Assessing Damage to Trees and Soil in Thinnings of Pine Stands

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The significant influence of methods and technological processes in thinnings on tree and soil damages in Scots pine (*Pinus sylvestris* L.) stands have been presented in this paper. Indexes of tree and soil surface damages have been used for assessment. Thinking about minimisation of damages to trees and soil on thinnings of pine stands it is necessary to adopt short wood method in which chain saw and forwarder are used. Rational is whole-stem method with chain saw and horse. The largest damages to soil were found when harvester and forwarder were used in a short-wood method on very wet soil.

Key words: damage to trees and soil, thinning, Scots pine, *Pinus sylvestris*, technological process

Introduction

The results of the work done at the Forest Research Institute in Warsaw as a scientific training fellow conducted during the period August 1–October 25, 2002 are summarised in this paper. During the training I participated in field studies and at elaboration of a report in the task entitled: "Assessing damage to trees and soil in thinning of selected pine stands". National Fund of Environment Protection and Water Management in Warsaw financed this task.

Damage to growing forests as a result of thinning operations is a problem that arose in the 1950's with the introduction of tractors into forestry work. Harvesting costs of different thinning methods has been inventoried in many countries and are known. However, thinning also causes indirect costs. Large injuries to stems and large roots will induce reductions in both growth and quality. Mechanical damage to the root system may lead to an increase in spread of root rot and increase the risk of wind-throwing (Wästerlund 1990). There is very little information on that subject. Only by knowing both direct and indirect logging costs, we can find the optimal solution for different circumstances (Sirén 1990).

Methods, technological processes and the distance between strip roads should be taken into account in order to reduce tree and soil damages. Fröding (1992), Sirén (1990), and Wästerlund (1990) have been researching harvesting trace in Scandinavian countries. Hakkila from Finland writes that there are great differences in the susceptibility to damage between tree species. Damage to spruce mostly results in the onset of decay, whereas pine is highly resistant to decay. Superficial root system of the spruce is hurt more easily (Hakkila *et al.* 1980). Results of research conducted in Sweden in pine and spruce stands at thinnings using short-wood method at low technical level, e.g. with chain saw and forwarder, point out that the share of damaged trees reaches 3%, while the single-grip harvester showed a damage frequency of 5.9% (strip road distance 24-25 m, width 4 m) (Fröding 1992).

In Lithuania Ožalas (1999) found that according to the modern thinning technologies the width of stand between hauls should be about 30 m, with no higher than 15-20% thinning intensity. In Latvia Epalts (1990) presents experimental data concerning tree stem, root system and ground cover damages.

The results from researches conducted in lowlands of Poland have shown that the share of damaged pine trees in late thinnings in the short-wood system (with chain saw and forwarder, harvester and forwarder), and the whole-stem system (with chain saw and horse) are distinctly lower (4.1-5.8%) than in other technological processes in whole-stem system (8.6-11.9%) (Suwała *et al.* 2000). Taking into account the damage to the forest and harvesting costs, the use of harvester is preferred over chain saw only in late thinnings (Suwała *et al.* 1997). Disturbances in the surface layer of soil in the cut-to-length system are limited to ruts only. In whole-stem system additional disturbances (grooves) occur during transport of wood (Suwała *et al.* 2000).

Field trials relating to the tree damage and soil disturbances as a result of logging systems employing the equipment and machines available in Poland were started. The trials were conducted in the thinned pine stands in the lowlands and mountain regions. Indexes of tree and soil surface damages were prepared and applied for damage assessment. The synthetic indicator of tree damage during thinning operations ranged between 0.9 and 10.2% while the synthetic indicator of soil damage ranged between 1.1-9.6% depending on the harvesting system and stand condition (Forest Research Institute 2001).

The aim of this work was to assess damage to trees and soil at late thinnings in pine stands. The results of investigation will be used to point out the least harmful – forest-friendly – wood harvesting method and technological process, because it is essential for sustainable forest management. It is very worthwhile to advance knowledge in tree and soil damage and their effects in a thinned stand.

Materials and methods

Research was conducted in pine stands after wood harvesting in late thinning in the lowlands of Poland. The research was realised in forest districts: Kwidzyn, Gidle, Czarne Człuchowskie, Bydgoszcz, Dąbrowa, Lubsko (table 1). Age of tree stands was 35-98 years, stand density - 0.7-1.1, volume - 120-363 m³/ha. The stands were investigated mainly on fresh coniferous and fresh mixed coniferous site types. Distances between strip roads were 20-40 m in processes C_s-PK and C_s-PC_w, in process K_r-PC_n the distance was amounted to 20-30 m. In process with harvester it was 20 m and only in one stand in process with harvester this distance was 40 m.

The research was conducted in 20 stands, so every technological process was estimated in 5 stands. The area in the stand was divided into plots. The area of each plot was 1000 m². 3 plots were delineated in the stand up to 3 ha and for every additional hectare – one sample plot. The distance between plots was counted as the whole length of strip roads divided into number of plots. The width of the plot was average distance between strip roads. Indexes of damages were counted from plots as the average.

Four technological processes of wood harvesting in stands of Scots pine were investigated. In the two processes short-wood method was used while the whole-stem method in the other two:

C_s-PK – whole-stem method, P – felling and delimbing with chain saw, K – hauling with horse;

C_s-PC_w – whole-stem method, P – felling and delimbing with chain saw, C_w – hauling stems by farm tractor equipped with winch;

K_r-PC_n – short-wood method, P – felling, delimbing and bucking with chain saw, C_n – wood extraction with tractor with trailer or by forwarder.

K_r-HF – short-wood method, H – felling, delimbing and bucking with harvester, F – wood extraction by forwarder.

Since there are a lot of detailed measurements and indicators, it is very hard to compare different injuries of trees and soil. Besides, generally known percentage of damaged trees, indexes of tree and soil damage were used too.

To assess tree and soil damages the following indicators were used:

- Percentage of damaged trees:

$$D_u=(d_u*100)/D\ [\%] \quad (1)$$

where: d_u – share of damaged trees, D – number of trees after thinning process;

- Index of tree damages (Suwała 1999):

$$U_d=(D_u+D_{0.1}+D_{100}+D_{0.125}+D_d)/5\ [\%] \quad (2)$$

where: D_u – percentage of damaged trees, $D_{0.1}$ – share of trees with at least one low wound, below 0.1m, D_{100} – share of trees with a wound of total area over 100 cm², $D_{0.125}$ –share of trees with at least one wound covering over 0.125 of the circumference, D_d – share of trees with xylem injury;

- Index of soil surface damage (Suwała 1999):

$$U_g=G_{ko}+G_{pb}+2*G_{bg}+G_{kp}\ [\%] \quad (3)$$

where: G_{ko} –share of rut volume at 10 cm depth of soil layer, G_{pb} –share of shallow rut volume (mainly soil compaction) of the average depth below 5 cm, at 10 cm depth of soil layer, G_{bg} –share of deep rut volume (grooved especially by dragged wood) of the average depth above 5 cm, and soil layer depth of 10 cm, G_{kp} – share of hoof track volume at 10 cm depth of soil layer.

ANOVA (Fisher test) was used to determine the influence of technological processes on the indexes of damages. The significance of differences between average indexes of damages was compared by Duncan test (at the significance level p=0.05).

Results

The percentage of damaged tree (1) in technological processes was (Figure 1):

C_s-PK: 4.8±3.8*;
C_s-PC_w: 8.2±6.0;

Table 1. The characteristic of investigated stands

No.	Plot location: Regional Directorate *Forest District*	Forest sub-district	Section	Tree species*	Site type**	Age	Degree of crop density	Stand density***	Stand quality class	Dbh [cm]	Height [m]	Volume [m³/ha]	Number of trees after thinning [/ha]	Technological process
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Gdańsk *Kwidzyn*	Polanka	37 f	9 P 1 B	BMśw	49	0,9	u.	Ia I	23 23	21 22	329	520	K_r-PC_n
2		Miłosna	38 c	P	BMśw	97	1,0	u.	II	34	24	363	413	C_s-PC_w
3		Piekarniak	188 i	9 P 1 B	LMśw	35	0,9	u.	Ia,5 I	16 18	15 18	215	943	C_s-PC_w
4	Katowice *Gidle*	Miroszowy	6 h	P	Bśw	70	0,8	u.	III	20	17	202	403	K_r-HF
5		Rędziny	77 i	P	Bśw	40	1,1	u.	II,5	13	12	182	1238	K_r-PC_n
6			77 k	P	Bśw	50	0,8	u.	I,5	22	17	221	770	K_r-PC_n
7		Żytno	176 f	P	Bśw	80	0,9	p.	II	28	21	307	492	K_r-HF
8			176 h	P	Bśw	80	0,9	u.	II	30	21	303	382	K_r-HF
9	Szczecinek *Czarne Człuchowskie*	Mszary	10 h	P	Bśw	45	0,8	u.	I,5	17	16	190	850	C_s-PK
10			11 a	P	Bśw	45	0,8	p.	I,5	20	16	200	600	C_s-PK
11			21 c	P	Bśw	36	0,9	u.	II,5	12	10	120	1472	C_s-PK
12		Pakotulsko	205 h	P	BMśw	55	0,8	u.	I,5	24	19	250	468	C_s-PK
13	Toruń *Bydgoszcz*	Brzoza	277 g	P	Bśw	98	0,8	p.	III,5	21	17	218	630	C_s-PC_w
14			278 a	P	Bśw	89	0,7	p.	II	28	23	270	374	C_s-PC_w
15			278 c	P	BMśw	89	0,8	p.	II	29	24	276	358	C_s-PC_w
16	Toruń *Dąbrowa*	Wilcze Błota	186 Ac	P	BMśw	72	0,9	u.	I	28	24	356	561	K_r-HF
17			186 Af	P	Bśw	72	1.1	u.	II,5	26	20	320	607	K_r-HF
18			187 a	P	Bśw	65	0,9	u.	II	23	19	284	1050	K_r-PC_n
19			217 g	P	BMśw	56	1,0	u.	I,5	22	20	311	917	K_r-PC_n
20	Zielona Góra *Lubsko*	Suchleb	131 d	9 P 1 B	Bśw	47 47	1,0	u.	I,5 II	20 19	16 18	254	1310	C_s-PK

* P – pine, B – birch
** Bśw – fresh coniferous forest, BMśw – fresh mixed coniferous forest, LMśw – fresh mixed broad-leaved forest
*** u – moderate, p – rare

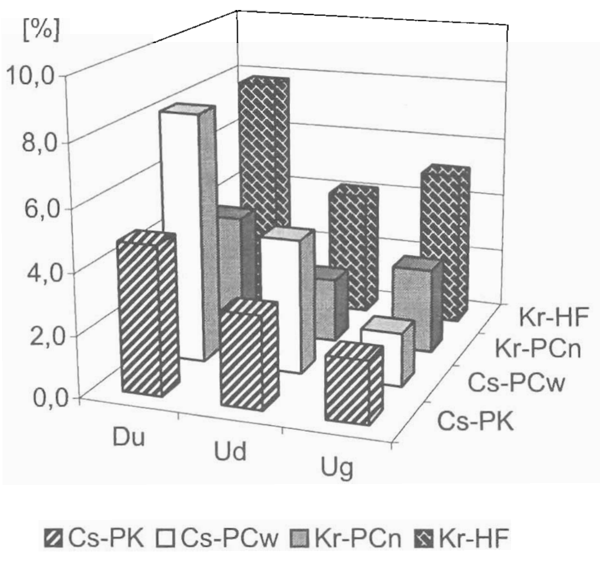

Figure 1. The share of damaged trees (D_u), index of tree damages (U_d) and index of soil damages (U_g) in thinnings of pine stands according to the method, technological process.

K_r-PC_n: 3.9±3.0;
K_r-HF: 7.8±4.7.
* standard deviation.

The percentage of damaged trees is significantly smaller in process K_r-PC_n than in processes K_r-HF and C_s-PC_w.

Damages of trees mainly happened by hauling / extracting. The damages are much smaller in processes with horse and forwarder and much bigger extracting whole stems with farm tractor equipped with winch.

Index of tree damages (2) in technological processes was:

C_s-PK: 3.0±2.7;
C_s-PC_w: 4.4±4.2;
K_r-PC_n: 2.1±1.9;
K_r-HF: 4.1±2.6.

In process K_r-PC_n tree damages are significantly smaller than in K_r-HF and C_s-PC_w. The largest tree damages are in the case of technological process with farm tractor equipped with winch.

Index of soil damages (3) in technological processes was:

C_s-PK: 2.0±0.9;
C_s-PC_w: 1.7±1.5;

K_r-PC_n: 2.8±2.0;
K_r-HF: 5.1±2.1.

Statistical analysis has shown that soil damages in process C_s-PK or C_s-PC_w is significantly smaller than in process K_r-HF.

The differences between tree wounds depend on the methods and technological processes at timber harvesting (Table 2). The biggest share of trees with low wounds (below 0.1 m) was in whole-stem method while wounds above 0.1 m dominate in short-wood method, especially in technological process K_r-HF (91% of damaged trees). Damaged trees with wounds covering less than 1/8 of the circumference were specific to all technological processes. In the case of technological process K_r-HF deep injuries (51% of damaged trees) were observed.

late thinnings in pine stands. The results again showed that the smallest share of damaged trees (D_u=3.9%) is by using short-wood method with felling, delimbing and bucking wood by chain saw and extracting with forwarder or tractor with trailer (K_r-PC_n). The largest damages (D_u=8.2%) are in the whole-stem method using farm tractor equipped with winch (C_s-PC_w). Percentages of damaged trees obtained during the former research were adequate: 4.1 and 8.6% (Suwała 1999). The percentage of damaged trees (7.3%) using harvester and forwarder is much higher than the one obtained during the former research (4.6%) (Suwała 1999). The reason for a big number of damaged trees could be explained by some errors in the work with harvester as well as some errors in establishment of operational roads (too narrow in some parts).

Table 2. The characteristics of tree wounds at timber harvesting according to applied methods and technological process.

Specification		Method			
		Whole-stem		Short-wood	
		C_s-PK	C_s-PC_w	K_r-PC_n	K_r-HF
		Distance between strip roads			
		20-40m	20-40m	20-30m	20-40m
Share of wounds in height classes, %	≤0.1m	81	56	26	9
	>0.1m	22	44	74	91
Share of wounds in damage classes, %	≤100cm^2	40	54	38	48
	>100cm^2	60	46	62	62
Share of wounds in classes of tree circumference, %	≤1/8	65	71	51	58
	>1/8	35	29	49	42
Share of wounds in depth classes, %	to wood material	65	65	67	49
	with xylem damages	35	35	33	51

In case of C_s-PK the tendency of increasing share of damaged trees was noticed in stands where distance between strip roads was longer (Table 3). But in K_r-PC_n and K_r-HF technological processes of short-wood method the share of damaged trees was decreasing while the distance between strip roads increased. It is logical, because the main part of damaged trees was situated near strip roads.

Taking into account differences in wood harvesting circumstances it is hard to compare results from different countries. We can notice that percentage of damaged trees using harvester and forwarder in this research is higher than the percentages presented by authors from foreign countries. Epalts (1989) on the basis of research realised in Latvia indicates 6.5% of damaged trees, Fröding (1992) from Sweden – 4% in pine stand and 7.2% in spruce stand.

Table 3. The share of damaged trees at timber harvesting according to the method, technological process and distance between strip roads.

Method									
Whole-stem						Short-wood			
Technological process									
C_s-PK			C_s-PC_w			K_r-PC_n		K_r-HF	
Distance between strip roads, m									
20	30	40	20	30	40	20	30	20	40
The share of damaged trees, %									
4.0	4.5	7.0*	7.9	14.0*	4.9*	6.4*	3.6	8.4	4.8*
Standard deviation									
3.9	3.9	3.7	4.5	9.9	4.9	6.0	2.4	4.8	3.2

* results only from one stand

Discussion

The percentages of damaged trees and indexes are similar to the results obtained during the earlier research of Warsaw Forest Research Institute (IBL) at

There are no significant differences in the results of soil damages in the case of whole-stem method using chain saw and horse (U_g=2.0%) and short-wood method using chain saw and forwarder or tractor with trailer (U_g=2.8%). They are similar to the results from earlier research at late thinning in pine stands in which index U_g was 2.4 and 3.2%, respectively. Damages of soil in technological process using harvester and forwarder obtained in our research were slightly larger (U_g=5.1%) than those during former research (U_g=3.8%). Most likely it was determined by soil wetness, which was the reason for deep ruts. Wood harvesting in this researched technological process was realised on very wet soil, while other technological processes were realised during very long period without rain, especially in case of whole-stem method using farm tractor equipped with winch and that is why damages of the soil in this process are very small.

Conclusions and proposals for practise

1. Technological processes of wood harvesting influence the amount of tree and soil damages in late thinning in pine stands.

2. Shares of damaged trees at late thinnings in pine stands are the following:

• the smallest in the short-wood method using chain saw for felling, delimbing, bucking and tractor with trailer or forwarder for wood extraction;

• larger in the whole-stem method using chain saw and horse and short-wood method using harvester and forwarder;

• the largest in the case of whole-stem method with felling and delimbing with chain saw and hauling by farm tractor equipped with winch.

3. Disturbances of surface layer of the soil in late thinnings in pine stands are smallest in the case of short-wood method with chain saw and tractor with trailer or forwarder and whole-stem method with chain saw and horse or farm tractor with winch. The differences between them are statistically insignificant.

It should be stressed, however, that the largest soil damages were after using harvester and forwarder, but the wood harvesting in this case was carried out on very wet soil.

4. In order to minimize tree and soil damages in late thinning in pine stands it is necessary to adopt short wood method with chain saw and tractor with trailer or forwarder. The most rational processes are horse logging and mechanical means of high technology (harvester and forwarder). In the last case it is necessary to avoid wood harvesting on very wet soil.

5. The investigation of consequences of forest damages may be very promising.

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References

Epalts, A. 1990. The impact of mechanized thinnings on the remaining stand. Proceedings of IUFRO Conference "Machine design and working methods in thinnings". Hyytiälä, Finland, 17-22 September 1989: 11-21.

Forest Research Institute. 2001. Report on scientific activity of Forest Research Institute in 2000. Warsaw: 46-50.

Fröding, A. 1992. Thinning damage to coniferous stand in Sweden (Beståndsskador vid gallring). Sveriges Lantbruksuniversitet. Garpenberg: 1-50.

Hakkila, P.,Wójcik, T. 1980. Thinning young pine stands with the Makeri tractor in Poland. Folia Forestalia, 433: 1-29.

Ožalas, G. 1999. Survey of problems in thinning of Norway spruce stands. Miškininkystė, 2 (44): 52-58.

Sirén, M. 1990. Cost of mechanized thinning to the stand – how to evaluate. Proceedings of IUFRO Conference "Machine design and working methods in thinnings". Hyytiälä, Finland, 17-22 September 1989: 23-40.

Suwała, M. 1999. Damages of trees and soil caused at timber harvesting in late thinnings of pine stands. (Uszkodzenia drzew i gleby przy pozyskiwaniu drewna w późnych trzebieżach drzewostanów sosnowych) „Prace Instytutu Badawczego Leśnictwa", Seria A, Nr 873: 1-86.

Suwała, M., Jodłowski, K., Rzadkowski, S. 1997. Thinnings in pine stands: mechanical damages and harvesting costs. Workshop proceedings "New trends in thinnings". Forest Research Institute, Slovakia and Joint FAO/ECE/ILO Committee on Forest Technology, Management and Training. Zvolen, Slovakia, 8-12 September 1997: 45-53.

Suwała, M., Jodłowski, K., Rzadkowski, S. 2000. Tree damage and soil disturbances at wood harvesting. Proceedings of the International Scientific Conference "Forest and wood technology vs. environment". Brno, Czech Republic, 20-22 November 2000: 357-365.

Wästerlund, I. 1990. Effects of damage on the newly thinned stand due to mechanized forest operations. Proceedings of IUFRO Conference "Machine design and working methods in thinnings". Hyytiälä, Finland, 17-22 September 1989: 41-56.

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ОЦЕНКА ПОВРЕЖДЕНИЙ ДЕРЕВЬЕВ И ПОЧВЫ ПРИ РУБКАХ УХОДА В СОСНЯКАХ

А. Гапшите

Резюме

В статье представлены результаты исследования влияния различных технологий рубок ухода на повреждения деревьев и почвы в сосняках. Для оценки использованы индексы повреждения деревьев и почвы. Наименьшие повреждения установлены при использовании бензомоторной пилы и форвардера при сортиментной заготовке древесины. Рациональным можно считать и хлыстовой метод, когда трелевка хлыстов осуществляется при помощи лошади. Наибольшие повреждения почвы найдены при использовании гарвестера и форвардера во влажных местах.

Ключевые слова: повреждения деревьев и почвы, рубки ухода, технологии, сосняки, *Pinus sylvestris.*