ECONOMIC ASPECTS REGARDING THE EXTRACTION OF WOOD USING HORSES: A CASE STUDY

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Abstract

This paper presents some aspects in the case of extracting wood with horses, insisting on its economic aspects. Three felling areas from production units P.U. V and P.U. VI, Marghita Forest District, Bihor Forest Administration were chosen. The areas included hygienic cuttings, thinning cuttings and progressive fellings, with small volumes of the average trees to allow extraction with horses. The logging costs were determined and then they were compared in different situations according to the share of extraction method by horses, respectively the traditional extraction by winches. The importance of determining unit rates to be grouped into group norms, centralized under the form of tables, with multiple inputs to estimate the logging costs as easily and accurately as possible was also highlighted. Thus, grouped norms have been drawn up for situations/variants of extraction by horses which render the unit costs in different situations. Three major factors that significantly influence the logging costs when using horses were identified, namely: the volume of the average tree, the degree of accessibility and the extraction distance by horses. The logging method has little influence, theoretically, but the cutting of large trees must be performed to facilitate the work by horses in the forest.

Key words: costs, felling area, horse skidding, logging technology, unit rates, volume of the average tree

INTRODUCTION

The logging costs are influenced by a number of factors [3], [10], but the chosen logging solution must be economically, environmentally and forestry optimal. Both the interests of the forester and the economic operator must be covered. In order to reduce the logging costs, the factors involved in the logging process must be analyzed and an optimal solution should be established, with minimal damage to the forest.

The extraction has a very large share in the logging process [4], (generally over 70% of expenses and physical work). Thus, choosing the extraction solution is an essential stage. Depending on the field conditions, the method of logging (wood system) is established and then the technology of logging is chosen. The logging technology is given by all the operations in their natural development order, necessary for the implementation of the adopted method and the optimal working solution [4], [9].

The means and methods of extraction are important factors that influence the logging costs. Thus, the following can be compared:
• ecological extraction variants with less ecological variants;
• variants with an extraction performed entirely by a certain machine (tractor, cable-way for logging), respectively with fragmented variants (e.g. by horse skidding);
• highly-mechanized variants (with a great need for new roads) with less mechanized variants, etc.

The working means must also be correlated with the minimum or maximum admitted slope gradient but also with the skidding and hauling distances, distinguishing thus between minimum, maximum admitted distances and optimum distances [8].

The degree of mechanization is given by the range of machines used, by the share of the mechanized activities at the expense of the operations executed manually or by horses.

Some authors consider the use of animals as an ecological solution for wood skidding [5],

[7], [12], but others believe that animals/horses should not be used in rough forest work in the 21st century (Romania has been criticized for using animals in the forest - horses and oxen).

The horse skidding is used in the felling areas located on a slope with a slope of less than 40%, in areas where extraction cannot be performed by winch up to the tractor road or the cable system. It is recommended for the extraction of short or multiple assortments, with small weights, for distances around 100-200m [6].

In this paper the logging costs obtained from the exploitation of three felling areas with and without horses are analyzed. A simulation is made regarding the costs in the case the share of the horse skidding operation increases at the expense of the winch skidding (pulled by winch mounted on the tractor).

The chosen felling areas are located within Marghita Forest District (Table 1), have an average slope, grade 3 of accessibility (average distance between 501 and 1,000 m), hill area, hardwood species and comprise three categories of works:
- Special cuts, hygiene cuttings;
- Care works, thinning cuttings;
- Regenerative, progressive fellings.

MATERIALS AND METHODS

With the help of a program made in Microsoft Excel, the logging costs were determined for the concrete situations in the field and a simulation was performed on how to extract the wood for three felling areas within production units P.U. V and P.U. VI, Marghita Forest District, Bihor Forest Administration [2] (Table 1):
- P1359134 E.V. (evaluation report) no. 143 Cuzepe in which special cuttings are foreseen-hygiene cuttings;
- P1359141 E.V. no. 125 Budoi, care works - thinnings;
- P1458512 E.V. no. 20701 Comp. Cuzap, regeneration - progressive cuts;
The inventory was made in 2018 and the felling areas were proposed for exploitation in 2018 and 2019.

Table 1. The situation of the three analyzed felling areas, characteristics

Characteristics of the felling areas	P1359134 143 Cuzepe	P1359141 125 Budoi	P1458512 20701 Comp.Cuzap
Production unit	P.U. V Cuzap	P.U. V Pădurea Neagră	P.U. V Comp.Cuzap
Compartment	83B, 84B, 87B, 88B	127B	120
Total volume, m³	60	373	188
Number of trees, pieces	104	790	310
Volume of average tree, m³/piece	0.58	0.47	0.61
Slope, degrees	20-23	20	15
Surface of felling area, ha	38.67	15.00	26.60
Type of cutting	Hygiene	Thinning	Progressive
Species	Go, Fa	Fa, Pl, Ca, Ci, Sc	Go
Degree of accessibility	G3	G3	G3
Usable seedlings, %	-	-	39.85
Exploitation period	20.08.2015-15.11.2018	16.10.2018-21.12.2018	22.01.2019-15.04.2019

Source: Management Plan P.U V, VI, Marghita Forest District [2].

In order to determine the logging costs, two situations as regards the working methodology were taken into consideration, as follows:
a. the initial data (general report, felling area sheet) is introduced in the programme Deviz_exploatari.xls, sheet initial data, the costs are automatically determined and out of the centralized sheet, the unitary tariff results for the whole wood, with/without branches, and separately costs for branches in case they would be brought to the platform;
b. grouped norms determined for the given felling area are used.
In the first case, in order to facilitate the calculation method regarding the determination of the logging costs for a certain felling area, the programme Deviz_exploatare.xls was used for the automatic calculation of the volumes, time, fuels and lubricants necessary for operations and phases and the direct, indirect (including animal feed, their care expenses, etc.). The total expenses were determined starting from the introduction of some initial data characteristic to each felling area. The programme also includes the hourly rates for 2019. The specific time norms used in the wood works, specific fuel consumption, wage grids [1], [11] are used automatically.
In the second case, the grouped norms were determined, being centralized under the form

of tables containing unit rates, for certain working conditions and factors, in various situations encountered in practice. These rates can be used for any felling site, carefully following the main factors as entries in the grouped norms.

For thinning cuttings, the volume of the average tree was considered to be between 0.04-0.45m³/tree, and for the regeneration cuttings, the volume of the average tree was considered > 0.45 m³/tree.

RESULTS AND DISCUSSIONS

The direct costs, fuel and lubricant costs, indirect and total costs were determined for the three felling sites (Table 2).

Table 2. Centralization of the costs with the exploitation of the three felling areas in the concrete field conditions by winch skidding (15-50m) and forest tractor – hauling

Calculated indices		Expenses necessary for the exploitation of the felling areas …, in lei/m³		
		P1359134	P1359141	P1458512
Total costs, without branches	lei	4,488.78	16,601.57	16,784.54
	lei/m³	81.61	48.97	99.91
Total costs, with branches	lei	5,032.19	20,083.30	18,302.25
	lei/m³	91.49	59.24	108.94

Source: Original data.

In order to show that the animal skidding is more expensive than the winch skidding of the harvested trees, a simulation was performed showing the influence of the two extraction means in the case of skidding operation upon the costs according to their share. The notations from figure 1 have the following meanings:
- T100 - the situation in which the extraction is made entirely by tractor;
- T80A20 - winch skidding is done on 80% of the felling area and animal skidding on 20% of the felling area;
- A100 - the skidding is performed entirely by animals.
The values were obtained for winch skidding on the distance category of 16-50m and for horse skidding on the maximum distance of 100m.
The total logging costs were also determined in case the skidding would be made entirely by horses, for two categories of skidding

distances with animals (d <100m and 101 <d <200m) for the three studied felling areas (Figure 2).
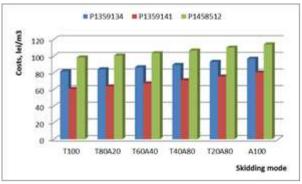

Fig. 1. Logging costs, for the three felling areas by winch skidding and/or animal skidding in different ratios
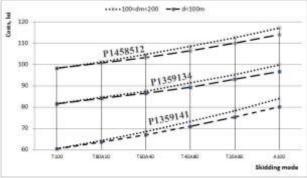Source: Original data.

Fig. 2. Representation of the logging costs for the studied felling areas, by animal skidding on two categories of distance
Source: Original data.

For production sector, the determination of unit daily rates, under the form of tables with multiple inputs, in carrying out the care works (cleaning, thinning) and the regeneration cuttings on operations and phases, under different working conditions, it is important to know the costs of logging in a given case, to determine the economic efficiency in a simple and rapid way.

The logging factors that are involved are: the logging method, the means and method of skidding, density, distances, slope, intensity of the cutting, volume of the average tree, pruning, with/without gathering the branches and so on.

If the exploitation technology also includes the animal skidding, some grouped norms for

harnesses can be used, some of them being determined below, as an example:

A. Rates for animal skidding and hauling according to distances, average tree volume, species groups (Tables 3 and 4)

Table 3. Rates for animal skidding and hauling in case of softwood

Volume of average tree, m³/tree	Rate for animal skidding including the preparation of the load on animals, on distances <… m, lei/m³						
	100	200	300	400	500	700	1000
<0.14	14.11	16.17	18.36	20.55	22.61	26.85	33.15
0.141-0.45	11.65	13.43	15.21	16.99	18.77	22.33	28.77
>0.45	9.59	11.23	12.88	14.52	16.03	19.32	24.39

Source: Original data.

B. Unit rates of exploitation according to the density of the extracted trees, slope, degree of accessibility (Tables 5 and 6)

Table 4. Rates for animal skidding and hauling in case of hardwood

Volume of average tree, m³/tree	Rate for animal skidding including the preparation of the load on animals, on distances <… m, lei/m³						
	100	200	300	400	500	700	1000
<0.14	16.03	18.77	21.51	24.11	26.72	31.92	41.37
0.141-0.45	12.60	14.93	17.13	19.32	21.51	25.89	31.51
>0.45	11.10	13.15	15.21	17.26	19.18	23.29	29.87

Source: Original data.

Specifications: *skidding by animals on maximum distances up to 300m, and by winches on category <15m, marked trees 100-400pcs, hauling 100% by forest tractor, on accessibility degrees, cold season, pruning <0.3, long wood system, slope <20º*

Table 5. Softwood rates, without collecting branches, depending on the skidding distance by animals and the degree of accessibility, lei/m³

The volume of the average tree, m³/tree	Rates according to the skidding distance by animals... and the degree of accessibility, lei/m³																			
	G1				G2				G3				G4				G5			
	<100	101-200	201-300	301-400	<100	101-200	201-300	301-400	<100	101-200	201-300	301-400	<100	101-200	201-300	301-400	<100	101-200	201-300	301-400
0.041-0.060	94.69	97.98	101.27	104.40	96.10	99.39	102.68	105.81	98.15	101.44	104.73	107.86	100.77	104.06	107.35	110.48	103.3	106.59	109.88	113.01
0.061-0.090	85.03	88.32	91.61	94.74	86.44	89.73	93.02	96.15	88.49	91.78	95.07	98.20	91.11	94.40	97.69	100.82	93.64	96.93	100.22	103.35
0.091-0.140	77.52	80.82	84.11	87.23	78.93	82.23	85.52	88.64	80.98	84.27	87.57	90.69	83.60	86.89	90.18	93.31	86.13	89.43	92.72	95.84
0.141-0.200	64.80	67.59	70.23	72.86	66.21	69.00	71.64	74.27	68.18	70.98	73.61	76.25	70.82	73.62	76.25	78.88	73.44	76.24	78.87	81.51
0.201-0.300	61.66	64.46	67.09	69.73	63.07	65.87	68.50	71.14	65.05	67.85	70.48	73.12	67.69	70.49	73.12	75.75	70.31	73.11	75.74	78.37
0.301-0.450	57.29	60.09	62.72	65.35	58.70	61.50	64.13	66.76	60.68	63.48	66.11	68.74	63.32	66.11	68.75	71.38	65.94	68.73	71.37	74.00
0.451-0.701	57.52	59.99	62.46	64.93	58.89	61.36	63.83	66.30	60.80	63.27	65.74	68.20	63.51	65.98	68.45	70.91	66.13	68.60	71.07	73.54
0.701-1.100	53.58	56.05	58.52	60.98	54.95	57.42	59.89	62.36	56.86	59.33	61.80	64.26	59.57	62.04	64.50	66.97	62.19	64.66	67.13	69.60
1.101-1.600	52.14	54.61	57.08	59.54	53.51	55.98	58.45	60.92	55.42	57.89	60.36	62.82	58.13	60.60	63.06	65.53	60.75	63.22	65.69	68.16
1.601-2.500	50.07	52.54	55.00	57.47	51.44	53.91	56.38	58.85	53.35	55.82	58.28	60.75	56.06	58.52	60.99	63.46	58.68	61.15	63.62	66.08
2.501-3.700	47.86	50.32	52.79	55.26	49.23	51.70	54.17	56.63	51.14	53.60	56.07	58.54	53.84	56.31	58.78	61.25	56.47	58.93	61.40	63.87

Source: Original data.

Table 6. Hardwood rates, without collecting branches, depending on the skidding distance by animals and the degree of accessibility, lei/m³

The volume of the average tree, m³/tree	Rates according to the skidding distance by animals... and the degree of accessibility, lei/m³																			
	G1				G2				G3				G4				G5			
	<100	101-200	201-300	301-400	<100	101-200	201-300	301-400	<100	101-200	201-300	301-400	<100	101-200	201-300	301-400	<100	101-200	201-300	301-400
0.041-0.060	96.09	99.38	102.7	104.6	97.79	101.1	104.4	106.3	100.3	103.6	106.8	108.7	103.7	107.0	110.3	112.1	106.7	110.4	113.3	115.2
0.061-0.090	85.46	88.75	92.04	94.00	87.16	90.45	93.74	95.69	89.64	92.93	96.22	98.16	93.05	96.34	99.63	101.56	96.12	99.41	102.70	104.62
0.091-0.140	76.69	79.98	83.27	85.31	78.39	81.68	84.97	87.00	80.87	84.16	87.45	89.47	84.28	87.57	90.86	92.87	87.35	90.64	93.93	95.93
0.141-0.200	67.75	70.55	73.18	74.75	69.45	72.24	74.88	76.44	71.93	74.72	77.36	78.91	75.34	78.13	80.77	82.31	78.50	81.29	83.93	85.46
0.201-0.300	62.97	65.77	68.40	70.05	64.67	67.46	70.10	71.74	67.15	69.94	72.58	74.21	70.56	73.35	75.99	77.61	73.72	76.52	79.15	80.76
0.301-0.450	58.85	61.64	64.28	65.94	60.54	63.34	65.97	67.63	63.02	65.82	68.45	70.10	66.43	69.23	71.86	73.50	69.59	72.39	75.02	76.65
0.451-0.701	56.24	58.71	61.18	62.73	57.87	60.34	62.80	64.35	60.38	62.85	65.32	66.86	63.77	66.24	68.71	70.24	66.85	69.31	71.78	73.30
0.701-1.100	53.66	56.13	58.60	60.17	55.29	57.75	60.22	61.79	57.80	60.27	62.74	64.29	61.19	63.66	66.13	67.67	64.27	66.73	69.20	70.73
1.101-1.600	50.26	52.72	55.19	56.78	51.88	54.35	56.82	58.40	54.40	56.87	59.33	60.91	57.79	60.26	62.73	64.29	60.86	63.33	65.80	67.35
1.601-2.500	48.13	50.60	53.07	54.67	49.75	52.22	54.69	56.29	52.27	54.74	57.21	58.80	55.66	58.13	60.60	62.18	58.73	61.20	63.67	65.24
2.501-3.700	46.03	48.50	50.97	52.58	47.66	50.13	52.60	54.20	50.18	52.64	55.11	56.71	53.57	56.04	58.50	60.08	56.64	59.11	61.57	63.15

Source: Original data.

C. Rates for the logging method in SHORT WOOD SYSTEM

If the trees have large volumes, it is recommended to cut the trees in the felling areas in short or multiple pieces in order to skid them by animals. Thus, a rate table can be designed depending on the logging method.

In tables 7 and 8, the grouped norms were accomplished for the logging method in short wood system, G3, animal skidding <400m and winch hauling <15m, gradient <20°, pruning <0.3, with forest tractor hauling, on the volume categories, density 100-400 trees/ha.

Table 7. Rates for Softwoods, the logging method in Short Wood System

The volume of the average tree, m³/tree	Rate, lei/m³, for a maximum animal skidding distance of … m							
	Softwood				Hardwood			
	<100m	<200m	<300m	<400m	<100m	<200m	<300m	<400m
0.041-0.060	99.27	102.56	105.85	108.98	100.57	103.86	107.15	109.06
0.061-0.090	89.61	92.90	96.19	99.32	89.94	93.23	96.52	98.46
0.091-0.140	82.03	85.32	88.62	91.74	81.11	84.40	87.69	89.71
0.141-0.200	72.43	75.23	77.86	80.49	75.80	78.60	81.23	82.78
0.201-0.300	67.50	70.30	72.94	75.57	69.12	71.92	74.55	76.19
0.301-0.450	63.13	65.93	68.56	71.19	64.55	67.34	69.98	71.63
0.451-0.701	62.90	65.37	67.84	70.31	61.80	64.27	66.73	68.27
0.701-1.100	58.80	61.27	63.74	66.21	59.02	61.49	63.96	65.51
1.101-1.600	57.05	59.52	61.99	64.46	55.42	57.89	60.36	61.93
1.601-2.500	54.67	57.14	59.61	62.08	53.01	55.48	57.94	59.54
2.501-3.700	52.46	54.93	57.40	59.86	50.73	53.20	55.67	57.26

Source: Original data.

CONCLUSIONS

According to the results highlighted in Table 2 and Figure 1, the animal skidding involves higher costs than the winch hauling in all the three analyzed situations, namely special hygiene cuttings, care works - thinning, regeneration - progressive fellings.

Comparing the unit rates obtained by the simulation proposed as a case study, it is observed that the distance in the case of animal skidding has a significant influence, the total logging costs increasing by 8.4% for distances up to 100m and by 12.9% for distances up to 400m in hardwoods and by 9.8-14.1% in softwoods for distances of 100-400m.

Regarding the application of the different methods of exploitation (short wood system versus long wood system) very close results are obtained: for softwood, at short distances (<100m) in the case of animal skidding, the costs increase by 1.1% for thin trees and by 2.6% for thick trees that have to be sectioned in short wood system in the felling areas. In hardwoods, the increase in costs is insignificant if the logging method is changed: + 0.3% for thin harvested trees and + 1.1% for very thick trees. The same is in the case of deciduous trees, the increases being very small: 1.0-2.2% for thin trees and 0.3-1.0% for thick trees. In conclusion, the logging method influences the total logging costs insignificantly, but the trees with high volume and weight must be sectioned to facilitate the animal work. There are measures that can be applied to reduce the effort of the animals when extracting: rounding (chopping, rounding with the axe) the ends of the logs, cutting it into pieces as short as possible, cleaning the branches, moving on the snow to make the effort as little as possible, the setting up of some hauling trails of 1.5 m width and with a maximum slope of 40%, helping the load to proceed and so on.

There are factors that reduce the logging costs in general regardless the means of extraction. In the analyzed case it is observed that the

volume of the average tree and the degree of accessibility have a major influence on the total costs (almost doubling the total costs).

If three factors that influence the costs significantly (volume of the average tree, degree of accessibility, skidding distance) are taken into account, an amplitude of 65.15 lei/m^3 is found in softwoods between the minimum rate obtained for large volumes, short distances, very good accessibility in the felling area and the exploitation of very thin trees, very distant felling areas from the permanent transport routes, long distances for animal skidding (Table 6).

Thus, in the case of the felling areas that are hardly accessible, with thick trees, it is recommended the entire extraction to be performed by tractor, but for hygienic work and thinning or extraction of trees with smaller volumes, it can also be used the horse skidding in order to protect the standing trees. We must not forget the ecological benefits of animal skidding; this wood extraction method brings little harm to the environment, the soil, the standing trees and the seedling. Therefore, in any exploitation activity, the control bodies must watch over the logging method and if the admitted damages are exceeded to recover these "losses" in order not to encourage those who exploit the wood to use destructive exploitation technologies.

At the moment and in the last few years, it is noticed a return in production of the requirement regarding the most accurate determination of the logging costs, the need for materials and fuels and an improvement of the plans and the way of determining the collection distances as well as the capture of several phases and operations that can intervene in the logging process, from stump to forest deposits are needed. Although the economic agents cannot be forced to make such detailed estimates, there is a growing interest to make documentation and calculations that will ensure them the efficiency of the works performed or a guaranteed profit following the tendering of a felling site and finally the wood recovery under a certain form. These unit rates grouped together should make their work easier, help

them make better decisions when tendering felling sites and increase the efficiency of their activity.

REFERENCES

[1]Anonymous, 1989, Norme şi normative de muncă unificate în exploatările forestiere. Centrala de exploatare a lemnului, Bucureşti
[2]Anonymous, 2017, Management Plan P.U V, VI, Marghita Forest District, Bihor Forest Administration.
[3]Barreto, P., Amaral, P., Vidal, E., Uhl, C., 1998, Costs and benefits of forest management for timber production in eastern Amazonia, Forest Ecology and Management, 108, 9-26.
[4]Ciubotaru, A., 1996, Elemente de proiectare şi organizare a exploatării pădurilor, 2nd edition, Braşov, Lux Libris Publishing House.
[5]Horodnic, S., 2014, Sisteme tehnologice forestiere cu impact ecologic redus, Suceava, University of Suceava Publishing House.
[6]Jourgholami, M., 2012, Small-Scale Timber Harvesting: Mule Logging in Hyrcanian Forests, Small-scale Forestry, 11, 255-262, DOI 10.1007/s11842-011-9174-y.
[7]Malatinszky, A., Ficosr, C., 2016, Frequency and Advantages of Animal-Powered Logging for Timber Harvesting in Hungarian Nature Conservation Areas, Croatian Journal of Forest Engineering, 37, 279-286.
[8]Ministry of Environment and Forests, 2011, Order 1540/2011, Norms regarding the establishment of the terms, methods and periods of exploitation of the timber in forests and forest vegetation outside the national forest stock, updated.
[9]Oprea, I., Sbera, I., 2004, Tehnologia exploatării lemnului, Olteniţa, Tridona Publishing House.
[10]Putz, F.E., Sist, P., Fredericksen, T., Dykstra, D., 2008, Reduced-impact logging: Challenges and opportunities, Forest Ecology and Management, 256, 1427-1433.
[11]Regia Naţională a Pădurilor Romsilva, 2019, Tarife minime utilizate in silvicultura si exploatari forestiere pe grile de salarizare.
[12]Shrestha, S., Lanfors, B.L., Rummer, R., Dubois, M., 2008, Soil Disturbances from Horse/Mule Logging Operations Coupled with Machines in the Southern United States, International Journal of Forest Engineering, 19(1), 17-23.