ENVIRONMENTAL AND ECONOMIC ASPECTS OF WOOD HARVESTING FOR THE MAIN PRODUCTS BY MEANS OF HARNESSES. A CASE STUDY

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RESEARCH ARTICLE

Abstract
This paper discusses various aspects of wood collection using horses, emphasizing ecological and economic considerations. Seven felling areas within the Production Unit (P.U.) III Galbena of the Bihor Forestry Administration in Romania were selected. These areas feature progressive cuts, with the exploitation method being changed to a definitive and multiple wood system. This adjustment was made to yield smaller wood pieces suitable for collection with horses. Operating costs were calculated and compared under different scenarios, specifically analyzing the impact of wood collection with horses versus the traditional method using winches.
Three major factors were identified as having a significant influence on operating costs when using horses: average log volume, accessibility, and collection distance. Although the wood system itself has limited theoretical influence, cutting larger pieces is necessary to facilitate efficient horse-based collection in the forest.

Keywords: wood system, ecological collection, felling area, costs, collection variant
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INTRODUCTION

One of the oldest and most environmentally friendly methods of transporting wood is the use of horses or other draft animals. This method is gentle on the soil and vegetation and is ideal for delicate terrains where heavy machinery would cause significant damage. Moreover, this method is highly adaptable in mountainous areas where mechanized access is difficult (Mitchell & Malechek, 1983). Animal traction reduces soil compaction, prevents erosion, and allows for selective extraction, protecting forests and resources in the long term. Animal traction protects the soil and contributes to maintaining the integrity of forest ecosystems (Mitchell & Malechek, 1983).

The benefits of this method of wood collection are:

-Zero carbon emissions: Using animals does not produce greenhouse gas emissions, thus contributing to the protection of the atmosphere.

-Minimal impact on soil and vegetation: Horses do not cause significant soil compaction and can maneuver through rough terrain without damaging the vegetation.

-Adaptability: animal traction can be used in various conditions, including in protected forests or mountainous areas.

The advantages of environmentally friendly forest accessibility methods are:

-Reducing impact on soil and water: by using extraction methods such as cables, animal traction, or low-capacity equipment, soil impact is minimized, preventing erosion and protecting water resources.

-Biodiversity conservation: ecological exploitation methods allow the forest to maintain its biodiversity by protecting habitats and reducing fragmentation (Giurgiu, 2006).

-Long-term sustainability: these methods ensure the natural regeneration of forests and maintain their productivity in the long term without degrading the ecosystem.

-Reducing greenhouse gas emissions: Using electric equipment or animal traction helps reduce carbon emissions and combat climate change.

Some authors consider the use of animal traction as an ecological solution to gather wood (Horodnic, 2014), while other foreign authors argue that animals/horses should not be used in heavy forest labor in the 21st century (Romania has been criticized for using animals – horses and oxen – in the forest).

It can be said that the use of horses in the exploitation of wood is an ecological way of extracting wood. However, there are some requirements regarding the use of animals/horses in collecting logs. First of all, the weight of the logs should be as light as possible, so it is recommended to use the horses for hygiene and care work, especially when the volume of the average log is small, frequently below 0.45 cm. If horses are to be used in primary operations, then the logs must be much shorter in length. Thus,it is mandatory to change the method of exploitation to the shortwood system. The multiple assortment method is accepted, but the pieces must be manageable for the horses to pull.

Of course, climatic conditions, land conditions, the state of the trails, the species, the shape of the logs, the slope, and other factors influence the weight of the load and the distance the horses can haul the logs. A lighter weight and a shorter length of the pieces will cause much less damage to the remaining trees, soil, and seeds (Bereziuc, 2006; Horodnic, 2003). Collecting wood with draft animals is certainly an environmentally friendly method of collection.

The tools and means of collection are important factors influencing the operating costs (Oprea, Sbera, 2004). Thus, you can compare (Timofte, Enescu, 2019):

- Eco-friendly collection variants with less eco-friendly variants;
- Variants with a full assembly using a specific machine (tractor, cableway) with fragmented variants (e.g., using horses to assemble);
- Highly mechanized variants (with a high need for new roads) with less mechanized variants, etc.

When a single method is used for the collection operation, it is called integral collection with a tractor/cableway. When multiple methods are used for the gathering operation, such as draft animals and a winch, it is called fragmented collection. The same applies to the skidding and forwarding operations: they can be done entirely with a tractor or in a fragmented manner using a cableway and tractor.

MATERIAL AND METHOD

The study was carried out at the Sudrigiu Forest District, production unit III Galbena (fig. 1), and included the analysis of 7 felling areas proposed for operation in the period 2021-2023. Even though the necessary documents for valorization were prepared, the operation of these parcels was postponed due to reduced accessibility, in the absence of an adequate collection network (Irimie, Timofte, 2019). There are even no roads available for tractors.

The felling areas are provided with progressive cuts and range in age from 117 years old (stand 1832) to 128 years old (stands 1887, 1911). Other data, such as volumes, degree of accessibility, age, and slope, are presented in Table 1.

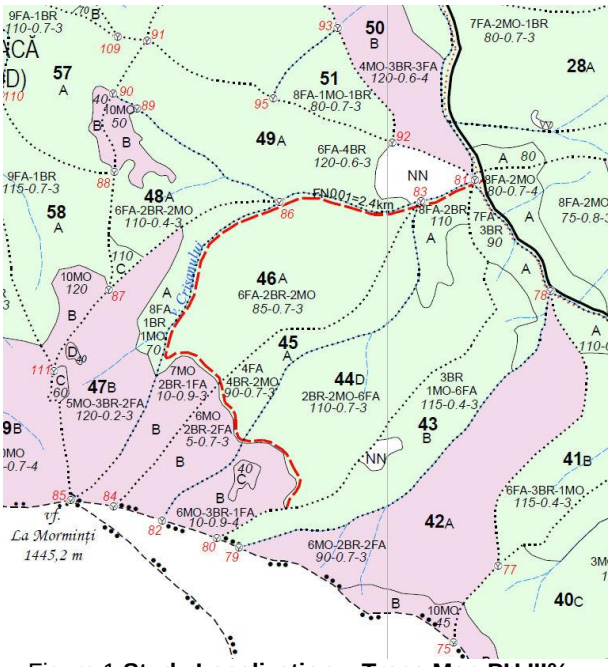

Figure 1 **Study Localization – Trees Map PU III%, Sudrigiu Forest District, Bihor Forest Administration (AS, 2014)**

To determine the costs of operation, as a working methodology, the initial data (general memo, felling plan) are entered into the program Deviz_exploatari.xls, on the initial data sheet (Timofte, 2012, updated). The program automatically determines the costs in a tabular format, and on the summary sheet, the unit tariff for the entire wood volume is shown, with/without crates, along with separate costs for logging residues in case they are brought to the platform.

Table 1

Data on analyzed partisans (Irimie, Timofte, 2023)

No. crt.	Coupe no./ year of inventory	Plots	Volume of the average tree, in m³/tree	Age, years	Area, ha	Volume, m3	Accessibility grade	Slope, degrees
1	742/2021	43B%	1.02	122	10.00	1964.0	3	30
2	1798/2021	43B%	1.15	122	5.00	1254.58	4	30
3	1802/2021	43B%	1.25	122	5.11	1507.27	4	30
4	1832/2021	48A%	1.25	117	5.50	926.25	4	25
5	1884/2022	48A%	1,11	118	9,29	1708,26	5	25
6	1887/2022	49A%	1,64	128	14,0	1652,11	3	34
7	1911/2022	49A%	2,10	128	10,0	1312,05	4	34
Total		-	-	-	58.9	10324.52	-	-

In order to facilitate the calculation of operating costs for a particular felling area, the program Deviz_exploatare.xls was used for the automatic calculation of volumes, time resources, and the fuel and lubricants required by operations and phases. Direct, indirect, and total expenses were determined based on the introduction of initial data characteristic of each forest district. The program also includes hourly rates as of 2023 and automatically applies the specific time norms used in wood exploitation works, specific fuel consumption (Ciubotaru, 1996), payroll grids, etc. The operating terms were taken from OM 1540/2011, updated by OM 487/2021.

A simulation is intended in which horses are incorporated into the gathering task in proportions of 20%, 40%, 60%, 80%, and entirely with horses (100%) of the harvested area, in place of the tractor-mounted winch. The purpose of this simulation is to show that as horses are increasingly used in the gathering operation, the costs will rise, reflecting the expense of this environmentally friendly method of extracting the wood mass compared to using tractor or cableway roads.

When using horses, the method of operation applied will be for final assortments. When using only winches mounted on tractors for the gathering operation, the method of operation will be in trunks and stems, which is also recommended in the APV.

For the horses, a maximum distance of 100 m was adopted in the calculations, and for the winch, the maximum distance given by the load cable (>50 m) was used. When using horses exclusively (fully assembled with horses), forming and tying the load to the tractor will require a minimum winch clearance (<15 m) in the calculations. These specifications are necessary because time norms and consumption vary depending on the gathering method and the distances over which the wood is collected.

RESULTS AND DISCUSSIONS

For the 7 felling areas, direct costs, fuel and lubricant costs, indirect costs and total costs were determined (Table 2).

Table 2

Centralization of the operating costs of the 7 felling areas by gathering with winch (>50m) and forwarding wood with forestry tractors

Calculated indices	Number of felling area						
	742/2021	1798/2021	1802/2021	1832/2021	1884/2022	1887/2022	1911/2022
Total costs, without crunch, lei	292328,89	146386,16	154479,45	100498,63	186314,15	166541,84	141084,46
Total costs, without crunch, lei/m³	122,15	125,38	110,33	118,37	116,50	107,37	116,40

In order to show that gathering with horses is more expensive than skidding the harvested parts with a winch, a simulation was conducted showing the influence of the two collection methods on the costs according to their weight. In Table 3 below, the following notations were used:

- ✓ T100 - the situation in which the collection is done entirely (100%) with the tractor;
- ✓ T80A20 - gathered with 80% winch, horses on 20% of the felling area;
- ✓ T60A40 - gathered with 60% winch, draft animals on 40% of the felling area;

✓ T40A60 - gathered with 40% winch, horses on 60% of the felling area;
✓ T20A80 - gathered with 20% winch, horses on 80% of the felling area;
✓ A100 - the operation is done entirely (100%) with animals/horses.

The values were obtained for skidding in the distance category >50 m for the first 5 situations and a distance <15 m for the last situation (A100), with the maximum distance to be gathered with the horses being 100 m.

Tabel 3

Operating costs, for the 7 felling areas with the method of gathering by pulling with winch on >50m and/or horses in different proportions, gathered with horses for a maximum distance of 100 meters

Felling areas	Costs, lei/mc	The way to collect, in different proportions, winch and/or horses					
		T100	T80A20	T60A40	T40A60	T20A80	A100
742	Direct - labor works	78,75	85,00	89,71	94,97	100,78	113,14
	Fuels and lubricants	13,43	12,81	12,30	11,96	11,79	12,09
	Indirect (expenses necessary for other activities required by the preparation and conduct of the operational works)	29,96	31,20	32,41	33,65	34,86	36,10
	Total costs	122,15	129,21	134,82	141,19	148,23	162,33
1798	Direct - labor works	71,34	77,55	82,23	87,45	93,22	107,53
	Fuels and lubricants	10,15	9,53	9,03	8,69	8,52	8,85
	Indirecte	43,89	44,34	44,78	45,22	45,64	46,09
	Total costs	125,38	131,62	136,44	141,97	148,18	163,47
1802	Direct - labor works	65,59	71,61	76,33	81,60	87,41	101,86
	Fuels and lubricants	7,24	6,61	6,10	5,76	5,58	5,92
	Indirecte	37,50	38,75	39,95	41,20	42,40	43,61
	Total costs	110,33	117,16	122,78	129,16	136,20	152,39
1832	Direct - labor works	66,63	72,35	76,87	81,95	87,57	101,07
	Fuels and lubricants	7,46	6,85	6,37	6,04	5,87	6,20
	Indirecte	44,29	44,74	45,19	45,61	46,06	46,48
	Total costs	118,37	124,14	128,82	134,19	140,30	154,75
1884	Direct - labor works	73,55	79,82	84,55	89,82	95,63	110,24
	Fuels and lubricants	9,63	9,00	8,50	8,16	7,98	8,32
	Indirecte	33,32	34,57	35,78	36,99	38,20	39,41
	Total costs	116,50	123,59	129,23	135,57	142,62	158,96
1887	Direct - labor works	67,23	73,29	78,03	83,32	89,14	103,86
	Fuels and lubricants	5,92	5,30	4,79	4,45	4,27	4,61
	Indirecte	34,21	35,46	36,67	37,88	39,08	40,29
	Total costs	107,37	114,25	119,90	126,25	133,30	149,75
1911	Direct - labor works	65,91	71,67	76,24	81,38	87,06	100,62
	Fuels and lubricants	7,79	7,16	6,66	6,32	6,14	6,47
	Indirecte	42,69	43,93	45,17	46,40	47,64	48,87
	Total costs	116,40	122,96	128,47	134,69	141,64	156,96

Additionally, the unit costs were represented in order of accessibility levels (from G1 to G5) and in order of increasing use of draft animals as a method of gathering wood, at the expense of winch usage (fig. 2).

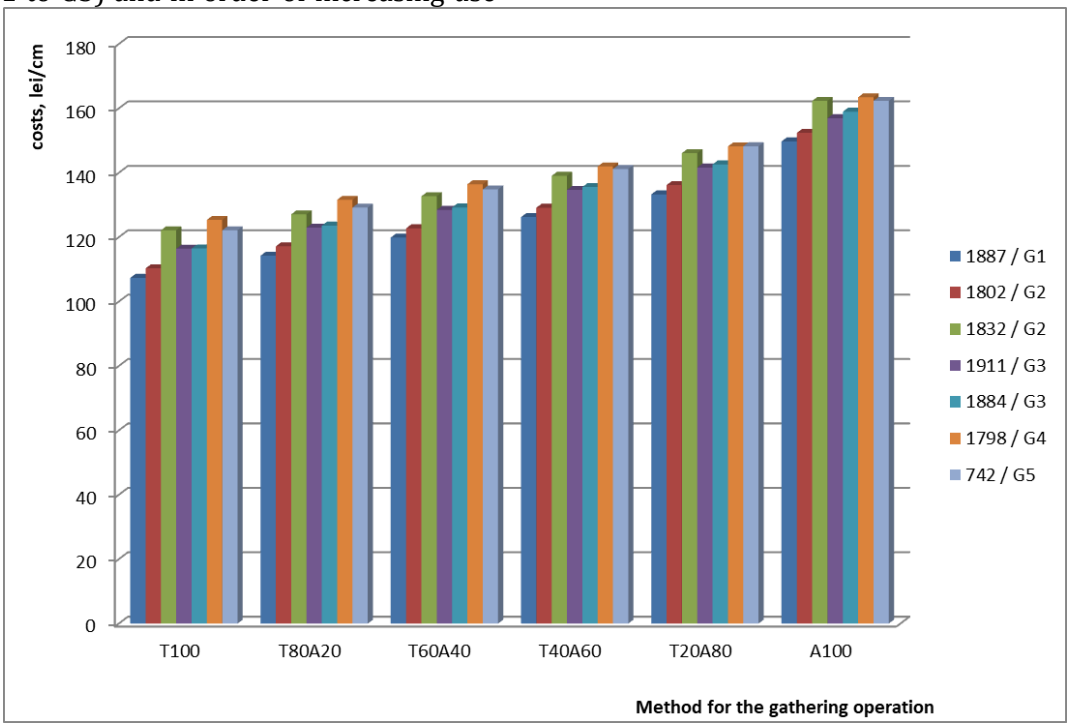

Figure 2 **Representation of the unit operating costs for the studied felling areas, depending on the method of gathering (horses and/or winches), in order of accessibility levels.**

CONCLUSIONS

Here is the revised version with "compartments" replaced by "felling areas":

Analyzing the results obtained in Figure 2 and Table 3, it is found that the addition of horses involves higher costs than the winch for all 7 analyzed felling areas, regardless of the degree of accessibility. There is a positive correlation between costs and the share of the operation to be gathered with the horses, but also between costs and the degree of accessibility.

Comparing the unit costs obtained by the simulation proposed as a case study, it is noted that the addition of horses has a significant influence, with the total operating costs increasing by 30.37% for stand 1798 to 39.48% for stand 1887 as the share of the horses increases from 0% (method T100) to 100% (method A100) to the detriment of the winch.

The skidding and forwarding operation method was only applied to full tractor collection (T100), and here the costs were the lowest for all 7 felling areas. For the other 5 situations (where the skidding is done partially or totally with the winches), the method was applied in final assortment, and the costs were higher.

Although the horses lead to higher costs, the length of the parts and their weight must be reduced to facilitate the work of the animals. There are measures that can be taken to reduce the effort of the animals when collecting: notching (beveling, rounding with the axe) the ends of the logs, cutting into pieces as short as possible, cleaning the logs at the face of the wood, moving on snow to make the effort as small as possible, arranging roads (paths) to be 1.5 meters wide with a maximum slope of 40%, helping to start the load, etc.

In conclusion, ecological methods for forest accessibility, such as the use of ecological forest roads, cableways, animal traction, and low-capacity equipment, contribute significantly to the protection of forest ecosystems. Implementing these solutions is essential to ensure sustainable exploitation while protecting biodiversity and essential natural resources. By applying these methods, forests can remain productive and functional in the long term, without compromising the ecological balance.

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