PRODUCTIVITY OF SINGLE GRIP HARVESTERS IN NATURE ORIENTED FORESTRY – PRELIMINARY RESULTS OUT OF STANDARDIZED LONGTERM DATA RECORDINGS

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Abstract: *Several features of nature oriented silvicultural concepts are influencing the productivity of harvesters. The goal of this project is to quantify statistical correlations and – from a methodological point of view - to compare daily recordings over a longer period with the productivity data found in cyclical work studies.*
A statistical analysis of about 450 standardized daily records of 12 long-boom single grip harvesters has been compiled and the level of productivity has been tested against 250 additional data sets from several additional harvesters. An analysis of further 1500 daily records will follow during the year 2003.

1. Results

Several features of nature oriented silvicultural concepts are influencing the productivity of harvesters. The goal of this project was to quantify statistical correlations and – from a methodological point of view - to compare daily recordings over a longer period of time with the productivity data found in cyclical time studies. A statistical analysis of about 450 standardized daily records of 12 long-boom single grip harvesters has been compiled and the level of productivity has been tested against 250 additional data sets from several additional harvesters. Tree species were spruce, pine and beech. An analysis of further 1500 daily records will follow during the year 2003.

The statisticical analysis refers to the time consumption per tree (productive machine hours including interruptions shorter than 15 min) as predicted variable. This approach is preferred in comparison to the direct consideration of productivity. Productivity is a derived term (volume per time) and the characteristics of the productivity function are mainly dominated by this transformation. This fact would complicate the modelling process. The problem is similar regarding the time consumption per cubicmeter. To demonstrate that Figure 1 shows the influence of the piece volume on the time consumption per cubicmeter and on productivity - other variables not considered. The productivity maximum simply is a mathematical consequence of the way how time consumption per tree increases with rising average tree volume.

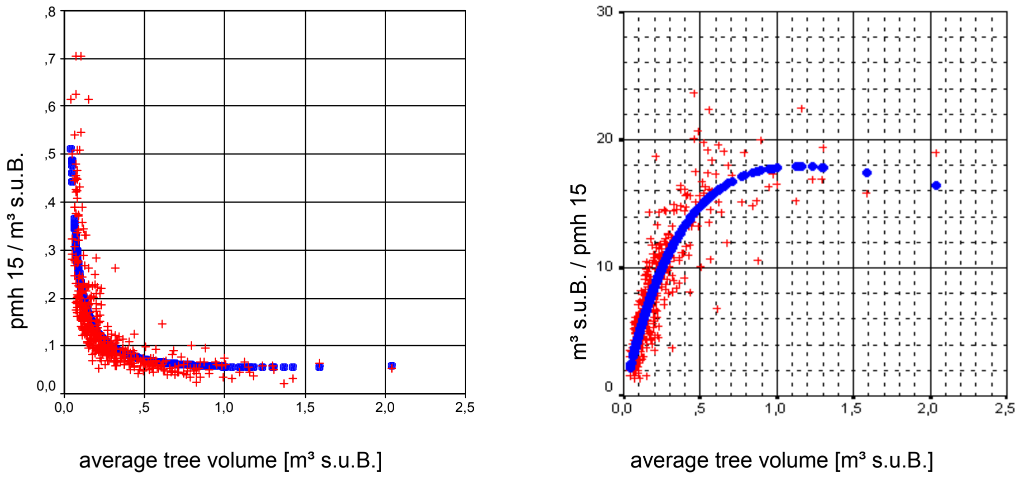

Figure 1: (a) time consumption (pmh15 per m^3 s.u.B.) depending on tree volume; (b) productivity [m^3 s.u.B./pmh15] depending on tree volume

For practical calculations the resulting statistical functions are given for different numbers of variables available (wheeled harvesters in thinnings/selective cutting):

$$\text{pmh15/Baum} = (21 + 25\cdot\text{tvol} + 11\cdot\text{tvol}^2) / 1000 \text{ (corr. } R^2\text{: 0,48; N = 395)} \quad (1)$$

$$\text{pmh15/Baum} = (18{,}2 + 22{,}9\cdot\text{tvol} + 9{,}2\cdot\text{tvol}^2 + 1{,}43\cdot\text{dist/tree}) / 1000 \text{ (korr. } R^2\text{: 0,56; N = 371)} \quad (2)$$

$$\text{pmh15/Baum} = (7{,}7 + 22{,}8\cdot\text{tvol} + 9{,}7\cdot\text{tvol}^2 + 1{,}48\cdot\text{dist/tree} + 6{,}6\cdot\text{cport} + 1{,}3\cdot\text{p/tree}) / 1000 \quad (3)$$

The variables are defined as follows:

tvol..........................average volume of timber per tree (volume/number of trees) [m^3 solid under bark] over 7 cm diameter including wood losses; range: <= 1,4 m^3/tree;

dist/tree....................average driving distance per tree [m]; range: <= 10 m /tree;

cport ....average portion of green crown per tree hight (between 0 and 1);

p/tree........................average number of assortment pieces per tree; (between 2,5 and 7);

Differences between spruce (picea abies) and pine (pinus silvestris) can be explained by different crown portions. Up to now the presumed influence of a number of other variables has not been verified although recorded and statistically analysed. It is assumed that the tree volumes of processed beech (fagus silvatica) were to low (<= 0,4 m^3) to cause remarkable unfavourable effects on time consumption. Also slopes up to 25 % induced no significant influence. Sometimes only down hill driving is possible. Of course higher driving times necessary for detouring must be calculated in that cases. Differences in the productivity level between the wheeled machines and an excavator based tracked harvester (54 daily records) did not occur as well.

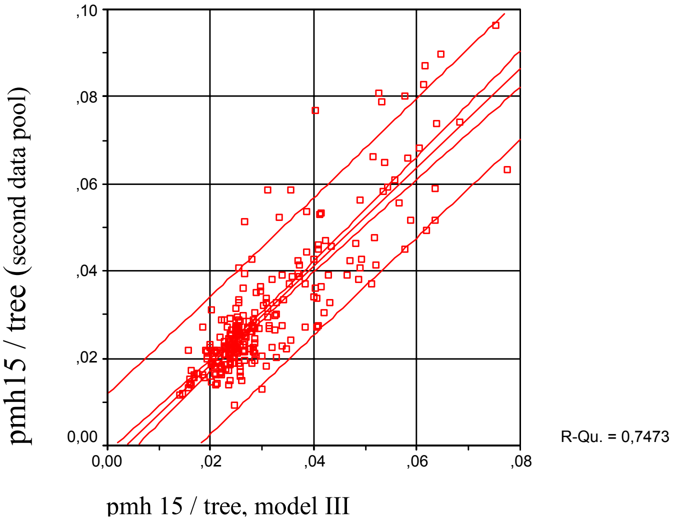

Figure 2: Comparison of estimated time consumption per tree (equation) and real values of the second data pool (the figure shows estimated 95% - confidence intervals for the single value and the mean)

About 250 further daily time consumption recordings of other stands and operators are used to validate the last equation. The estimation of these values by the function above (III) shows good consistency (Figure 2). Analogically the relations in Figure 3 and 4 have been clearly verified.

To derive productivity and costs per cubicmeter the percentage of merchantable timber has to be implemented. On average the wood losses (processed but remaining in stand as residues) fluctuate widely but decrease significantly with increasing tree volume (Figure 3).

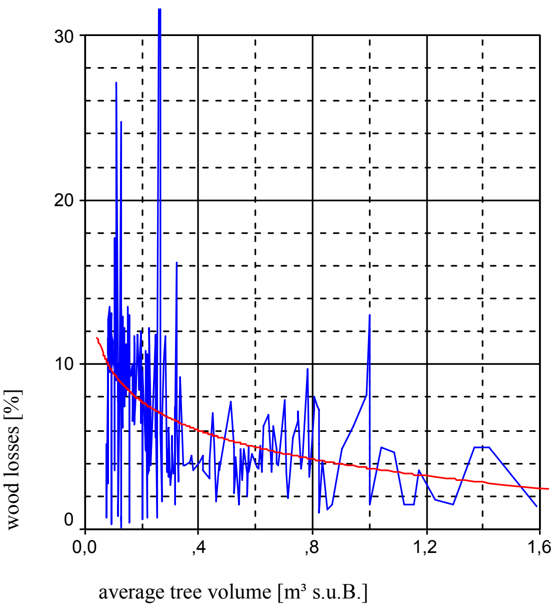

Figure 3: Average wood losses (processed but remaining in stand) depending on average tree volume (conifers)

wood loss [%] = 3,7 – 3,5 • ln (Bvol) [m³ s.u.b.] (R^2 = 0,193, N= 221) (4)

The study reveals that there is a positive and roughly linear correlation between the average tree volume and the engine power of harvesters applied. With increasing tree size, stronger machines are used.

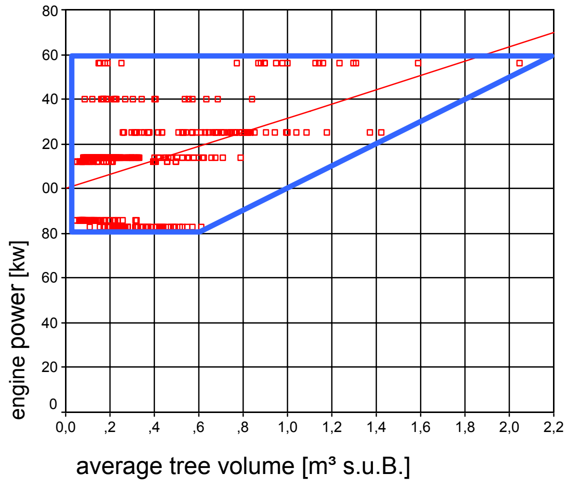

Figure 4: Engine power [kW] and average piece volume (tree) [m³ s.u.B.]

By calculating average values for 0,1 m³ steps of tree volume linear regression provides the following equation:

engine power [kW] = 100,9 + 32,2•tvol (R^2 = 0,799; F = 59,7; N = 17 steps of 0,1 m³) (5)

2. Comparison to time study results

A number of time study results has been collected over several years. The productivity curves of some wheeled machines based on such intensive experiments can be seen in Figure 5.

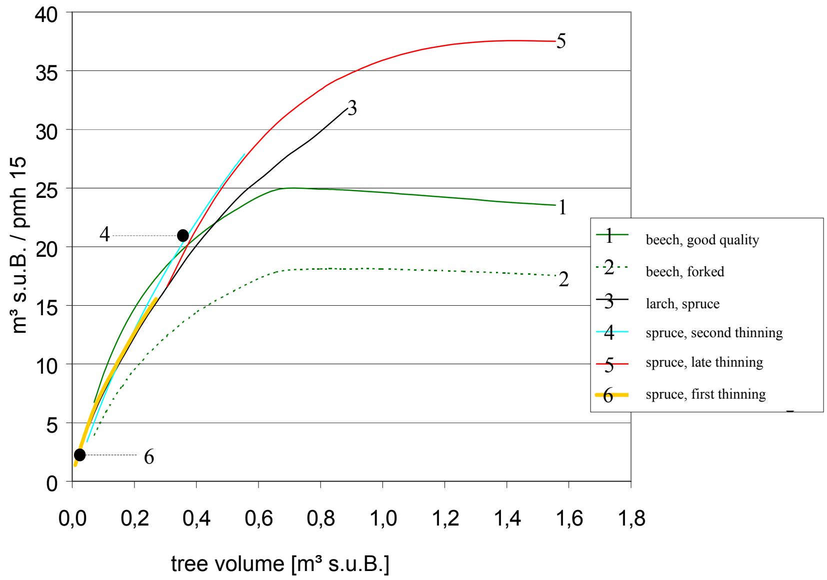

Figure 5: Productivity of wheeled single grip harvesters (time studies) [m³ / pmh15]; calculated proportion of non productive times: 20

Four other studies were compared with the time consumption model based on daily records. Two of the operators were also included in the long term observation by daily records. Figure 6 demonstrates the difference between the average time consumption per tree estimated by the daily record model (pmh15) and the clocked „single tree times“ (basic time: driving, positioning of harvester head, felling, processing; other crane movements for e.g. manipulating logs or logging residues; non productive times excluded) of these four field studies.

As examined the arithmetic difference between the calculation of time consumption referring to mean stem volume or single stem volume is relatively low. The difference can only partially be explained by non productive times respectively the difference between basic time and the productive machine hour as defined above. Obviously there remains a factor of about 1,5 which describes the systematical deviation of results gained by these different study methods.

Until further data are analysed it will be recommended to discuss short term time studies critically if they are used to calculate long term productivity levels in practice. A similar but slightly lower factor should be calculated for skidder extraction.

Such differences in performance levels due to study methods are not a new phenomenon. But they sometimes have been underestimated in connection with harvester productivity. The argument that mainly machine dominated work processes scarcely react on different performance levels of operators is obviously not applicable considering harvester operations.

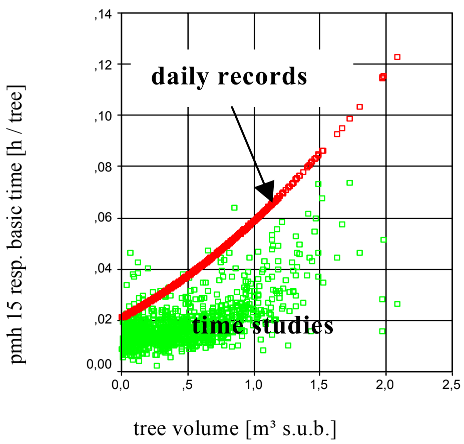

Figure 6: time consumption per tree (time study, basic time!) and average values (pmh15!) estimated by daily record model

3. References

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