ACTA SCIENTIARUM POLONORUM
*Acta Sci. Pol.*
*Silv. Colendar. Rat. Ind. Lignar. 10(3) 2011, 5-14*

# RESULTS OF LARGE-SIZE TIMBER EXTRACTING WITH A GRAPPLE SKIDDER

Mariusz Bembenek[1], Piotr S. Mederski[1], Jörn Erler[2], Dieter F. Giefing[1]
[1]Poznań University of Life Sciences
[2]Dresden University of Technology

**Abstract.** A new HSM 904Z 6WD skidder of a large size was tested in a 140-year-old beech stand in northern Poland. The aim of the study was to analyse machine productivity and impact on the soil (bulk density and cone penetrometer test) and the remaining natural regeneration caused by skidding. Trees were cut by chainsaw and, if possible, felled into the direction of the skidroads. After delimbing, logs with a top diameter of a minimum 7 cm over the bark were prepared. The average skidding operational productivity including piling was 21.0 $m^3 \cdot h^{-1}$. At the same time, the level of damage in natural regeneration was: 18% (38% due to both: felling and skidding). An analysis of the soil after skidding showed that the density had grown by 15-30 $g \cdot cm^{-3}$. Increase of penetration resistance was up to 2.77 MPa as the biggest.

**Key words:** grapple skidder, productivity, soil disturbance, damage in natural regeneration

## INTRODUCTION

The development of skidders dates back to 1949 when a Walters four-wheel drive truck was tested as a skidder in Orleans, Ontario [Silversides 1988]. This was to replace animal participation in forest work and to improve productivity in this hard job. Nowadays, due to high labour costs, improving productivity and lowering costs is still an important issue. Limited labour and high economic competition in Central Europe make manual work expensive which also reflects on the costs of forest operations [Erler 2005]. Such a situation requires the introduction of very productive machines for timber extraction operated by one person. In a boreal forest zone, forest operations are based on harvesters and forwarders. In Central Europe, in contrast to North America or Scandinavian countries, large areas of forest consist of broadleaved species. These conditions limit mechanised (harvester-forwarder) operations in mature broadleaved and mixed stands of older age classes due to the large size of timber being extracted [Bacher-

Corresponding author – Adres do korespondencji: Dr Mariusz Bembenek, Department of Forest Utilisation of Poznań University of Life Sciences, Wojska Polskiego 71 A, 60-625 Poznań, Poland, e-mail: mariusz.bembenek@up.poznan.pl

-Winterhalter et al. 2006]. In such conditions the long wood system is still carried out. In order to improve productivity in the long wood system a new skidder was developed within the ForstInno project: the HSM 904Z 6WD. The results presented in this paper are relevant to the current problems regarding the development of forest operations and studies recognized as important in engineering and operational management in the future [Heinimann 2007 a, b].

Sustainable forestry requires operations with the lowest harmful impact on the environment [Paschalis 1996]. In order to increase biodiversity, natural regeneration is fostered. The hypothesis was that the new skidder might be helpful in minimizing damage in natural regeneration with respect to minimal soil disturbances and satisfactory productivity parameters due to grapple use.

## MATERIAL AND METHODS

### Study area and forest operation

Research was carried out in March 2007 in northern Poland, the Regional Directorate of the State Forests Gdańsk. Three sample plots marked as SP 01, SP 02 and SP 03 were selected in a 140-year-old beech (*Fagus sylvatica* L.) stand 63b, in which final felling after natural regeneration was prescribed. Timber harvesting was carried out within the long wood system: cutting, felling and delimbing was done by two chainsaw operators in the stand area. Two people also carried out crosscutting of logs after skidding next to the transport road. Logging and all soil measurements were carried out in temperatures over 0°C, the soil was not frozen and there was no snow. For skidding a newly constructed HSM 904Z 6WD was used, empowered with 176 kW Iveco engine. The machine had 6 wheels with Trelleborg 750/65-34 T442 tyres in front and Trelleborg 750/50-26.5 T442SB tyres at the rear boogie system. A 7.2 m long crane with lift power 5 tonnes was mounted in the back, as well as a double drum Adler HY 16 SR winch with a pulling power of 2 × 16 tonnes. The skidder was 2.7 m wide, 10.7 m long and 2.7 m high and had a weight of 17 400 kg.

Before felling trees, measurements of the trees were carried: DBH, height of trees and their crowns were taken with the Haglöf Digitech Professional and Vertex III (Table 1).

In the analysed forest operation, the skidder drove on marked, 3.5 m wide, parallel skid roads at 40 m intervals. In three SP 0.25 ha, trees were cut and felled into the direction of the skid roads. Before skidding the trees were delimbed and the tops of the trees were cut at a min. 7 cm over bark diameter. When skidding was carried out, single logs were pulled towards the skid roads and a load of usually three logs was formed before the second stage of skidding. Afterwards, the whole amount was grabbed and hauled 200-300 m to the centre point for further crosscutting and piling.

### Time analysis and productivity

During tree cutting, log preparation, skidding and crosscutting, the timing was measured (at all stages of the whole operation) using a stop-watch. Each stage of logging was differentiated according to the schedule of work time classification [Mederski

Table 1. Sample plots characteristics
Tabela 1. Charakterystyka drzewostanu na powierzchniach próbnych

| Sample plot Po-wierzch-nia próbna | Number of trees Liczba drzew | Tree characteristics – Parametry drzewa | | | | | | | | Harvested volume Pozyskana miąższość $m^3$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | BHD pierśni-ca cm | max/min maks./min. | H m | max/min maks./min. | Hc Hk m | max/min maks./min. | V $m^3$ | max/min maks./min. | |
| SP 01 PP 01 | 35 | 42.0 | 61.0 / 28.0 | 24.1 | 33.5 / 18.9 | 11.9 | 18.4 / 5.0 | 1.55 | 5.27 / 0.39 | 54.12 |
| SP 02 PP 02 | 22 | 45.0 | 90.0 / 27.0 | 24.3 | 32.0 / 15.0 | 13.8 | 18.5 / 7.5 | 2.00 | 8.44 / 0.53 | 44.13 |
| SP 03 PP 03 | 23 | 47.0 | 63.0 / 33.0 | 23.8 | 28.0 / 18.0 | 13.5 | 21.0 / 7.5 | 2.16 | 5.14 / 0.79 | 49.64 |

Hc – height of a tree crown base (mean for a sample plot), SP – sample plot.
Hk – wysokość podstawy korony (średnia dla powierzchni próbnej), PP – powierzchnia próbna.

2006]. Finally, the data obtained concerning operational time ($T_{02}$) of felling, skidding, crosscutting and piling was used in the analysis of operational time of forest operation productivity ($P_{02fo}$), understood as:

$$P_{02fo} = \frac{Q}{T_{02f1} + T_{02f2} + T_{02se} + T_{02c1} + T_{02c2} + T_{02sp}} \quad (1)$$

where:

- Q – the volume of extracted wood, $m^3$,
- $T_{02f1}$, $T_{02f2}$ – times of fellers,
- $T_{02se}$, $T_{02sp}$ – times of skidder extraction and skidder piling,
- $T_{02c1}$, $T_{02c2}$ – times of crosscutters.

**Soil disturbance and damage in regeneration**

The bulk density was analysed on all skid roads. Soil samples for dry bulk density were taken by means of Kopecky soil cores: 5 cm diameter, 100 $cm^3$. Samples were collected every 10 m from the ruts and beyond the ruts where no evidence of compaction was observed. In the analysis, soil beyond the ruts was considered to have the same properties as soil from the rut area before harvester driving. Soil samples were collected from the surface mineral layer, oven dried for 24 h at 105°C and weighted on an accurate (0.01 g) laboratory scale. Additionally, a cone penetrometer test (CPT) was carried out at depths 5-40 cm (at depth intervals of 5 cm) every 5 m along the strip roads: within the left (LR) and right (RR) rut, beyond left (LLR) and beyond right (RRR) rut using a hand penetrometer (Eijkelkamp Agrisearch Equipment, the Nederlands). A sixty-degree cone was used with a cone basal area surface 1 $cm^2$.

Damage to the natural regeneration of trees was analysed in 1 $m^2$ plots, whose centres were scattered evenly every 10 m on the sample plots. After final felling and skidding, a classification of trees with damage was carried out with respect to the cause of damage (felling or skidding) and type of damage (broken or bent tree, scratched bark or wood tissues).

## RESULTS

### Productivity of thinning operation

The mean operational productivity of the whole forest operation per person ($P_{02fo}$) was 18.0 $m^3 \cdot h^{-1}$ (Table 2). This was obtained from 83 trees which gave 147.9 $m^3$ of merchantable timber (min diameter over bark 7 cm). The average volume of wood obtained from one tree was 1.8 $m^3$.

Table 2. Operational productivity (per person) of whole forest operation (felling, skidding, cross-cutting, piling) and tree characteristics
Tabela 2. Wydajność operacyjna (na osobę) całego procesu pozyskiwania i zrywki drewna (w tym przerzynka i mygłowanie) oraz główne parametry drzew

| | $P_{02fo}$ | $P_{02f}$ | $P_{02se}$ | $P_{02se}+P_{02sp}$ | $P_{02c}$ | Trees Drzewa | V | Mean tree V Średnia V drzewa |
|---|---|---|---|---|---|---|---|---|
| | $m^3 \cdot h^{-1}$ | | | | | n | $m^3$ | |
| SP 01 | 18.2 | 10.8 | 28.6 | 23.4 | 10.1 | 35 | 54.1 | 1.5 |
| SP 02 | 18.3 | 10.8 | 33.0 | 19.8 | 9.7 | 22 | 44.1 | 2.0 |
| SP 03 | 17.3 | 13.8 | 30.0 | 19.8 | 5.6 | 26 | 49.6 | 1.9 |
| Mean Średnia | 18.0 | 11.8 | 30.5 | 21.0 | 8.5 | 28 | 49.3 | 1.8 |

V – volume of extracted timber (min 7 cm over bark).
V – miąższość zrywanego drewna (min. 7 cm z korą).

### Soil disturbance and damage in regeneration

The increase in bulk density was from 0.02-0.55 $g \cdot cm^{-3}$. The biggest increase was observed in plots with the smallest initial density beyond the ruts (SP 02 and 03). The mean bulk density beyond the ruts ranged from 1.43-1.60 $g \cdot cm^{-3}$and in the ruts 1.71-1.82 $g \cdot cm^{-3}$; this density increase was statistically significant (Table 3). Changes in bulk density were observed at a mean soil moisture of 25% but changes in moisture after skidding were not statistically significant.

The smallest changes in bulk density (9%) were on SP 01 (Fig. 1). An increase of 20% on SP 02 and 03 were on skidroads with the lowest bulk density beyond the ruts (1.43 and 1.52 $g \cdot cm^{-3}$).

The CPT results showed a considerable increase in soil resistance in the ruts (Fig. 2, Table 4) which was statistically significant. On SP 01 and 02 the changes in penetration resistance were statistically significant, both, after 26 and 18 skidder passes. These changes were also significant in SP 01, but only at 5 and 10 cm depths.

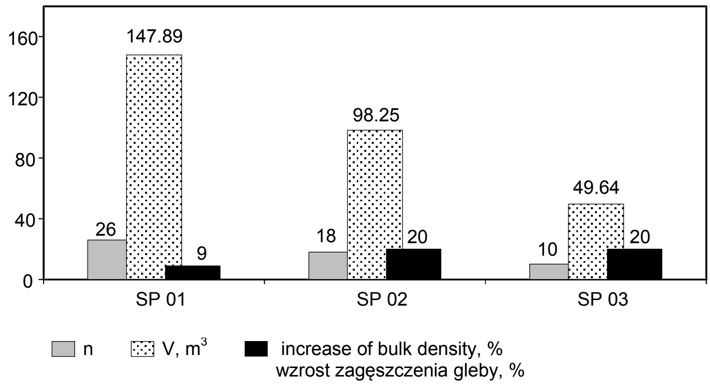


Fig. 1. Number of passes, volume of skidded timber across sample plot and bulk density increase
Rys. 1. Liczba przejazdów, miąższość zerwanego drewna oraz wzrost zagęszczenia gleby

Felling and skidding caused the most intensive damage in natural regeneration on SP 02: 43%. On the same sample plot the biggest amount of damage from felling was found: 28%. Damage due to skidding was the most significant on SP 03: an amount of 22%. The largest number of broken trees were observed on SP 03, but on SP 02 the largest number of bent trees were found (Fig. 3).

Table 3. Bulk density as influenced by treatment: test t, $p < 0.5000$
Tabela 3. Zagęszczenie gleby przez skider: test t, $p < 0,5000$

| | | Mean Średnia | Standard deviation Odchylenie standardowe | N | Difference Różnica | Standard deviation difference Odchylenie standardowe, różnica | t | p |
|---|---|---|---|---|---|---|---|---|
| SP 01 | BR/PK | 1.60 | 0.076334 | | | | | |
| | WR/WK | 1.74 | 0.088075 | 6 | –0.15 | 0.084739 | –4.2907 | 0.007783 |
| SP 02 | BR/PK | 1.52 | 0.066298 | | | | | |
| | WR/WK | 1.82 | 0.073570 | 6 | –0.30 | 0.107149 | –6.9539 | 0.000945 |
| SP 03 | BR/PK | 1.43 | 0.178724 | | | | | |
| | WR/WK | 1.71 | 0.106862 | 6 | –0.28 | 0.225615 | –3.0781 | 0.027527 |

BR – beyond rut, WR – within rut.
PK – poza koleiną, WK – w koleinie.

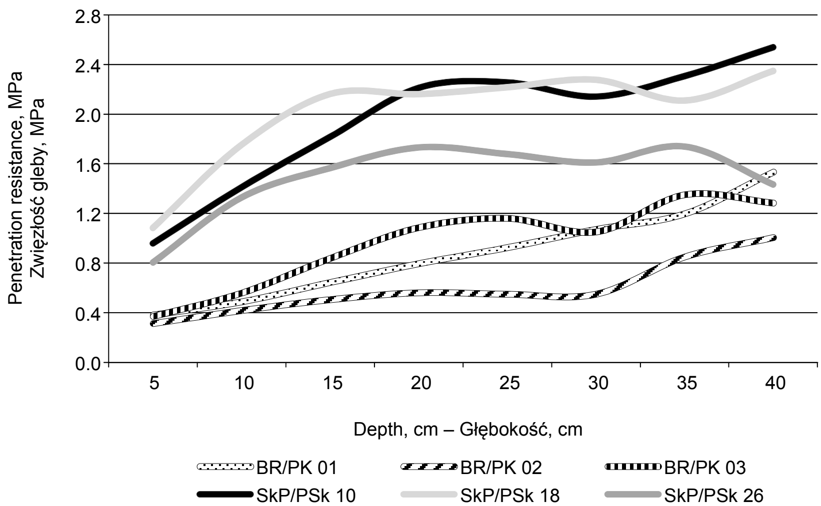


Fig. 2. Cone penetrometer test results, mean values of resistance in function of depth: BR – beyond rut, e.g. 01 – number of the sample plot, SkP – skidder passes, e.g. 10 – number of passes

Rys. 2. Zwięzłośc gleby, średnie wartości na badanych głębokościach: PK – poza koleiną, np. 01 – numer powierzchni próbnej; PSk – przejazdów skidera, np. 10 – liczba przejazdów skidera

Table 4. Cone penetrometer test, resistance
Tabela 4. Zwięzłość gleby mierzona penetrometrem

| Depth – Głębokość cm | | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|---|
| | | MPa | | | | | | | |
| SP 01 | LLR/PLK | 0.34 | 0.46 | 0.59 | 0.69 | 0.96 | 1.02 | 1.27 | 1.63 |
| | LR/LK | 0.96 | 1.49 | 1.80 | 2.17 | 2.30 | 1.91 | 2.22 | 2.66 |
| | RR/PK | 0.96 | 1.32 | 1.82 | 2.24 | 2.20 | 2.36 | 2.38 | 2.40 |
| | RRR/PPK | 0.42 | 0.52 | 0.70 | 0.90 | 0.89 | 1.12 | 1.11 | 1.43 |
| SP 02 | LLR/PLK | 0.39 | 0.53 | 0.52 | 0.50 | 0.57 | 0.56 | 0.91 | 1.11 |
| | LR/LK | 1.20 | 1.82 | 2.15 | 2.14 | 2.56 | 2.65 | 2.61 | 2.77 |
| | RR/PK | 0.96 | 1.67 | 2.16 | 2.17 | 1.86 | 1.88 | 1.59 | 1.91 |
| | RRR/PPK | 0.23 | 0.30 | 0.49 | 0.62 | 0.52 | 0.54 | 0.78 | 0.89 |
| SP 03 | LLR/PLK | 0.34 | 0.58 | 0.89 | 1.19 | 1.09 | 1.36 | 1.64 | 1.35 |
| | LR/LK | 0.87 | 1.31 | 1.34 | 1.99 | 1.83 | 1.40 | 1.68 | 1.69 |
| | RR/PK | 0.74 | 1.34 | 1.78 | 1.46 | 1.52 | 1.81 | 1.78 | 1.16 |
| | RRR/PPK | 0.39 | 0.53 | 0.78 | 0.98 | 1.22 | 0.74 | 1.05 | 1.21 |

LLR – beyond (to the left) left rut, LR – on the left rut, RR – on the right rut, RRR – beyond (to the right) right rut.

PLK – poza lewą koleiną (na lewo od koleiny), LK – w lewej koleinie, PK – w prawej koleinie, PPK – poza prawą koleiną (na prawo od koleiny).

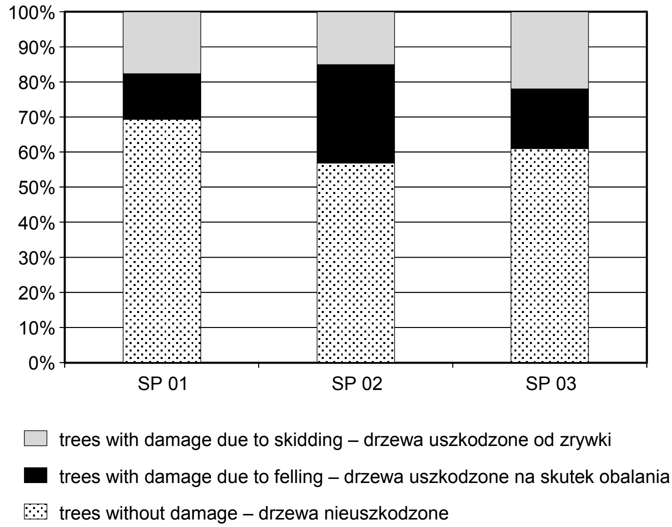


Fig. 3. Proportions of damage in natural regeneration
Rys. 3. Uszkodzenia drzew naturalnego odnowienia

## DISCUSSION

### Productivity of thinning operation

The mean overall operational productivity of logging $P_{02fo}$ was 18.0 $m^3 \cdot h^{-1}$ in which pure skidder productivity during extraction was $P_{02se}$ 30.5 $m^3 \cdot h^{-1}$ with an average tree 1.8 $m^3$. These satisfactory results were obtained thanks to the high potentials of the new skidder as well as good work organization. Cutting of trees was carried out by two chainsaw operators, only one of which was specialized in cutting trees and the other was responsible for delimbing. However, some help was exchanged from time to time. This cooperation lead to a very high mean 11.8 $m^3 \cdot h^{-1}$ productivity of felling. The lowest productivity was observed at the crosscutting point and it was due to waiting for skidder transport. This suggests that possibly one person with a chainsaw could be enough at the crosscutting point, which would eventually increase the whole forest operation. On SP 01 the biggest number of trees were felled, but at the same time mean volume was the smallest. This did not influence overall $T_{02fo}$ productivity and suggests that 1.5 $m^3$ of single skidded tree volume guarantees a high level of performance.

The obtained productivity seems to be very good when compared with e.g. 11.6 $m^3 \cdot h^{-1}$ achieved by the Timberjack 240C in a mountainous fir stand skidding very large trees up to 3.9 $m^3$ [Sabo and Prošinsky 2005]. Using a rope skidder Ecotrac 120V, productivity can reach 6 $m^3 \cdot h^{-1}$ [Horvat et al. 2007], or using LKT-81 Turbo: 7.15 $m^3 \cdot h^{-1}$ in the mountains in an 82-year-old fir stand [Porter and Strawa 2006].

Overall, skidder productivity can be influenced by various factors, skidding distance and terrain conditions – mountainous or flat terrain – playing a major role. The HSM 904Z 6WD skidder is a powerful machine for large timber extraction. Due to its very good traction potentials it is also designed for skidding in hilly areas.

**Soil disturbance and remaining stand damage**

The increased bulk density due to HSM 904Z 6WD skidder in the analysed beech stand is similar to the four-wheel-drive LKT skidder, which caused compaction ranging from 0.20-0.25 $g \cdot cm^{-3}$ [Giefing et al. 1995, Giefing and Mana 1995, Hołota 1998]. As similar changes were observed after the use of the LKT skidder, which is at least three times lighter, pressure on the ground could be similar due to the narrower wheels and tyres. In the analysed beech stand, the bulk compaction increase to 1.82 $g \cdot cm^{-3}$ might be influential on further stand growth [Wojtkowiak and Siwiński 2002]. Changes in bulk density were also observed between the ruts [Ampoorter et al. 2007, Weise 2007]. The recorded soil compaction suggests the design of permanent skidroads which would limit harmful changes to skidroad areas. Further limitation of soil damage could be obtained from a thinner net of skidroads [Suwała 1995, 2003]. However, Erler's research [2002, 2005] outcome was that the optimal distance between skidroads is 40 m.

The results of CPT are similar to those obtained by Moskalik [2002]. As this author analysed the changes after skidding with a much lighter LKT-81 skidder – the conclusion can be similar to the one above: narrower tyres cause higher pressure.

More damage in natural regeneration on SP 02 may be due to felled trees. On this plot, trees had the longest crowns and the mean volume of timber per tree was the biggest: 2 $m^3$. Moreover, one of the felled trees had a volume 8.44 $m^3$. Logically, felled trees with bigger crown sizes can result in bigger damage and scientific evidence of such a correlation is also available in Sowa and Szewczyk research [2000 a, b].

The felled trees in most cases broke young trees – the skidding of logs usually bent them. A lower level of damage due to skidding was achieved due to grapple manoeuvres helping to avoid places with natural regeneration.

## CONCLUSIONS

1. The mean operational productivity of the whole forest operation per person ($P_{02fo}$) was 18.0 $m^3 \cdot h^{-1}$ with the average volume of 1.8 $m^3$ of wood obtained from one tree.
2. The increase in bulk density was from 0.02-0.55 $g \cdot cm^{-3}$. The biggest increase was observed in plots with the smallest initial density beyond the ruts (SP 02 and 03).
3. The mean bulk density beyond the ruts ranged from 1.43-1.60 $g \cdot cm^{-3}$and in the ruts 1.71-1.82 $g \cdot cm^{-3}$; this density increase was statistically significant.
4. Changes in bulk density were observed at a mean soil moisture of 25% but changes in moisture after skidding were not statistically significant.
5. The cone penetrometer test (CPT) results showed a considerable increase in soil resistance in the ruts which was statistically significant. On SP 01 and 02 the changes in penetration resistance were statistically significant, both, after 26 and 18 skidder passes. These changes were also significant in SP 01, but only at 5 and 10 cm depths.
6. Felling and skidding caused damage in natural regeneration on average to 38% of trees (only 18% due to skidding).

## REFERENCES

Ampoorter E., Goris R., Cornelis W.M., Verheyen K., 2007. Impact of mechanized logging on compaction status of sandy forest soils. For. Ecol. Manag. 241, 162-174.

Bacher-Winterhalter M., Becker G., Sauter U., 2006. Ist bestandespflegliche Aufarbeitung mit mechanisierter Holzernte möglich? [Is ecologically compatible mechanised forest operation possible?]. AFZ-der Wald 2, 55-57 [in German].

Erler J., 2005. Was kostet die Rückegasse? [How much does a strip road cost?]. AFZ-der Wald 6, 297-301 [in German].

Erler J., Güldner O., 2002. Technologisch differenzierte Standorte [Technological differentiation of stands]. AFZ-der Wald 10, 484-488 [in German].

Giefing D.F., 1997. Untersuchungen von technologischen Prozessen der Holzgewinnung im Pflegehieben (Die methodologischen Fragen der Untersuchungen) [Study on thinning operations (research methods related questions)]. In: Technology of woodprocessing and utilisation of wood in complex interior. Ed. D. Horský. Technická Univerzita Zvolen, 213-218 [in German].

Giefing D.F., Mana M., 1995. Influence of improvement felling in beech stands on the soil. Rocz. AR Pozn. 273, Leśn. 33, 53-62.

Giefing D.F., Mana M., Grochala S., 1995. Influence of improvement felling in beech stands on the soil. Rocz. AR Pozn. 273, Leśn. 33, 53-62.

Heinimann H.R., 2007 a. Forest operations engineering and management – the ways behind and ahead of a scientific discipline. Croat. J. For. Eng. 28, 107-121.

Heinimann H.R., 2007 b. Precision forestry – what's that? Schweiz. Z. Forstwes. 158 (8), 235--242.

Hołota R., 1998. Ekologiczne aspekty procesów technologicznych pozyskiwania buka pospolitego (*Fagus sylvatica* L.) w cięciach rębnych [Ecological aspects of final felling operations in beech stands (*Fagus sylvatica* L.)]. PhD thesis. Pozn. Univ. Life Sci. Poznań [in Polish].

Horvat D., Zečić Ž., Šušnjar M., 2007. Morphological characteristics and productivity of skidder ECOTRAC 120V. Croat. J. For. Eng. 28, 11-25.

Mederski P.S., 2006. A comparison of harvesting productivity and costs in thinning operations with and without midfield. For. Ecol. Manag. 224, 286-296.

Moskalik T., 2002. Analysis of forest soil compactness changes as result of machines driving. In: Forest utilization in sustainable multifunctional forestry. Ed. P. Paschalis. SGGW Warszawa, 158-163.

Paschalis P., 1996. Użytkowanie lasu wielofunkcyjnego [Forest harvest in multiple use forest]. Sylwan 1, 5-11 [in Polish].

Porter B., Strawa P., 2006. Analiza pozyskiwania i zrywki drewna w drzewostanach jodłowych [Analysis of logging and skidding operations in fir stands]. Sylwan 1, 67-72 [in Polish].

Sabo A., Prošinsky T., 2005. Skidding of fir rounwood by Timberjack 240C from selective forests of Gorski Kotar. Croat. J. For. Eng. 26, 13-27.

Silversides C.R., 1988. The impact of forest operations and techniques upon forest mechanization in Eastern Canada. Meddelelser fra Norsk Institutt for Skogforskning, 41.16, 233-250.

Sowa J., Szewczyk G., 2000 a. Damage to beech upgrowth caused by cutting pine trees from dominant stand as influence by habit characteristics of trees. Zesz. Nauk. AR Krak. 376, 45-55.

Sowa J., Szewczyk G., 2000 b. The size of damage in the silver fir and Norway spruce upgrowth resulting from cutting and felling the nurse crop pine stand and spruce stand. Acta Agr. Silv. 38, 75-89.

Suwała M., 1995. Wpływ wybranych metod i środków pozyskiwania drewna na uszkodzenia nadziemnych części drzew oraz powierzchniowych warstw gleby w późnych trzebieżach drzewostanów sosnowych [Effect of selected methods and means of timber harvesting on damages of the over ground tree parts and surface soil layers in late fellings of pine stands]. Pr. Inst. Bad. Leśn. Ser. A, 786, 59-71 [in Polish].

Suwała M., 2003. Uszkodzenia drzew i gleby przy pozyskiwaniu drewna w wybranych rębniach złożonych na terenach nizinnych [Tree damage and soil disturbances as result of wood harvesting in chosen complex cutting systems on the lowland]. Pr. Inst. Bad. Leśn. Ser. A, 949, 23-38 [in Polish].
Weise G., 2007. Beurteilung der Steigfähigkeit von Forstmaschinen [Analysis of forest machines maneuverability on slopes]. Forsttechn. Inform. 9, 125-128 [in German].
Wojtkowiak R., Siwiński M., 2002. Soil compaction as a results of crushing logging residues. In: Forest utilization in sustainable multifunctional forestry. Ed. P. Paschalis. SGGW Warszawa, 164-172.

## EFEKTY ZRYWKI DREWNA ZNACZNYCH ROZMIARÓW SKIDEREM CHWYTAKOWYM

**Streszczenie.** Zrywka drewna znacznych rozmiarów w negatywny sposób oddziałuje na środowisko glebowe i drzewostan. Zastosowanie skidera chwytakowego może prowadzić do zmniejszenia negatywnych skutków zrywki drewna przy jednoczesnym zachowaniu zadowalających parametrów wydajnościowych i ekonomicznych. Celem badania było określenie wydajności skidera chwytakowego HSM 904Z 6WD oraz jego wpływu na glebę (zagęszczenie i zwięzłość) oraz naturalne odnowienie. Badania przeprowadzono w 140-letnim drzewostanie bukowym w północnej Polsce. Ścięte i obalone drzewa (w kierunku szlaków) po okrzesaniu i odcięciu wierzchołków (min. 7 cm z korą) były zrywane na stół manipulacyjny. Średnia wydajność operacyjna skidera (wraz z mygłowaniem) wyniosła 21,0 $m^3 \cdot h^{-1}$, uszkodzenia odnowienia naturalnego dotyczyły 38% drzew (tylko 18% od zrywki), a zagęszczenie gleby zwiększyło się o 15-30 $g \cdot cm^{-3}$. Zwięzłość gleby wzrosła maksymalnie do 2,77 MPa.

**Słowa kluczowe:** skider chwytakowy, wydajność, uszkodzenia gleby, uszkodzenia odnowienia naturalnego

*Accepted for print – Zaakceptowano do druku: 15.12.2011*

*For citation – Do cytowania: Bembenek M., Mederski P.S., Erler J., Giefing D.F., 2011. Results of large-size timber extracting with a grapple skidder. Acta Sci. Pol., Silv. Colendar. Rat. Ind. Lignar. 10(3), 5-14.*