THE IMPACT OF DIFFERENT CARRIAGES ON SOIL AND TREES DURING SKIDDING IN THE ROMANIAN FORESTS

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Abstract: *Comprehensive field studies revealed distinct differences in soil structural changes and trees damages by quality and extent, depending on traffic of wheeled or tracked machines. Tracks are more soil protective on slopes than on flat terrain, although their "compaction" level is somewhat lower than for wheels alone. In this paper the results of researches concerning the damages that were made to the remaining trees located near the skidding tracks, regarding the damages made to the soil and to the litter and also with regard to the total surface of the stands affected by skidding operations are presented.*

Key words: *section system, tree damages, soil damages.*

1. Introduction

It is known that the logging activity causes damages to the remaining trees, to the seedling and to the soil. The total values of the damages are related to several factors that can be grouped into several categories:

- site factors, respectively the nature of the solidification bedrock (characterized by geomorphological resistance), field declivity, the depth of the soil, climatic conditions during the logging etc.;
- biocenotic factors, respectively the stand composition, the stand and seedling density;
- technical-economic factors, respectively the applied cutting method, the logging technology that is used etc.

Objectives followed in the present paper:

- establishing the damages produced to the remaining trees in correlation with the field declivity and with the means used for wood skidding;
- establishing the damages produced to the soil, respectively the litter disarrangement and the dislocation of the humus layer.

2. Research Placement. Working Method

The researches were conducted in mixed stands (beech and coniferous), located in the mountainous area where cuttings were made, for the transformation of the selection system.

For tree damage estimation, the stands are located near the City of Braşov, in the lower part of the Postăvaru Massif and are part of the eight compartments (18, 19 A, 20, 38, 44, 51, 52 and 53) from the no. V Noua Management Unit with a total surface of 131 ha (Table 1). The geological substratum is represented by polygene conglomerates with medium geo-morphological

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resistance. The main relief forms are slopes with $20^0 \ldots 40^0$ declivities, with an undated configuration and an altitude between 660 and 1050 m. The main soils are Eutric Cambisoils, Districc Cambisoils and Haplic Luvisoils [5] with prevalent loamy - sandy texture in A_0 layer and loamy or loamy - clay in the B_t layer (for tree damage).

For soil damages, the researches were made in the same Management Unit but in compartments 27b, 28, 29, 30, 31 and 32 (Table 2) on a 99.5 ha surface (Table 4). These compartments are located on slopes with different expositions, on altitudes between 630 and 910 m and declivities between 20 and 35^0. The geological substratum is represented by conglomerates. The soil, which is prevalent medium deep, with clay texture, is framing in Eutric Cambisoils and Luvisoils types [5].

General conditions of the compartments (*for tree damages*) Table 1

Current number	Compartment	Surface [ha]	Forest site characteristics				Stand characteristics					
			Altitude [m]	Exposition	Declivity [degree]	Forest site type	Composition	Age [years]	Site class / Stand density	Number of trees/ha	Volume [m^3]	Forest type
(0)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1	18	25.6	660 910	NW	25	3322	9Br1Fa	140	III/0.7	473	467	2121
2	19 A	9.0	770 900	NW	30	3332	8Br2Fa	120	III/0.8	412	454	2221
3	20	13.8	720 930	SE	20	3332	7Br3Fa	130	III/0.7	433	354	2212
4	38	15.6	670 870	NW	25	3312	5Br5Fa	90	III/0.8	624	300	2251
5	44	18.5	740 1050	NW	30	3333	7Br2Fa1Mo	100	II/0.8	598	575	2211
6	51	17.9	750 1050	E	30	3333	8Br2Fa	100	II/0.8	520	460	2211
7	52	10.4	720 1050	E	28	3333	7Br2Fa1Mo	100	II/0.8	480	520	2212
8	53	20.2	710 1000	SE	28	3333	6Br3Fa1Mo	100	II/0.8	530	480	2211

Br - Fir; Fa - beech; Mo - spruce

The logging method was trunk and mast.

The observation of the itinerary and of the sample plots was the research method used to evaluate the damages that were made to the remaining trees.

The research plots were oriented on the line of the steepest slope having a quadrant shape with a 20 m flank. For the "first skidding" and yarding operations, the observations have been made along the animal yarding and tractor tracks on a 5 m distance from the tracks' axis.

The following observations were made in each sample plot: the total number of standing trees and the total number of harvested trees were countered and for the remaining trees the species, the damage type and their dimensions were recorded and also the DBH for each tree was measured.

General conditions of the compartments (*for soil damages*) Table 2

Current number	Compartment	Surface [ha]	Forest site characteristics				Stand characteristics				
			Altitude [m]	Exposition	Declivity [degree]	Forest site type	Composition	Age [years]	Site class / Stand density	Volume [m^3]	Forest type
(0)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(11)	(12)
1	27b	13.00	630 910	N	27	3333	6Br4Fa	140	II/0.6	385	2211
2	28	18.10	670 880	NE	25	3333	6Br4Fa	125	II/0.7	357	2211
3	29	17.80	770 870	SE	20	3332	6Br4Fa	135	III/0.7	376	2212
4	30	14.90	630 770	S	20	3332	5Br5Fa	90	III/0.8	300	2212
5	31	21.90	610 770	N	20	3332	6Fa2Br2Mo	70	III/0.8	336	2212
6	32	13.80	600 720	E	35	3332	2Br6Fa2Mo	70	III/0.7	271	2212

Br - Fir; Fa - beech; Mo - spruce

The damaged trees were classified in accordance with the damage type and gravity in small, mild and strongly damaged using the Petrescu method [4], respectively:

- small scars, with the width being less than 25% of the trunk circumference;
- mild scars, which affect between 25 and 50% of trunk circumference;
- big scars, which affect more than 50% of the trunk circumference.

To estimate the damages made to the soil on the animal or tractor tracks and on the concentrated hauling paths, transversal profiles were made on which the abscissa and ordinate were measured and then the volume of the dislocated soil was calculated. The intensity of the soil damages were appreciated taking into account the following classification:

- low damaged surfaces: where the litter was disarranged or removed;
- moderately damaged surfaces: where up to 50% from the A layer (the humus layer) was removed;
- strongly damaged surfaces: where the A layer was removed between 50 and 100%;
- very strongly damaged surfaces: where the A layer was completely removed and ditches were made.

3. The Results of the Researches

The results of the researches are stratified in accordance with the field declivity, the skidding distance and the skidding means that were used. The skidding solutions involve different variants of situations [1-3], in accordance with the field conditions specific to each compartment.

The 51st compartment from the No. V Noua Management Unit (Figure 1) is situated on a very hilly slope with 70…80% declivity. In these conditions, the yarding was made by hauling up to the creek located at the

basis of the slope, from this point on being sent by tractor up to the tractor track.

The 52nd and 53rd compartments from the No. V Noua Management Unit (Figure 1) comprise slopes with a lower declivity, up to 60%, a fact that determined a mixed yarding, with animals and by hauling, in accordance with the variations of the declivities. The forwarding was also realized using the tractor, on tractor track which presents an easy slope on the first part from downhill, but also a maximum admitted declivity uphill (25%). On some secondary valleys from the 53rd compartment, the wood was "first skidded" with animals till the tractor track.

The 44th compartment from the No. V Noua Management Unit (Figure 2) is located on a rippled slope, with 50…70% prevalent declivity, where hauling was applied for wood yarding. From the secondary valleys, the wood was "first skidded" with the skyline FUL - 401, mounted in two positions and also with animals. At forwarding tractors were used, the tractor tracks having lower declivities.

Compartment 38 from the No. V Noua Management (Figure 2) comprises a curved slope, with 40…60% prevalent declivity. In these conditions, the yarding was made with animals and by hauling. The forwarding was made using tractor on a low declivity tractor track.

The 19th and 20th compartments from the No. V Noua Management (Figure 3) have lower declivity slopes (generally under 40%) which generally impose performing yarding with animals. The wood forwarding was made by tractor on tractor tracks with very low declivities.

The situation regarding the damages produced to the trees is presented in Table 3.

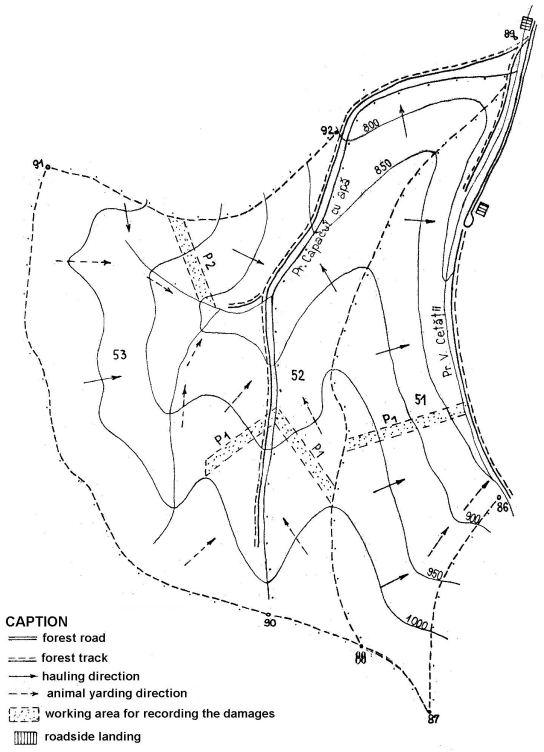

Fig. 1. *Layout regarding wood skidding in compartments 51, 52 and 53*

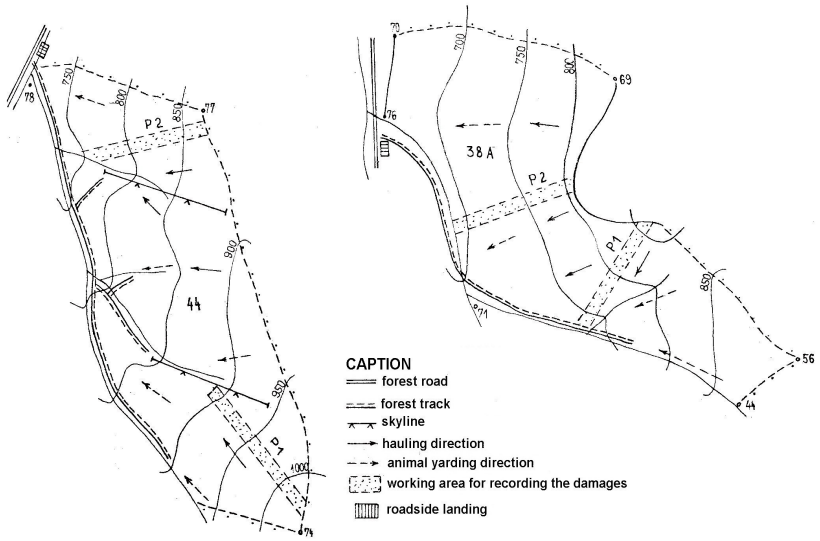

Figure 2. Layout regarding wood skidding in compartments 38A and 44

Fig. 2. *Layout regarding wood skidding in compartments 38A and 44*

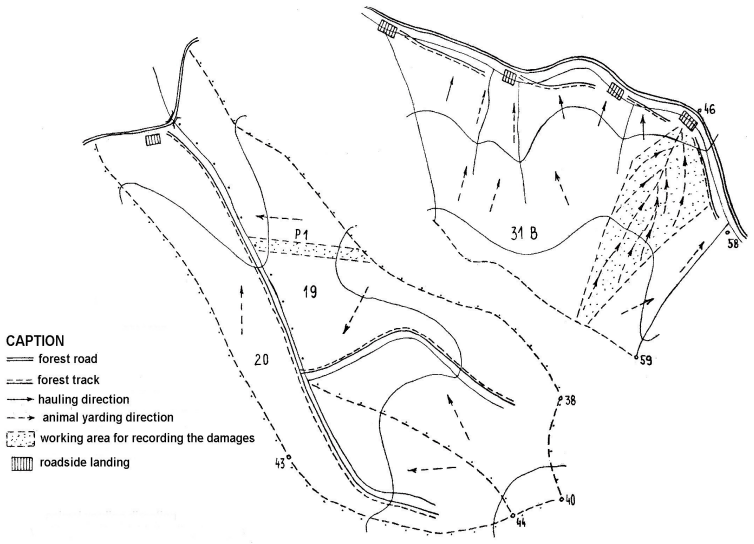

Fig. 3. *Layout regarding wood skidding in compartments 19 and 20*

Regarding these damages some aspects could be highlighted:

- the damages increase, as it is normal, when the distance increases, being insignificant in the areas near the ridge (generally up to a 100 m distance) and having a maximum value at the basis of the slopes;

- on the slopes with declivities that are higher than 60% the damages attain the maximum values Thus, in the compartments 51, 53 and 44 between 33.8 and 38%, were damaged from which between 3.4 and 6.6%

Table 3

The situation of the damages produced to the standing trees at yarding on the sample plots

No.	Compart-ment	Sample plot [m^2]	Declivity [%]	Initial trees		Harvested trees		Remaining trees		Damaged trees							
										Low		Mild		Strong		Total	
				No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
(0)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Yarding by hauling																	
1	51	4400	55-83	241	100	30	12.4	211	87.6	50	23.7	17	8.1	14	6.6	81	38.4
2	53	2800	55-60	159	100	43	27.0	116	73.0	30	25.9	11	9.5	12	10.3	53	45.7
3	53	2400	23-53	220	100	72	32.7	148	67.3	33	22.3	9	6.1	8	5.4	50	33.8
4	44	3600	50-63	146	100	28	19.1	118	80.9	26	22.0	13	11.0	4	3.4	43	36.4
5	38	3200	38-58	191	100	26	13.6	165	86.4	25	15.2	8	4.8	1	0.6	34	20.6
Animal yarding																	
6	52	2800	30-42	165	100	27	16.4	138	83.6	14	10.2	2	1.4	2	1.4	18	13.4
7	19	1200	42-50	93	100	10	10.7	83	89.3	14	16.8	-	-	-	-	14	16.8

were strongly damaged;

- on the slopes with declivities under 60% low-value damages were recorded; under 20% from the total number of the trees suffered damages, and only 1.2% can be considered as being strong damages (registered at compartments 44 and 38);

- in case of steeper slopes, the trees located on their lower part are more strongly damaged and the danger of stands degradation on these areas could appear. Thus, in compartment 51 on the last 60m, more than 65% of the trees were damaged the more strongly damaged being more than 14%. These damages are accentuated in case of preparing the loads for forwarding using the tractor, the winch cable is placed behind the trees in order to achieve the load control. In this situation, in compartments 53 45.7% of the trees were damaged, from which 10.3% were strong damaged as a result of the negative effects of the hauling and traction with the winch mounted on tractors.

Comparing the yarding made by hauling and the one uniformly made by animals, the damages are more reduced in the second case. Thus in compartment 52.13% from the trees were damaged, out of which 1.4% were strongly damaged. In compartments 19 and 20, where measurements were made on a percentage sampling basis no mild or strongly damaged trees were found, but in this case the intensity of the intervention was lower.

In compartment 31 a path network for animals was studied (Table 4). It was determined that the probability of damaging the trees located on the edge of the paths depends directly on the distance of these trees from the real axis of the "first skidding" route. In this way, trees with different damage degrees can be practically registered anyway along the route. Summing up the damages on the entire network, it was certain that 38.4% of the trees were damaged, out of which 2.2% were strongly damaged. Between the paths, the trees were not damaged, which means that animal yarding is more favorable for this mean than for the hauling. Also, it was recorded that animal yarding on the contour line had as result a massive damage of the trees located downhill, because of the loads' friction with these trees.

The injuries made to the standing trees located along the tractor tracks were studied in compartments 44 and 38A (Table 5). For the other tractor tracks this study was not necessary because the tractor tracks had more than 3m width, the tractors were moved on the creeks' bed or on wide wheel tracks from de previous harvestings. In case of the analyzed tractor tracks, most of the trees from the edge were damaged

Table 4

The situation of the damages produced to the standing trees along the routes at animal yarding

No.	Compart-ment	Skidding distances [m]	Number of trees placed on edge	Damaged trees							
				Low		Mild		Strong		Total	
				No.	%	No.	%	No.	%	No.	%
(0)	(1)	(2)	(3)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
1	31	280	45	7	15.6	8	17.8	2	4.4	17	27.8
		140	24	6	25.0	-	-	-	-	6	25.9
		100	23	7	30.4	4	17.8	-	-	11	47.8
		120	14	5	35.7	2	14.3	-	-	7	50.0
		60	4	1	25.0	1	25.0	-	-	2	50.0
		140	19	6	31.6	-	-	1	11.0	4	44.6
		100	9	3	33.33	-	-	-	-	3	33.33
TOTAL			**138**	**35**	**25.4**	**15**	**10.8**	**3**	**2.2**	**53**	**38.4**

Table 5

The situation of the damages produced to the standing trees along the tractor tracks

No.	Compart-ment	Skidding distances [m]	Number of trees placed on edge	Damaged trees							
				Low		Mild		Strong		Total	
				No.	%	No.	%	No.	%	No.	%
(0)	(1)	(2)	(3)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
1	44	320	45	13	28.9	14	31.1	8	17.8	35	77.8
2	38	240	45	17	37.8	12	26.7	11	24.4	40	88.9

(77.8% and respectively 88.9%), from which 24.4% were strongly damaged.

As a result of wood harvesting and of skidding works, the soil was affected, and some modifications were registered. In Table 6 the volume of dislocated soil by wood logging works is presented. The layout of the compartments were the measurements were made is presented in Figure 4.

The moderately and strongly degraded surface (5.5 ha) in which the humus layer was partially or totally removed, usually comprises portions in hauling and animal yarding were performed. The very strongly degraded surface (1 ha) comprises hauling paths and "first skidding" tracks for animals or tractors.

The relatively great differences regarding the nature and the ampleness of the soil modification which is observed between different compartments is because of work methods, which are influenced by the interventions' intensity, by the medium volume of the trees, by the field characteristics etc.

It is certain that the total volume of dislocated soil as an effect of logging works is of 4027 m^3, from which more than

The volume of dislocated soil by wood logging works Table 6

No.	Specifications	Surface [ha]	Dislocated soil volume [m^3]						Total
			27b	28	29	30	31	32	
(0)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	Moderate damaged surface	4.25	538	131	14	112	57	1	1653
2	Strong damaged surface	1.25	580	40	13	32	51	-	716
3	Very strong damaged surface	1.00	730	494	414	-	7	13	1668
Total		**6.50**	**1848**	**665**	**441**	**944**	**115**	**14**	**4027**

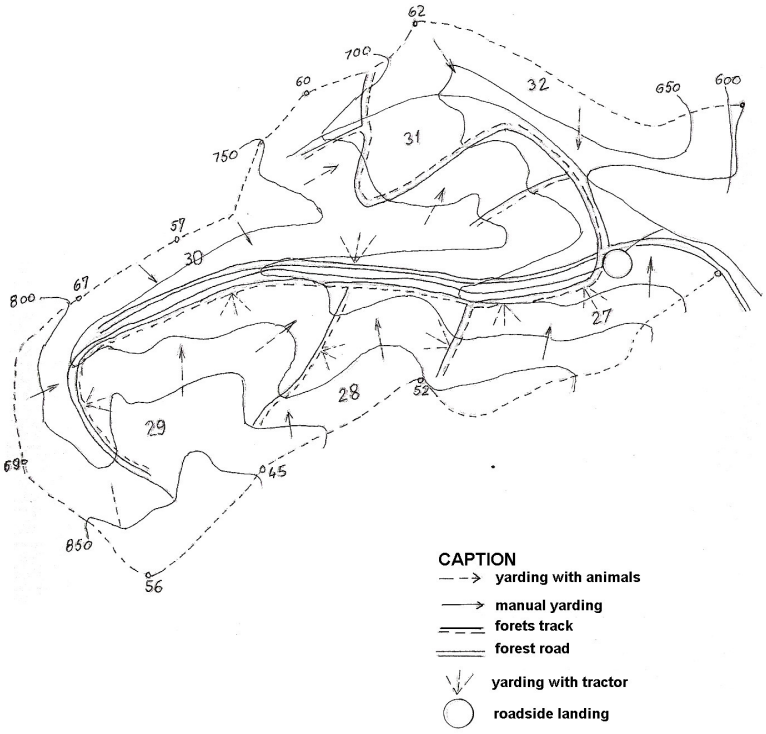

Fig. 4. *Layout regarding wood skidding in compartments 27 -32*

half were dislocated on the "first skidding" tracks for animals or tractors. These tracks have a 2.25 ha surface from the total of 99.5 ha surface of the cutting area (≈2%).

In relation to the data presented in Table 6, with the total surface of cutting area and the compartments' surface, the dislocation indexes were calculated (Table 7). Their value for compartments is between 1 m^3/ha and 142 m^3/ha and shows the close link which exists between the intervention intensity and the field characteristics, the logging technology and the damages made to the soil.

Thus, in compartments 31 and 32, in which the interventions' intensity was reduced and the wood yarding was made with animals, the dislocation indexes are lower than 10 m^3/ha. In compartments 27b and 30, in which the cuttings were more intense and the wood yarding was made by hauling, the dislocation indexes value is much greater respectively 63 m^3/ha, compartment 31, and 142 m^3/ha in compartment 27b.

The results of the researches made in No. V Noua Management Unit regarding the logging work influence on the soil degradation, led to some important conclusions:

- the wood logging works, represented by cutting for the transformation of the selection system, trigger some modifications of the soil, starting with litter disarrangement to a very strong degradation of the soil profile;

- the total affected surface as a result of logging interventions is of 19.73 ha, which represents 20% of the total surface of the cutting area. This surface comprises, on the one hand, fields with disarranged or removed litter which amount to 13.23 ha and, on the other hand, moderately, strongly and very strongly damaged fields which amount to 6.50 ha;

The values of soil dislocation indexes Table 7

No.	Compartment	Total surface	Total dislocated volume [m^3]	Dislocation indexes [m^3/ha]
(0)	(1)	(2)	(3)	(4)
1	27b	13.00	1848	142
2	28	18.10	665	37
3	29	17.80	441	25
4	30	14.90	944	63
5	31	21.90	115	5
6	32	13.80	14	1
Total		**99.50**	**4027**	**40.5**

- the total effective damaged surface by partial or total removal of the humus layer comprises both scattered insular portions as a result of hauling and animal yarding (5.27 ha) and concentrated hauling paths and tracks for animal yarding and tractors (1.23 ha). Prevalent is the moderately damaged area (4 ha) and it comprises insular portions having 50% of the humus layer removed as a result of hauling and yarding with animals;

- from the total damaged surface (6.50 ha), 4.86 ha were damaged as a result of hauling, 0.45 ha as a result of animal yarding and 1.19 ha as a result of "first skidding" with animals and tractor. Although the surfaces where the yarding was realized by hauling or with animals has almost the same area, the damaged surface by hauling is more than ten times as big in comparison with the surface affected by animal yarding, a fact that highlights the destructive character of hauling;

- the soil damage is generally in relation with the cutting intensity. Thus, in compartment 27b and 30, in which the interventions had a forceful character, the total affected surface was of 5.13 ha while in compartments 31 and 32 where the interventions had a lower intensity the damaged surface is just of 0.40 ha;

- the total volume of dislocated soil in the cutting area as result of logging works is of 4027 m^3 and is mostly a result of animal yarding (61%), especially because of spread hauling which determines soil removal on many insular surfaces located especially in compartments 27b and 30;

- the dislocation indexes have values between 1 m^3/ha (compartment 32) and 142 m^3/ha (compartment 27b); the medium dislocation index calculated for the cutting area is of 40.5 m^3/ha which represents an estimated loss of approximately 100675 EURO/ha.

4. Conclusions

In conclusion, during the wood logging process important changes are made to the living soil cover starting from litter disarrangement to powerful soil degradation. Also, a significant number of trees are damaged, a fact that will affect the wood quality of remaining trees in the future. These damages are lower than the one made in even stand cuttings.

The main means that are recommended to reduce these damages are:

- limitation of hauling usage in the skidding process;

- in order to reduce the damages that are made to the trees placed along the routes, at animal yarding, it is recommended to place logs in curves;

- in order to reduce the damages that are made to the trees along the tractor tracks it is recommended to place logs along the tracks or to ensure individual protection of the trees;

- performing the logging in periods when

the soil is dried or is covered with snow;

- limiting the trailing and half - trailing during the skidding;
- introducing, where it is possible, the skylines.

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