ACTA SCIENTIARUM POLONORUM
Acta Sci. Pol.
Silv. Colendar. Rat. Ind. Lignar. 8(3) 2009, 5-14

ECOLOGICAL ASPECTS OF WOOD HARVESTING AND SKIDDING IN PINE STANDS WITH USE DIFFERENT TECHNOLOGIES

Katarzyna Glazar, Marianna Maciejewska
Poznań University of Life Sciences

Abstract. The new look at the forest economy takes into consideration maximum protection of forest ecosystems, first of all. The purpose of the research was to estimate the influence of wood harvesting and skidding technologies on forest environment, particularly on soil and remained stand. The traditional wood harvesting and skidding technology (compact sawing machine, tractor with winch) was more friendly for soil environment than the newest technology (harwarder). Decrease of the negative influence of engineering wood harvesting and skidding process on forest environment is possible through application of both technologies and technical means correctly selected for the purpose. Besides, the operator's practice is of a significant meaning.

Key words: damages of soil, damages of trees, harwarder

INTRODUCTION

The presently existing forest economy concept motivates scientists to take up research concerning the balance between human interference in the natural environment and its development capability [Maciejewska 2005]. The practical explanation of the standpoint is found in the Forest Act and other regulations.

"The degradation of the natural environment increasing for years now alongside with the insisting influence of unfavourable biotic and non-biotic factors threaten the existence of forests. The aforementioned threat is the effect of both the gigantic size and rate of changes in the natural environment resulting from human activity. The simplified and schematic forest economy brings about the process of forest impoverishment. Thus the forest protection must be targeted at minimising both current and future threats of external (civilisation and climate-related) and internal nature (simplified economical solutions applied so far)." [Zarządzenie... 1999].

The obligatory Forest Act: *Ustawa o lasach dated 28 September 1991* and regulation: *Zarządzenie nr 11A Dyrektora Generalnego Lasów Państwowych dated 11 May*

Corresponding author – Adres do korespondencji: Katarzyna Glazar, Department of Forest Technology of Poznań University of Life Sciences, Wojska Polskiego 71 C, 60-625 Poznań, Poland, e-mail: katmac@up.poznan.pl

1999 define the principles of forest economy. The forest economy in Polish forests should be conducted basing on ecological principles, especially taking into consideration forests, soils and water protection, as well as wood and other products resulting from rational farming." [Ustawa... 1991].

Wood harvesting causes strong disturbances in forest ecosystems, being frequently of the nature evoking a very strong environmental stress [Paschalis and Porter 1994]. The new look at the forest economy assumes, first of all, maximum protection of the forest ecosystems and environmentally friendly technologies to be obligatorily applied (technologies at decreasing to minimum soil and remained trees damage) [Kamiński 1988, Giefing 1999, Gil 1999, Suwała 2004, Grodecki and Stempski 2005, Maciejewska 2005].

The purpose of the research was to estimate the influence of wood harvesting and skidding technologies on forest environment, particularly on soil and left stand.

MATERIAL AND METHODS

The research was carried out in pine stands (V age class), in which was executed late thinning (LT) in short wood system (SWS) with use of two different technologies of harvesting and skidding.

On the surface of LT M wood harvesting and skidding were carried out with harwarder Buffalo Dual by Ponsse while on LT M-M the wood harvesting was carried out using the Husqvarna 357XP power saw, and wood skidding with tractor Ursus 1634 with winch.

On both surfaces an estimation and stock-taking of soil damages was performed. For this purpose on surface LT M (1.5 ha) 82 rectangular trial surfaces were founded, and on surface LT M-M (1.8 ha) 154 circled (radius 2 m) trial surfaces were made.

On surface LT M trial surfaces were situated on skidding roads (the soil damages were situated only there). For soil damages estimation, two kinds of the skidding roads were selected:

– main skidding roads, length of over 30 m,
– subsidiary skidding roads, length up to 30 m.

On each main skidding road, on its each tenth meter, rectangular trial surface was founded, of 4 m dimension (width of skidding road) x a (a = 0.1 L/n; L – length of skidding road [m], n – number of trial surfaces on skidding road).

On subsidiary skidding roads, owing to their length limited to 30 m, only one trial surface was founded with dimension of 4 m x a, placed half way of subsidiary skidding road. The total area of all the trial surfaces founded on surface LT M constituted 10% of all skidding roads. On surface LT M-M centers of circled trial surfaces were nodal points of grid having flanks of 10 m x 10 m.

The estimation of soil damages was carried out according to six-level scale (Table 1) [Grodecki et al. 2000]. The soil damages was described as percentage of trial surface in definite stage of six-stage scale. Besides, the remained stand was estimated. The estimation of trees damages (the stem, root collar and roots) was carried out according to four--level scale (Table 2) [Grodecki et al. 2000].

Table 1. The soil damages scale
Tabela 1. Skala uszkodzeń gleby

The level of soil damage Stopień uszkodzenia gleby	The characteristic of damage Charakterystyka uszkodzenia
1	forest litter preserved, lack of packed places ścioła zachowana, brak śladów ubicia
1a	forest litter infringed, undisturbed soil, lack of packed places ścioła naruszona, gleba niezakłócona, brak śladów ubicia
2a	forest litter removed, the mineral soil uncovered, but undisturbed ścioła usunięta, gleba mineralna odsłonięta, ale niezakłócona
2b	mineral soil mixed with forest litter gleba mineralna wymieszana ze ściołą
3	deeply damaged soil, superficially removed, its deeper layers uncovered gleba głęboko zniszczona, powierzchniowo usunięta, głębsze jej warstwy odsłonięte
4	packed soil, distinct packed places as a result of motor vehicle drive or load gleba ubita, wyraźne ślady ubicia przez pojazd lub ładunek

Table 2. The trees damages scale
Tabela 2. Skala uszkodzeń drzew

The level of tree damage Stopień uszkodzenia drzewa	The characteristic of damage Charakterystyka uszkodzenia
I	abrasion on stem area with not large bark loss otarcie na powierzchni pnia z niewielkim ubytkiem kory
II	bigger superficial abrasions, bigger bark losses, bark splinters (invisible though) suggesting cambium damages większe powierzchniowo otarcia, większe ubytki kory, odbicia kory sugerujące (niewidoczne jednakże) uszkodzenia miazgi
III	visible cambium damages, wood uncovered, but undamaged widoczne uszkodzenia miazgi, drewno odsłonięte, ale nieuszkodzone
IV	damaged wood drewno uszkodzone

The main indices of damages of both soil and trees were estimated:

1. The index number of soil damages:

$$I_s = \frac{\sum A_{1a-4}}{A} \cdot 100\%,$$

where:

I_S – index number of soil damages,

$\sum A_{1a-4}$ – total of soil damaged area in 1a-4 level,
A – area of stand.

2. The index number of strong soil damages:

$$I_{Ss} = \frac{A_3 + A_4}{A} \cdot 100\%,$$

where:
I_{Ss} – index number of strong soil damages,
A_3 – soil damages area in level 3,
A_4 – soil damages area in level 4,
A – area of stand.

3. The synthetic index number of soil damages:

$$S_{IS} = \frac{0.1 \cdot A_{1a} + 0.3 \cdot A_{2a} + 1 \cdot A_{2b} + 3 \cdot A_3 + 3 \cdot A_4}{A},$$

where:
S_{IS} – synthetic index number of soil damages,
A_{1a} – soil damages area in level 1a,
A_{2a} – soil damages area in level 2a,
A_{2b} – soil damages area in level 2b,
A_3 – soil damages area in level 3,
A_4 – soil damages area in level 4,
A – area of stand.

4. The index number of trees damages:

$$I_T = \frac{\sum T_D}{N_T} \cdot 100\%,$$

where:
I_T – index number of trees damages,
$\sum T_D$ – total of trees damaged,
N_T – number of trees in stand.

5. The index number of strong trees damages:

$$I_{Ts} = \frac{T_{III} + T_{IV}}{N_T} \cdot 100\%,$$

where:
I_{Ts} – index number of strong trees damages,
T_{III} – number of trees damaged in level III,
T_{IV} – number of trees damaged in level IV,
N_T – number of trees in stand.

6. The synthetic index number of trees damages:

$$S_{IT} = \frac{0.25 \cdot T_I + 0.5 \cdot T_{II} + 2 \cdot T_{III} + 3 \cdot T_{IV}}{N_T},$$

where:

S_{IT} – synthetic index number of trees damages,
T_I – number of trees damaged in level I,
T_{II} – number of trees damaged in level II,
T_{III} – number of trees damaged in level III,
T_{IV} – number of trees damaged in level IV,
N_T – number of trees in stand.

7. The synthetic index number of forest environment damages:

$$S_{IST} = S_{IS} + S_{IT},$$

where:

S_{IST} – synthetic index number of forest environment damages,
S_{IS} – synthetic index number of soil damages,
S_{IT} – synthetic index number of trees damages.

RESULTS

The results of soil damages estimation and stocktaking are shown in Table 3. On surface LT M, level 1 was 77% of surface area (area between skidding roads). On skidding roads (23% of surface area) level 4 was 14%. On this surface there were no soil damages of levels 2a, 2b and 3.

Table 3. The structure of soil damages on surfaces LT M and LT M-M
Tabela 3. Struktura uszkodzeń gleby na działkach TP M i TP R-M

Surface Działka	The level of soil damage Stopień uszkodzenia gleby											
	1		1a		2a		2b		3		4	
	%	m^2	%	m^2	%	m^2	%	m^2	%	m^2	%	m^2
LT M (area besides skidding roads) TP M (pow. poza szlakami)	**77**	11 550	–	–	–	–	–	–	–	–	–	–
LT M (skidding roads) TP M (szlaki)	**8**	1 200	**1**	150	–	–	–	–	–	–	**14**	2 100
LT M-M TP R-M	**75**	13 500	**16**	2 880	**2**	360	**6**	1 080	**1**	180	–	–

On surface LT M-M, level 1 was taken up by 75% of surface area. Level 1a reached 16%, level 2a – 2%, level 2b – 6% and level 3 – 1%. On this surface there was no level 4 of soil damages.

The main index numbers of soil damages are shown in Table 4. The index number of soil damages (I_S) on surfaces: LT M and LT M-M amounted to 15% and 25%. The index number of strong soil damages (I_{Ss}) amounted: on surface LT M to 14%, and on surface LT M-M to 0%. The synthetic index number of soil damages (S_{IS}) was fourfold bigger on surface LT M with reference to surface LT M-M.

Table 4. The indexes number of soil damages on surfaces LT M and LT M-M
Tabela 4. Wskaźniki uszkodzenia gleby na działkach TP M i TP R-M

Index number Wskaźnik	Symbol Symbol	Unit Jednostka	Surface Działka	
			LT M TP M	LT M-M TP R-M
Index number of soil damages Wskaźnik uszkodzeń gleby	I_S W_G	%	15	25
Index number of strong soil damages Wskaźnik dotkliwych uszkodzeń gleby	I_{Ss} W_{Gd}	%	14	0
Synthetic index number of soil damages Syntetyczny wskaźnik uszkodzeń gleby	I_{SIS} Sw_G	–	0.421	0.116

For both surfaces numbers of trees damages alongside with site and level of damages were determined (Table 5). After harvesting and skidding works had been finished, 357 trees were left on surface LT M. Seven trees were damaged (2%): 4 in level I (root collar), 1 in level II, 1 in level III and 1 in level IV. On surface LT M-M remained 420 trees. Twenty one of trees were damaged (5%): 19 in level I, 1 in level II and 1 in level IV. The damages were located on root collar (18 trees) and on stem (3 trees).

Table 5. The structure of trees damages on surfaces LT M and LT M-M
Tabela 5. Struktura uszkodzeń drzew na działkach TP M i TP R-M

Level of tree damage Stopień uszkodzenia drzewa	Surface – Działka					
	LT M – TP M			LT M-M – TP R-M		
	stem strzała	root collar szyja korzeniowa	root korzenie	roots collar szyja korzeniowa	stem strzała	roots korzenie
I	0	4	0	2	17	0
II	0	1	0	0	1	0
III	1	0	0	0	0	0
IV	1	0	0	1	0	0

The main index number of trees damages are shown in Table 6. The index number of trees damages (I_T) on surface LT M and LT M-M reached about 2% and 5%. The index number of strong trees damages (I_{Ts}) on surface LT M and LT M-M was 0.53% and 0.23%. The synthetic index number of trees damages (S_{IT}) was about 13% lower on surface LT M than on surface LT M-M.

Table 6. The indexes number of trees damages on surfaces LT M and LT M-M
Tabela 6. Wskaźniki uszkodzeń drzew na działkach TP M i TP R-M

Index number Wskaźnik	Symbol Symbol	Unit Jednostka	Surface Działka	
			LT M TP M	LT M-M TP R-M
Index number of trees damages Wskaźnik uszkodzeń drzew	I_T W_D	%	~2	5
Index number of strong trees damages Wskaźnik dotkliwych uszkodzeń drzew	I_{Ts} W_{Dd}	%	~1	~0
Synthetic index number of trees damages Syntetyczny wskaźnik uszkodzeń drzew	S_{IT} Sw_D	–	0.017	0.020

The synthetic index number of forest environment damages (S_{IST}) for surface LT M and surface LT M-M reached 0.438 and 0.136.

DISCUSSION

The mechanical technology of wood harvesting has an unfavourable influence on soil environment. The higher index numbers of soil damages for surface LT M compared to surface LT M-Mdo not result from typical but additional aspects, which stimulate destructive influence on soil in wood harvesting and skidding. The following should be mentioned:

- the number of late thinning cuttings with harwarder – the operator's professional experience (the late thinning cutting with harwarder was carried out for the first time),
- the method of forest works with application of skidding roads network (the designed skidding roads network was not sufficient for technology in focus).

The high participation of level 4 soil damage area (packed soil, distinct packed places as a result of motor vehicle drive or load) on surface LT M was a result of the accepted damages scale. It was, theoretically, the most onerous damage for forest soil environment. On surface LT M level 4 soil damages areas with mineral soil mixed with forest litter (level 2b) or deeply damaged, area removed and its deeper layers uncovered (level 3) were found. Additionally on this surface were found areas with packed soil only. It is questionable then if level 4 state of damages implies the most onerous state for forest environment.

On surface LT M-M, on which wood skidding was carried with the tractor with winch, no level 4 of soil damages were found.

The kind of wood skidding had an influence on this result. The wood assortment dragged behind the vehicle covered packed tracks of soil (as a result of motor vehicle drive) (level 4) and concurrently caused soil damages other of kinds (mixing of mineral soil with forest litter, mineral soil uncovering, deep soil damage). This double soil area infringement was ascribed to level 1a-3. During the damage estimation, was guided by its visible effect, and not suspected effect. The assumed methods and obtained on their basis results show that traditional wood harvesting and skidding technology is more friendly for soil environment than the newest technology. Probably, the operator's professional experience with the newest machine (harwarder Buffalo Dual) is incomparably smaller, than that with traditionally applied machines and methods. None of the applied technologies is sufficiently ecological to be applied on protected area (in central part of the investigated surface an area of club mosses under strict protection was encountered). The implementation of wood harvesting and skidding technological process, that is: the level of work mechanization, the technology and technical means selection, the methods of forest works in stand, the cutting correctness, and worker's professional qualifications were causes of differences in value of soil damages indexes for surfaces LT M and LT M-M, on which the same improvement cutting - late thinning were carried out. Both surfaces were localized in the same pine stand.

After the carried out late thinning, the level of left trees damages was described as relatively low. On surface LT M, the lesser number of damaged trees was the result of a smaller density of the stand before late thinning was carried out. Owing to a lower number of trees free manipulation of harwarder was possible. On surface LT M-M, the method of applied wood skidding was the cause of a greater number of damaged trees. On both surfaces bark was damaged most while cambium least frequently.

CONCLUSIONS

1. Wood harvesting in late thinning with harwarder was characterised by bigger soil damages than the one carried out by help of manual-mechanical technology (the index number of strong soil damages I_{Ss} equaled to: 14% – mechanical technology, 0% – manual-mechanical technology).

2. The trees damage level in wood harvesting in mechanical technology, as well as in manual-mechanical technology was low and reached 2% (mechanical technology) and 5% (manual-mechanical technology).

3. Decrease of the negative influence of engineering wood harvesting and skidding process on the forest environment is possible applying technologies and technical means correctly selected for the purpose. Besides, the operator's practice is of vital significance.

REFERENCES

Giefing D.F., 1999. Wpływ pozyskiwania drewna w czyszczeniach późnych drzewostanów sosnowych na środowisko. Część 2. Gleby [The influence of wood harvesting in late cleaning of pine stands on environment. Part 2. Soils]. Sylwan 6, 91-100 [in Polish].

Gil W., 1999. Problemy wyboru środków do operacji pozyskaniowo-zrywkowych [The problems of technical means selection in wood harvesting and skidding]. Sylwan 6, 47-56 [in Polish].

Grodecki J., Różański H., Stempski W., Gornowicz R., Jabłoński K., Naparty K., Pilarek Z., Wojtkowiak R., 2000. Środowiskowe i produkcyjne skutki udostępniania drzewostanów siecią szlaków operacyjnych [The environmental and production effects of forest works in pine stands with application of skidding roads network]. DGLP Warszawa [typescript; in Polish].

Grodecki J., Stempski W., 2005. Wpływ technologii na poziom uszkodzeń środowiska leśnego podczas pozyskiwania drewna z cięć trzebieżowych. Użytkowanie lasu a trwały i zrównoważony rozwój leśnictwa [The influence of technology on forest environment damages level in wood harvesting from thinning cutting. The forest utilization and standing and sustainable forest management]. Kat. Użytk. Lasu AR Poznań 21-27 [in Polish].

Kamiński E., 1988. Użytkowanie lasu a ochrona środowiska leśnego [The forest utilization and forest environment protection]. Sylwan 10, 1-8 [in Polish].

Maciejewska M., 2005. Ekologiczne i ekonomiczne aspekty pozyskiwania drewna z drzewostanów sosnowych z zastosowaniem różnych technologii [The ecological and economic aspects of wood harvesting in pine stands with use different technologies]. Kat. Techn. Leśn. AR Poznań [typescript; in Polish].

Paschalis P., Porter B., 1994. Próba oceny uszkodzeń drzew w wyniku prac zrywkowych w sosnowych drzewostanach przedrębnych [The trees damages estimate in effect skidding works in pine stands]. Sylwan 9, 17-21 [in Polish].

Suwała M., 2004. Uszkodzenia gleby w drzewostanach sosnowych przy pozyskiwaniu drewna w praktyce leśnej [The soil damages in pine stands during wood harvesting in forest practice]. Sylwan 1, 87-101 [in Polish].

Ustawa o lasach z dnia 28 września 1991 roku [The Forest Act of 28 September 1991]. Dziennik Ustaw z 8 listopada 1991 roku, nr 101, poz. 444 (zm. Dz.U. 2007, nr 181, poz. 1286; Dz.U. 2007, nr 64, poz. 427, Dz.U. 2007, nr 59, poz. 405, Dz.U. 2006, nr 245, poz. 1775, Dz.U. 2006, nr 227, poz. 1658, Dz.U. 2005, nr 175, poz. 1462, Dz.U. 2005, nr 175, poz. 1460, Dz.U. 2005, nr 167, poz. 1399, Dz.U. 2005, nr 157, poz. 1315) [in Polish].

Zarządzenie nr 11A/1999 Dyrektora Generalnego Lasów Państwowych z dnia 11 maja 1999 r. (zn. spr. ZG-7120-2/99) zmieniające Zarządzenie nr 11 Dyrektora Generalnego Lasów Państwowych z dnia 14 lutego 1995 roku w sprawie doskonalenia gospodarki leśnej na podstawach ekologicznych (zn. spr. ZZ-710-13/95) [The Regulation of State Forests General Director of 11 May 1999 in the matter of the forest economy perfecting on ecological assumptions]. 1999. Dostępny w Internecie: http://www.lp.gov.pl/zd/z11A-1999/dz_view [dostęp 03.07.2009; in Polish].

ASPEKTY EKOLOGICZNE POZYSKIWANIA I ZRYWKI DREWNA Z DRZEWOSTANÓW SOSNOWYCH Z ZASTOSOWANIEM RÓŻNYCH TECHNOLOGII

Streszczenie. Nowe spojrzenie na gospodarkę leśną uwzględnia przede wszystkim maksymalną ochronę ekosystemu leśnego. Celem prowadzonych badań była próba oceny wpływu stosowanych technologii pozyskania i zrywki surowca na środowisko leśne, a w szczególności na glebę i pozostający drzewostan. Przyjęta metodyka i uzyskane na jej podstawie wyniki wykazały, że tradycyjna technologia pozyskania i zrywki drewna (pilarka, ciągnik z wciągarką) okazała się bardziej przyjazna dla środowiska glebowego, niż technologia najnowsza (harwarder). Zmniejszenie negatywnego wpływu procesu technologicznego pozyskania i zrywki drewna na środowisko leśne (w szczególności glebę

i pozostający drzewostan) jest możliwe do osiągnięcia poprzez prawidłowy dobór technologii i środków technicznych oraz odpowiednie udostępnianie drzewostanu, dostosowane do wybranej technologii. Nie bez znaczenia pozostaje doświadczenie operatora.

Słowa kluczowe: uszkodzenia gleby, uszkodzenia drzew, harwarder

Accepted for print – Zaakceptowano do druku: 24.08.2009

For citation – Do cytowania: Glazar K., Maciejewska M., 2009. Ecological aspects of wood harvesting and skidding in pine stands with use different technologies. Acta Sci. Pol., Silv. Colendar. Rat. Ind. Lignar. 8(3), 5-14.