberjack 240 D	26	30
FF – HS d.o.o. Bihac	Timberjack 240 A	28	25 - 30
	Timberjack 240 D	27	25 - 30
	John Deere 540 G	17	30
d.o.o. Mele – Company Bosanski Petrovac	LKT 81 T	28	25
	Timberjack 240 A	26	30
	Timberjack 240 D	26	30
MUŠANOVIĆ d.o.o. Bosanski Petrovac	Timberjack 240 A	28	30
	Timberjack 240 B	27	30
S.M.A invest Hadžipašić	Timberjack 240 A	26	30
	Timberjack 240 D	28	30

The private companies use forwarders predominantly from two manufacturers: John Deere and Ponsse. The most commonly used forwarder models include the John Deere 1110 D, 1210 E, 1210 G, and 1410 D, along with the Ponsse Buffalo. The age of the forwarders ranges from 6 to 23 years, with the oldest being the John Deere 1110 D (23 years) used by d.o.o. LELIĆ – KOMERC, while the newest units, John Deere 1210 E and 1210 G, used by d.o.o. Mele – Company Bosanski Petrovac, are between 6 and 10 years old. Daily output is varying between 60 m³ and 135 m³ per working day. The highest productivity is achieved by newer forwarders operated by d.o.o. Mele – Company Bosanski Petrovac (135 m³), while even older machines like the John Deere 1410

D and the Ponsse Buffalo maintain high outputs ranging from 100 to 120 m³ (Table 5).

Table 5 Forwarders structure and productivity

Tablica 5. Struktura i proizvodnost forvardera

Company Name <i>Ime poduzeća</i>	Models <i>Model</i>	Age, year <i>Starost, god.</i>	Productivity, m ³ /day <i>Proizvodnost, m³/dan</i>
d.o.o. LELIĆ – KOMERC	John Deere 1110 D	23	60
LOZIĆ d.o.o.	John Deere 1210 G	12	120
FF – HS d.o.o. Bihać	John Deere 1410 D	19	110
d.o.o. Mele – Company Bosanski Petrovac	John Deere 1210 E John Deere 1210 G	10 6	135 135
MUŠANOVIĆ d.o.o. Bosanski Petrovac	Ponsse Buffalo	9	120
S.M.A invest Hadžipašić	John Deere 1410 D	17	100 - 120

Productivity of forwarders varies significantly depending on terrain conditions, extraction distances, and piece size. Marčeta et al. (2024) established productivity of 7.84 m³/h for 0.7 m³ pieces for HSM 208T. Borz et al. (2021) reported net productivity of 14.4 m³/h for the HSM 208F HVT-R2 forwarder. Proto et al. (2018) found productivity values ranging from 15 to 25 m³/h at an extraction distance of approximately 750 m, and about 15 m³/h for a John Deere 1110E. Proto et al. (2017) also recorded productivities of 14.4 and 15.7 m³/h, for John Deere 1110D and 1010D machines. On flat terrain, Pandur et al. (2018) noted productivity of approximately 18 m³/h at a 1.1 km extraction distance, while Dinev et al. (2015) found values between 44 and 53 m³/day for steep terrain at 0.8 km. Slamka and Radocha (2010) reported productivity of 11 m³/h for a payload of 12 – 13 m³ at 1.1 km on mild to moderate slopes. The high efficiency of forwarders in this investigation, higher than in studies presented, is largely the result of their combined use with skidders in most compartments, where skidders pre-haul the timber to main skid trails and forwarders collect and transport the logs to forest landings.

3.4 Second transport phase (long-distance transport) – Druga faza transporta (daljinski prijevoz)

The PFC operates a fleet of 8 timber trucks distributed across its management units, with vehicle ages ranging from 1 to 33 years and average daily

outputs between 25 and 30 m³ per day. The most commonly used truck models are IVECO TRAKKER 410, IVECO TWAY, and various Mercedes models. In the private sector, three of the surveyed companies, d.o.o. LELIĆ – KOMERC, KH – JAVOR Bihać, and Lonić – Comp d.o.o. own their own timber trucks, with fleets consisting mainly of Mercedes models aged between 5 and 26 years (average 17.8), achieving similar daily outputs (25 – 30 m³) (Table 6). Other private companies rely on external transport services. All trucks are equipped with hydraulic cranes and trailers that allow greater flexibility and efficiency in long-distance timber transport.

Table 6 Truck structure and productivity

Tablica 6. Struktura i proizvodnost kamiona

Company name <i>Ime poduzeća</i>	Models <i>Model</i>	N	Age, year <i>Starost, god.</i>	Productivity, m ³ /day <i>Proizvodnost, m³/dan</i>
PFC	MERCEDES 2631	2	28	25
	MERCEDES 2635	1	33	25
	IVECO TRAKKER 410	3	7	30
	IVECO AD 380T	1	28	30
	IVECO TWAY	1	1	30
d.o.o. LELIĆ – KOMERC	MERCEDES 2648	1	25	25 - 30
KH – JAVOR Bihać	MERCEDES 2646	1	14	30
Lonić – Comp d.o.o.	MERCEDES 2648	1	26	30
	MERCEDES 2646	1	21	30
	MERCEDES 3351	1	5	30
Total – <i>Ukupno:</i>		13		

Halilović et al. (2015) concluded that in FB&H trucks without hydraulic cranes were predominantly older than ten years (83%), while those equipped with hydraulic cranes, despite a slightly younger age profile, also exhibited significant wear, with an average age of 11.9 years. Notably, public enterprises operated exclusively older trucks, whereas 62% of the trucks used by private contractors were less than ten years old.

4. Conclusions – Zaključci

Forest exploitation in this region predominantly relies on the assortment method, which, although environmentally justified due to efficient preparation of timber for extraction, is characterized by a low level of mechanization and a high degree of manual labor. Both public and private operators per-

form felling and processing exclusively using chainsaws, as no harvesters or other advanced mechanized systems are in continuous use. Although in rare cases harvesters appear temporarily, typically through external companies, their broader application remains limited due to regulatory constraints. The current legislative and sub-legislative frameworks are not fully adapted to the operational and safety requirements of modern forestry machinery, particularly harvesters and cable yarding systems, which hampers technological advancement and adoption of mechanized solutions suitable for challenging terrain.

The average age of chainsaws is relatively low (2.44 years), reflecting periodic replacement, particularly in the private sector. However, skidders and trucks show a much higher degree of technical obsolescence, with average ages of 26.1 and 17.8 years, respectively. This is especially pronounced in the public company, where some machines have been in operation for nearly three decades. Forwarders constitute the most modern segment of mechanization, with an average age of 12.75 years, and demonstrate high efficiency, largely due to their combined use with skidders. In this system, skidders conduct pre-hauling to main trails, while forwarders collect and transport timber to roadside landings. The average daily productivity varies according to equipment and working conditions, with skidders achieving outputs between 24.1 and 30 m³ per day, and forwarders reaching outputs from 100 to 135 m³. Trucks used for long-distance transport demonstrate consistent performance, averaging daily outputs of 28 to 30 m³.

Despite some recent investments in newer forwarders and chainsaws, the overall mechanization within the public company remains largely outdated and only partially mechanized, which constrains the potential for productivity improvements, cost efficiency, and ergonomic advancements. Private enterprises have shown greater commitment to renewing their machinery, especially in the forwarder segment. This situation reflects a broader trend across many European forestry sectors, where private contractors have increasingly taken over operational tasks formerly executed by state enterprises, albeit often constrained by limited capital, machinery, and workforce qualifications (Šporčić et al. 2017). Logging contractors, who predominantly perform cutting and forwarding operations, exhibited the lowest profitability, largely due to high machinery investment costs, limited bargaining power, and a customer base dominated by a few large

forest companies (Kronholm et al. 2021). Jylhä et al. (2020) highlighted that larger contractors operating modern harvesters and forwarders consistently outperform smaller peers in productivity. Nevertheless, both sectors face the ongoing challenge of aging equipment in primary transport operations and the need for continuous modernization. Advanced age of many skidders suggests potential risks related to operational reliability, maintenance costs, and worker safety. The current reliance on older machinery highlights the urgency of strategic investment in modern forestry equipment and work technologies, supported by regulatory reforms that would enable the adoption of advanced mechanized systems such as harvesters and cable yarding. Only through such comprehensive modernization sustainable forest management, economic viability, and improved working conditions can be ensured in the future. Nevertheless, systemic challenges, such as price competition, capital constraints, and difficulties in recruiting skilled labor continue to hinder the growth and profitability of forestry contractors (Kronholm et al. 2021). Common challenges persist across regions. These include high capital investment requirements, volatile timber prices, client concentration risk (few buyers dominating the market), and difficulties in recruiting and retaining skilled machine operators (Penttinen et al. 2011, Eriksson et al. 2017).

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Sažetak

Analiza šumarskih strojeva u Unsko-sanskom kantonu (BiH)

Ovo istraživanje analizira stanje mehanizacije i produktivnost šumarskih radova koje provodi ŠPD »Unsko-sanske šume« d.o.o. Bosanska Krupa te privatni izvođači u Unsko-sanskom kantonu (Bosna i Hercegovina). Podaci su prikupljeni strukturiranim upitnicima usmjerenih na javno poduzeće i osam privatnih poduzeća koja sudjeluju u sječi, privlačenju, izvozu i transportu drva. Rezultati pokazuju da se sječa i izrada obavljaju isključivo motornim pilama, bez integracije harvesteri ili suvremenih mehaniziranih sustava. Prosječno motorne pile imaju relativno malo godina (2,44 godine) jer se redovito zamjenjuju, osobito u privatnim poduzećima. Nasuprot tomu skidéri i kamioni pokazuju značajnu tehničku zastarjelost, s prosječnom starošću od 26,1 odnosno 17,8 godina. Forvarderi čine najsuremeniji segment mehanizacije, s prosječnom starošću od 12,75 godina i dnevnom proizvodnosti između 100 i 135 m³. Skidéri, uglavnom marke Timberjack i LKT, postižu dnevne učinke od 24,1 do 35 m³, dok noviji forvarderi, uključujući modele John Deere i Ponsse, pokazuju mnogo veću proizvodnost. Kamioni, koji služe za transport na velike udaljenosti, ostvaruju stalne učinke od 28 do 30 m³/dan. Usporedna analiza proizvodnosti otkriva da je učinkovitost lokalno korištene mehanizacije u nekim slučajevima konkurentna međunarodnim standardima, ali je često inferiorna zbog zahtjevnoga terena i zastarjele opreme. Unatoč djelomičnim modernizacijskim naporima, ukupna razina mehanizacije ostaje skromna, osobito u javnom sektoru. Regulatorna ograničenja, ograničena kapitalna ulaganja i stara oprema i dalje ograničavaju tehnološki napredak i ekonomsku održivost šumarskih radova u regiji.

Ključne riječi: mehanizacija u šumarstvu, produktivnost, skidéri, forvarderi, motorne pile, Bosna i Hercegovina

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