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A MODEL DESCRIBING FORWARDER BASED LOGGING PERFORMANCE IN PINE STANDS THINNINGS

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Abstract. Logging is an important element of wood production. Its modelling gives an opportunity to compare different scenarios before the work has started and may be helpful in future operations planning. A computer program was created which includes basic factors influencing forwarder efficiency: parameters of the machine, the stand and the assortments. The results of the simulation confirm relations between certain factors and forwarder performance given by other authors. Counted absolute values may be higher than real. Relative comparison of relations between factors is more accurate.

Key words: wood logging, work performance, SWS, forwarder, model

INTRODUCTION

Need for managing the forests according to the idea of sustainability and increasing demand for wood force forestry to use new solutions considering the economical side, environmental issues and the human factor while making every decision. Mechanization of wood harvesting and logging has developed rapidly in the last two decades in many European countries and in the last couple of years also in Poland [Nowacka 2002].

Since final fellings, especially clear-cuts historically began much earlier than pre-final cuttings, harvesting techniques on clear cuts have been described better than in thinnings. Nevertheless thinnings are one of the basic operations executed in the process of silviculture. The Polish forestry model is based on many thinnings to get high quality assortments in the final fellings. According to the Central Statistical Office (GUS) report "Forestry 2009" in 2008 area of pre-final cuttins was 436 000 ha which in comparison with 44 500 ha of final fellings shows how important tending is. In the country there was then 1,03 billion m^3 in the first four age classes (up to 80 years) which was 60% of the total large timber [Leśnictwo... 2009]. From the cited data it is clearly visible that thinnings are and will be in the future one of the main operations performed in Polish forests.

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Biodiversity should also be considered. It is additionally supported by the Rio de Janeiro Convention [Rio de Janeiro Convention... 1992]. Moreover, FSC and PEFC certification (mainly in the State Forests) bring up the standards not only of the environmental issues but also of working conditions of the employees.

All the foregoing factors make it necessary for the forestry sector to adapt to this kind of works. It forces looking for new solutions which would cope with the higher standards. Forwarders are machines which meet these requirements. They meet all the environmental standards. Compared with other mechanized methods forwarder based logging – especially combined with a harvester – is believed to be less harmful for the environment and safer for the workers [Nurminen et al. 2006, Máchal and Bartoš 2009]. Percentage of damaged trees in technological processes in the short wood system (SWS) based on a forwarder is clearly lower than in the long wood method [Suwała 2003]. Moreover, forwarders need less human workforce and they are more effective when there is no dense forest road network which is an important factor in Poland.

Global trends show decrease of the forest workers supply which, when combined with increase of the employment costs causes a necessity of mechanization of every possible process. Machines are now needed not only to perform the planned actions faster and more effective but to be able to do them.

Considering all that it is reasonable to take action in order to determine basic parameters describing forwarder based logging performance. Such knowledge makes effective both planning and actual logging positively influencing the economic outcome. Moreover, if one can limit the total distance travelled by the machine (which means also time, in which the forest ecosystem is disturbed and the amount of exhaust fumes and oil emissions) the negative impact on environment will be also reduced.

In order to be described the parameters conditioning logging efficiency they should be first defined. Below is a list of factors given by various authors [Jiroušek et al. 2007, Kellogg and Bettinger 1994, Maksymiak and Grieger 2008, Więsik 1998, Nurek 2002 a, b]:
- load preparation,
- logging distance,
- number of assortments,
- assortment dimensions,
- the way the forwarder travels on the surface of the stand,
- kind and size of the machine,
- terrain conditions,
- road and strip road network density,
- thinning intensity,
- weather conditions and seasons,
- operators experience and motivation.

It should be considered that logging cannot be treated as a separate process which ought to be perfected and made more efficient. The most beneficial assortment dimensions for today's forwarders may not satisfy the wood industry. On each step processes should then be optimized in a broader perspective.

MATERIAL AND METHODS

Results of modeling a forwarder based logging were examined. The model is theoretical. The forwarders work was divided into four basic operations the times and distances of which would be variables in the logging analysis. They were: empty run, load forming, loaded run, unloading. The model was based on technical characteristics given by producers and on data entered by the user. Based on that the computer program calculated the time needed to forward given assortments in various scenarios.

Computer model

The model was created in the C# (C Sharp) language in the Visual Studio 2008 environment. The program works on operating systems Windows XP and later. In case one has an older version of Windows installing .NET (dot NET) platform is necessary. It does not work on other operating systems.

Task of the model. The task of the model is to calculate forwarders hourly performance after entering by the user parameters determining it. These are: machine data, stand data and assortments data. They all are presented in Table 1. There is a possibility to choose a forwarder in the program. There are predefined parameters of machines, nevertheless there is possibility to edit each of them.

Assumptions of the model. Main assumptions of the model are:

1. Four main working operations:
– empty run (divided into the strip road and the forest road)
– load forming
– full run (divided into the strip road and the forest road)
– unloading.

2. Even wood distribution all over the forest surface.

3. The stand is always a rectangle.

4. Strip roads are parallel and in equal distances from each other.

5. Wood packets are placed right next to the strip roads and their sizes are matched with the grapple size (cross sectional area of the open grapple).

6. The grapple-packet connection efficiency = 100%, each packet (apart from the last one in the strip road, which is usually smaller as a result of even wood distribution) has exactly the same cross sectional area as the grapple and the grapple always takes the whole packet at a time.

7. The forwarder cannot move back, once it enters a strip road it must go to the end of it, even if after loading one packet it will be full it still needs to go to the end of the strip road in order to leave it.

8. The forwarder starts logging from the packet which is the furthest away from the wood pile (where logging ends) – the furthest strip road, the furthest packet.

9. There can be only one assortment in the load space of the forwarder – even if a given assortment is over and there is still space, the forwarder cannot mix assortments and must go and unload first.

10. If the forwarder is on the last strip road and there are only 3 packets left after loading full we assume that these will be transported together in the same cycle – in reality this situation may not happen but without this assumption the program would calculate another full cycle even for one packet.

Table 1. Basic parameters in comparison to which other calculations took place
Tabela 1. Ustawienia wyjściowe, przy których był zmieniany tylko badany parametr

Forwarder		Forest stand Drzewostan		Assortments Sortymenty	
				length długość m	percentage udział %
Grapple cross sectional area, m^2 Pole przekroju chwytaka, m^2	0.35	Length, m Długość, m	150	2.5	70
Load space cross sectional area, m^2 Pole przekroju wózka, m^2	4	Width, m Szerokość, m	200	3	30
Load space length, m Długość wózka, m	5	Distance between centers of strip roads, m Odległość między środkami szlaków, m	30		
Velocities Prędkości		Thinning intensity on 1 ha, mp Pobór miąższości z 1 ha, mp	40		
On forest road empty run, m/s Prędkość na drodze jazda pusta, m/s	2	Terrain difficulty Trudność terenu	1		
On strip road empty run, m/s Prędkość na szlaku jazda pusta, m/s	1.75	Additional distance Dodatkowa droga	0		
Load forming speed , m/s Prędkość formowania, m/s	0.2				
On strip road full run, m/s Prędkość na szlaku jazda ładowna, m/s	1.4	For these parameters the performance calculated equals 25.9 mp/h Dla tych parametrów program oblicza wydajność 25,9 mp/h			
On forest road full run, m/s Prędkość na drodze jazda ładowna, m/s	1.6				

11. The first strip road starts half of the distance between strip roads away from the edge of the stand – as a result of even strip road distribution.

12. The first packet of each assortment is located half of the distance between packets away from the forest road – as a result of even wood distribution.

13. In the load space of the forwarder two piles of one assortment can be transported on condition the length of the load space equals or is greater than two lengths of the assortment.

Figure 1 presents a visual representation of the surface. Assumptions were made that the stand is a rectangle with evenly distributed strip roads and its parameters are:

a – distance between the centers of the strip roads, the width of a strip road is 4 m
b – length of the stand – it is always the side on which the forest road is, even if it is shorter than the other side
c – width of the stand – is the other side of the rectangle and it is also the length of a strip road.

The program mathematically describes the course of the logging operation executing a number of algorithms consistent with the assumptions given above.

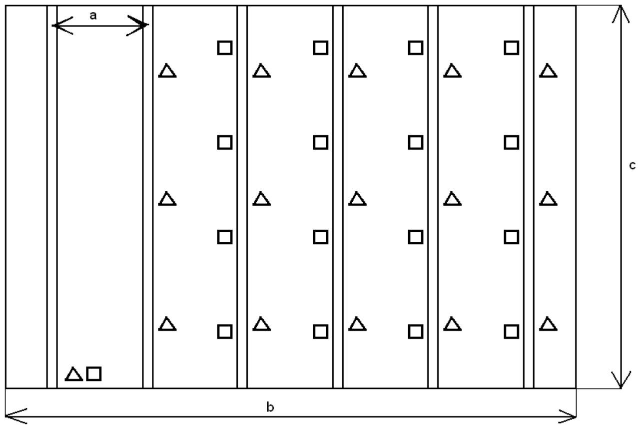


Fig. 1. Visualization of the thinning area with deployment of strip roads and assortments
Rys. 1. Poglądowy obraz powierzchni

RESULTS

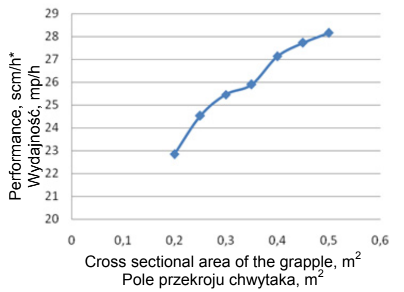
In order to define the basic parameters influencing logging performance the program was given a number of settings, in relation to which only one parameter was changing and the performance was adjusting accordingly. They are all presented in Table 1. The graphs show in sequence relationships between performance and respective parameters used in the program.

In general logging performance increases with:
- increase of sizes of the grapple and the forwarders load space,
- increase of mean speeds,
- decrease of the overall distance,
- increase of the thinning intensity,
- decrease of the number of assortments,
- proper correlation between the assortments length and load space length.

DISCUSSION

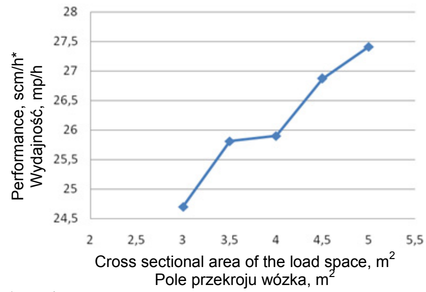
Models available in literature use a limited number of variables (1-3) vital for the forwarders performance [Ghaffarian et al. 2007]. The model presented by the authors describes the issue comprehensively enclosing the most important parameters influencing logging performance.

The results seem correct since they confirm other works dedicated to this problem, for example: Jiroušek et al. [2007] state, that performance increases with increase of the load size and decreases with increase of the distance. Kellogg and Bettinger [1994] come with the same conclusion: performance increases with increase of the load size and decrease of the distance.



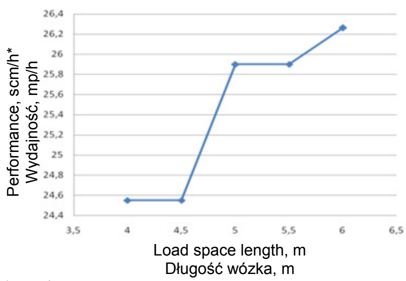
*Performance presented in scm (stacked cubic meter, which means the volume is calculated together with the empty spaces between the wood) as opposed to m^3 which is a cubic meter solid

Fig. 2. Relationship between logging performance and cross sectional area of the grapple
Rys. 2. Zależność wydajności zrywki od pola przekroju chwytaka



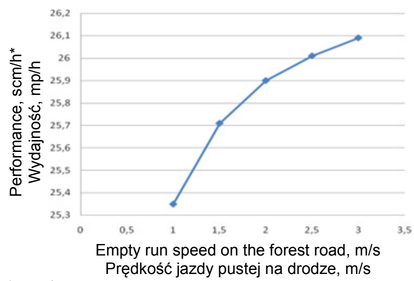
*See Fig. 2.

Fig. 3. Relationship between logging performance and cross sectional area of the load space
Rys. 3. Zależność wydajności zrywki od pola przekroju wózka forwardera



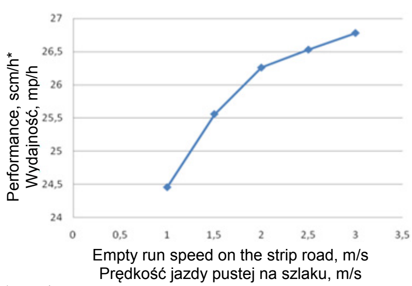
*See Fig. 2.

Fig. 4. Relationship between logging performance and load space length
Rys. 4. Zależność wydajności zrywki od długości wózka forwardera



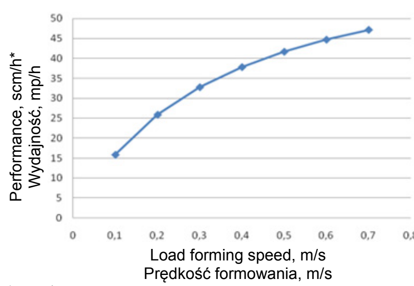
*See Fig. 2.

Fig. 5. Relationship between logging performance and empty run speed on the forest road
Rys. 5. Zależność wydajności zrywki od prędkości jazdy pustej na drodze



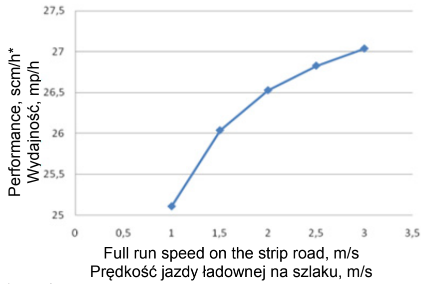
*See Fig. 2.

Fig. 6. Relationship between logging performance and empty run speed on the strip road
Rys. 6. Zależność wydajności zrywki od prędkości jazdy pustej na szlaku



*See Fig. 2.

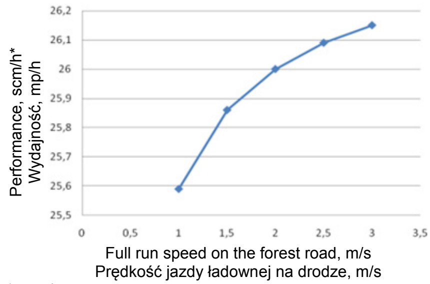
Fig. 7. Relationship between logging performance and load forming speed
Rys. 7. Zależność wydajności zrywki od prędkości formowania



*See Fig. 1.

Fig. 8. Relationship between logging performance and full run speed on the strip road

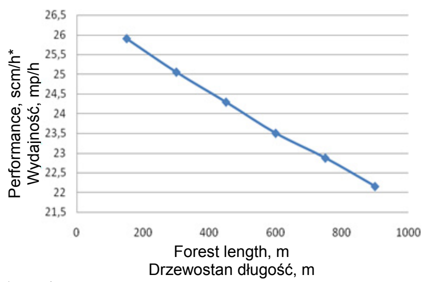
Rys. 8. Zależność wydajności zrywki od prędkości jazdy ładownej na szlaku



*See Fig. 1.

Fig. 9. Relationship between logging performance and full run speed on the forest road

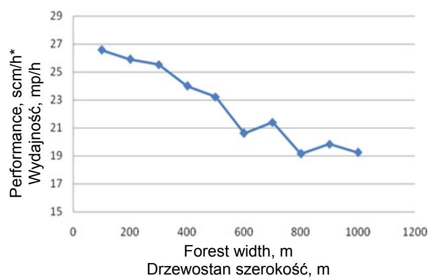
Rys. 9. Zależność wydajności zrywki od prędkości jazdy ładownej na drodze



*See Fig. 2.

Fig. 10. Relationship between logging performance and forest length

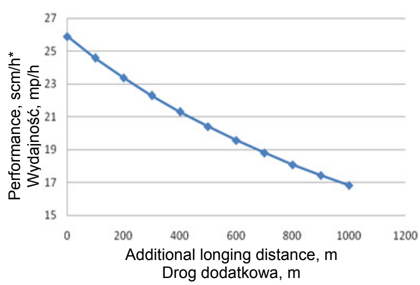
Rys. 10. Zależność wydajności zrywki od długości drzewostanu



*See Fig. 2.

Fig. 11. Relationship between logging performance and forest width

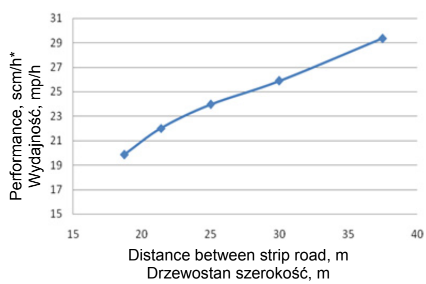
Rys. 11. Zależność wydajności zrywki od szerokości drzewostanu



*See Fig. 2.

Fig. 12. Relationship between logging performance and additional logging distance

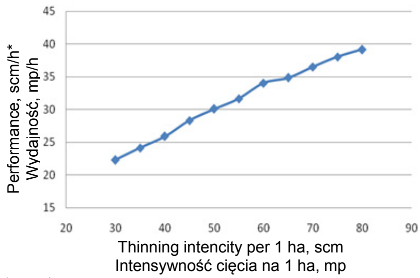
Rys. 12. Zależność wydajności zrywki od dodatkowej drogi między drzewostanem a stosem



*See Fig. 2.

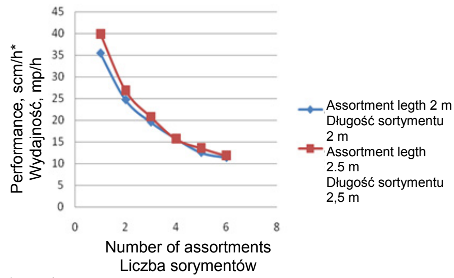
Fig. 13. Relationship between logging performance and distance between strip roads

Rys. 13. Zależność wydajności zrywki od odległości między środkami szlaków



*See Fig. 2.

Fig. 14. Relationship between logging performance and thinning intensity
Rys. 14. Zależność wydajności zrywki od intensywności cięć na 1 ha



*See Fig. 2.

Fig. 15. Relationship between logging performance and number of assortments. All assortments have the same length
Rys. 15. Zależność wydajności zrywki od liczby sortymentów. Wynik przy wszystkich sortymentach tej samej długości

Results are presented only for one set of data and only for changes of one parameter. Moreover it would be difficult to show a combined influence of a couple of factors on performance since they often interfere nonlinearly and do not correlate directly.

SUMMARY

The presented model may be used not only when trying to determine logging performance for given parameters but most of all to compare planned scenarios, for example: when selecting machines depending on the parameters of assortments, when planning logging costs based on assortment dimensions, when planning forest roads and strip roads, when introducing new solutions in forest works – it gives an opportunity to follow potential effects of changing the strategy (to increase thinning intensity?, to limit the number of assortments?).

Attention should be paid to the fact that the model may give overestimated values. It is a result of it being based on certain ideal assumptions which never occur in reality. It should not be used as a tool calculating accurate absolute values. It may better serve to determine relative values.

The advantage of a theoretical model is its flexibility. With empirically collected data for certain conditions the user can practically apply it to model their own efficiency.

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MODEL OPISUJĄCY WYDAJNOŚĆ ZRYWKI FORWARDEREM W TRZEBIEŻACH DRZEWOSTANÓW SOSNOWYCH

Streszczenie. Zrywka jest ważnym elementem procesu pozyskania drewna. Jej modelowe opracowanie daje możliwość porównania różnych scenariuszy jeszcze przed rozpoczęciem pracy i może być pomocne w planowaniu przyszłych operacji. Stworzono program komputerowy, który kompleksowo obejmuje podstawowe czynniki wpływające na wydajność nasiębiernej zrywki drewna ciągnikiem typu forwarder: parametry maszyny, drzewostanu oraz sortymentów. Wyniki działania programu potwierdzają zależności uzyskane przez innych autorów opisujących relacje między poszczególnymi parametrami a wydajnością zrywki. Obliczone wartości bezwzględne mogą być większe niż rzeczywiste. Względne porównanie różnych kombinacji daje większą dokładność.

Słowa kluczowe: zrywka drewna, wydajność pracy, SWS, forwarder, model

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