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ELECTRONIC JOURNAL OF POLISH AGRICULTURAL UNIVERSITIES

2012
Volume 15
Issue 1
Topic
FORESTRY

KOMÁRKOVÁ-KINSKÁ V., KOMÁREK M., 2012. HARVESTER TECHNOLOGIES IN MOUNTAINOUS CONDITIONS, EJPAU, 15(1), #08.

Available Online http://www.ejpau.media.pl

HARVESTER TECHNOLOGIES IN MOUNTAINOUS CONDITIONS

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ABSTRACT

The example of deploying the John Deere 1070 DT 3 harvester in the conditions of the Jeseníky Mountains demonstrates the dependences of the costs of the harvester technology on the conditions. There is an example of a quality designed forest transport network in this area which enables using modern harvesting-transportation technologies as well as using a cableway in terrains with high gradients.

Key words: harvester technologies, forest transport network, terrain gradients, timber storage, harvester outputs, harvesting costs

INTRODUCTION

Timber harvesting has gone through a revolutionary development in recent decades. Since the 1950s the progress in forest harvesting mechanisation has been characterized among other things by a marked development of forest road networks. The deployment of the means of mechanisation was unthinkable without thorough conceptual rebuilding of forest roads. This not only included the technical parameters of transport roads (dimensional conditions, gradients, design speed, pavement and surface treatment of roads), but the total transport road concept was of essential importance under all sorts of conditions. (the "General Plan of Forest Transport Network" was created.) Geomorphological conditions were very important for the building a modern transport network.

In the second half of the previous century, a lot of literature was written in our country as well as abroad which dealt with a theoretical solution to transport networks [5,6,8]. Mathematical models of forest transport networks were created as well as practical manuals on the detailed routing of transport roads and lower category roads [9] in relation to the changing possibilities of timber transport both at the stage of collection, and transport away. Special forest tractors (hinged frame tractors – 1964) and the later spread of fully mechanized skidding sets have shifted the problems of timber collection. The entry of harvesters (after 1990 in our country) has changed the whole concept of extraction-transport process technologies [7]. The concept of log conversion depots promoted until that time gradually lost its important function.

From the 1960s to 1980s, the Czech Republic managed to create a newly designed forest road network in many areas where the route layout of transport forest roads well ensures the transport serviceability of forest growths and creates quality prerequisites for collecting the harvested timber and its transport away. Paradoxically, forty years of the state ownership of all forests in the Czech Republic enabled often large-scale solutions to the forest road network even in difficult mountainous conditions.

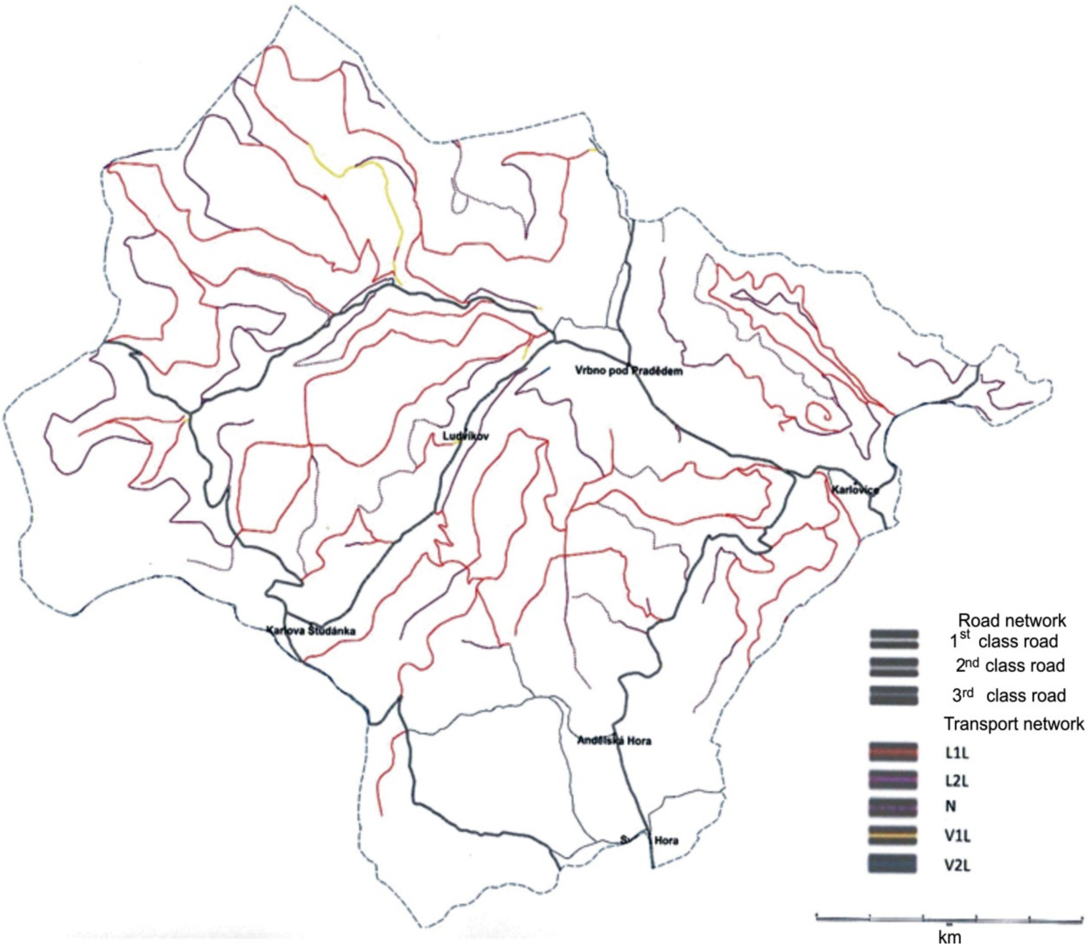

Fig.1: Karlovice – transport network (road network:class1-3 roads, collection point network)

A clear example of the forest road network in mountainous conditions is the Jeseníky Mountain Region (Fig.1 – Karlovice ve Slezsku Forest Management Area), where the routes of the public road network usually follow valleys with occasional crossings over a mountain pass. The forest transport road network continues public roads using the system of contour roads, thus enabling traffic accessibility to the whole forest complex. The Karlovice Forest District (identical to the Karlovice ve Slezsku Forest Management Area) in the very centre of the Hrubý Jeseník Mountains is an example of an optimized forest road network which guarantees traffic accessibility for the most modern harvesting technologies. Both modern motor-manual methods of timber harvesting with the collection by means of special tractors, and various cableway systems (Fig.2) can be used there. When harvesters are used, even in very difficult terrain, it is possible to deliver timber from depots at the collection point directly to customers, despite the fact that the terrain in this area is highly difficult. The storage period of harvested timber is thereby reduced to an absolute minimum. Belt harvesters have not been widely used in the local conditions yet. One of the reasons is the high transportation costs due to the unavailability of this type of harvester in the region [2].

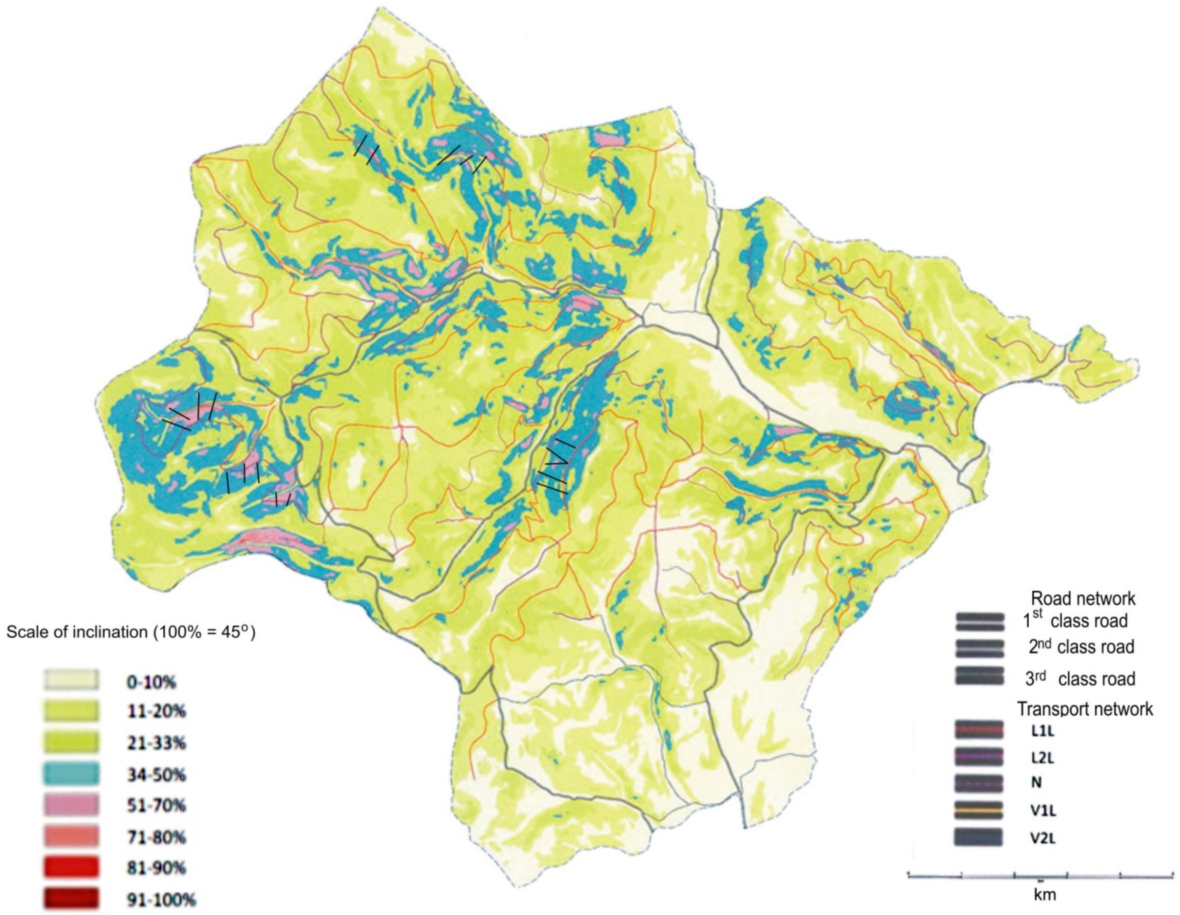

Fig. 2: Karlovice - terrain gradients (sorting according to the Macků, Simanov, Popelka scale) , transport network and cableway tracks

GOAL

The analysis of harvester deployment in the conditions of the Karlovice Forest District and Bruntál Forest District will point out the problems of the use of harvester technologies in our forest management. The dependence of individual cost items in the harvester operation will be searched by means of regression lines in individual scatter charts.

Another goal is to prove the importance of a well-designed forest road network on specific examples from forestry practice both for using the harvester, and for the possibility to directly deliver timber from a collection point to a customer.

METHODOLOGY

The analysis of all collected economic and technical data of the ongoing harvesting (harvesting-transport) process is an absolute condition for the successful utilisation of harvester technologies. This thesis uses the analysis of a three-year data file (2008 – 2010) of the operation of a John Deere 1070 DT3 harvester in various terrain conditions. The thesis compares specific data on the work of a harvester junction in the conditions of the Karlovice Forest District. At the same time, three particular cases of applying the harvesting technology in different terrain conditions will be analyzed. The authors of the thesis continuously monitored the following data on harvester operation:

Total financial costs are broken down to: material costs according to the pre-specified items, repairs and maintenance, wage costs, overhead costs in the specific breakdown according to individual items including leasing. All these cost items were referred to the total output in m^3 according to time sections. The following dependences were derived from the analyzed financial and performance data of harvester operation: the dependence of wage hourly costs on the total volume of the processed timber, the total costs (in CZK/hour and CZK/hour/m^3) on the total volume of the processed timber.

Description of the Model Territory

The Karlovice Forest Management Area is identical with the Forest District of Lesy České republiky, state enterprise, Karlovice, organisationally included in the Frýdek-Místek Regional Headquarters. The total area intended for the forest function fulfilment is 12 386 ha. The north-west part of the Forest Karlovice Management Area is included in the natural forest area 27 – the Hrubý Jesenik Mountains, the south-east part belongs to the forest area 28 – the foothills of the Hrubý Jesenik Mountains. In the whole territory of the Forest Management Area there are 52 sets of forest types with 113 forest types. As for the area, 38 sets of forest types with 89 forest types prevail in the growth groups.

Terrain gradients are important in this area (Table 1). The terrain with the gradient of 0 – 20% forms less than one half, the gradient of 21 - 33% has nearly the same share in the terrain and nearly one fifth (17.9%) is formed by terrains with the gradient exceeding 33%. There are also terrains with the gradients above 50% or even above 70%.

Making the Area Accessible to Transport and Forest Road Network

The Karlovice Forest Management Area forms a continuous complex of forests in the area of the Hrubý Jeseník Mountains going from the foothills up to the top of Praděd. The relative elevation difference between the lowest point of 470 m above sea level (the Opava River in Karlovice) and the top of Praděd (1 492 m above sea level) is 1 022 m. The whole territory of the Forest Management Area is well accessible for transport by a regularly spread network of transport roads. These roads are mostly paved with a hard surface (65%) and continue the public road network (Fig. 1).

The highest locations of the Forest Management Area were made accessible by wide contour roads which were built with the parameters of transport roads (1L, 2L) which extended the network of transport roads after drainage and gradual pavement. The total length of forest roads is 197.8 km, which is 15.5 $m \cdot ha^{-1}$. The length of other roads in the cadastre of the Forest District is 46.0 km. The total length of roads available for transporting timber in the cadastre of the Forest District is 243. 8 km, which is 19.12 $m \cdot ha^{-1}$.

The technical conditions of the Forest Management Area are given by the characteristics of the terrain and the quality and quantity of the forest transport network. The classification of terrain properties provides a detailed overview of the terrain in individual growths and growth groups and enables sorting out the harvesting fund for the needs of planning the harvest technology and transport of timber and for the selection of suitable mechanisation deployment.

Application of Harvesters in the Karlovice Forest Management Area
and the Bruntál Forest Management Area

A John Deere 1070 DT3 harvester operated in various conditions as is usual in forest plants in the period of 2008––2010. To obtain representative data, we present the comparison of the harvester operation in the region of the Karlovice Forest District and the Bruntál Forest District – the first of which – the Karlovice Forest District – was described above. The Bruntál Forest District has better terrain conditions for the use of harvester technology.

We only state the following data from the whole extensive material of monitored data (as specified in the methodology): The dependence of wage hourly costs on the total processed timber volume, the dependence of total costs on the total processed timber volume. In addition, we also give detailed descriptions of two specific cases of using the harvester technology and an example of motor-manual harvesting using a cableway – all of that in the Karlovice Forest District.

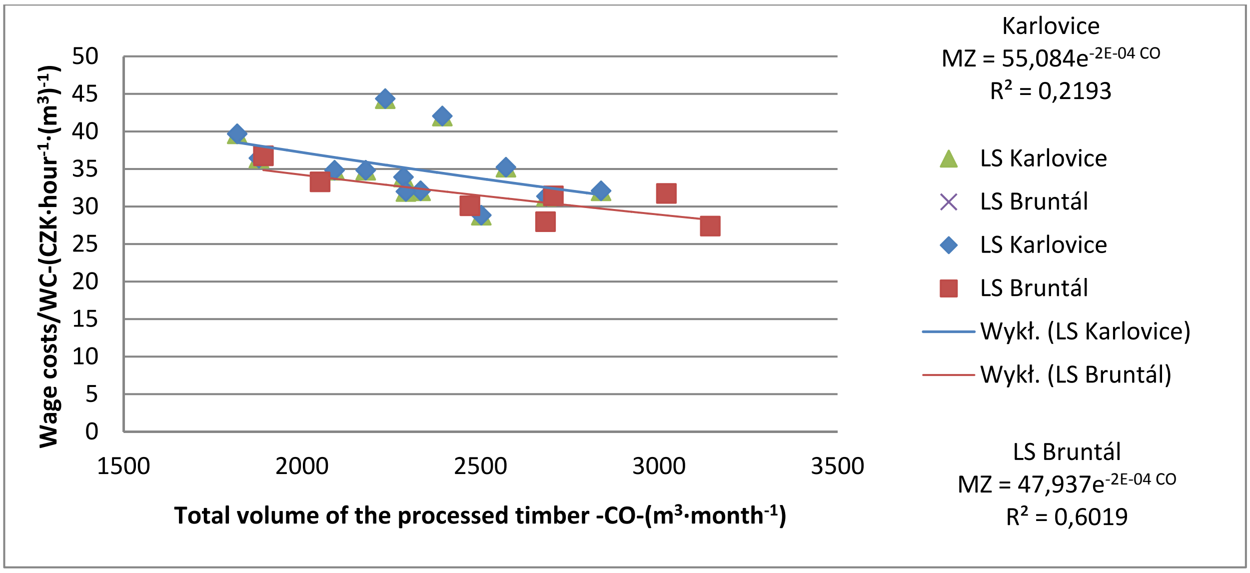

Fig.3 : Dependence of wage hourly costs on the total volume of the processed timber

Hourly wage costs tend to evenly decline depending on the total processed timber volume in the area of the Karlovice Forest District which is similar in comparison to the F Bruntál Forest District. After a more detailed analysis, other factors influencing hourly costs were proven: in particular the average stem volume of the harvested tree and terrain.

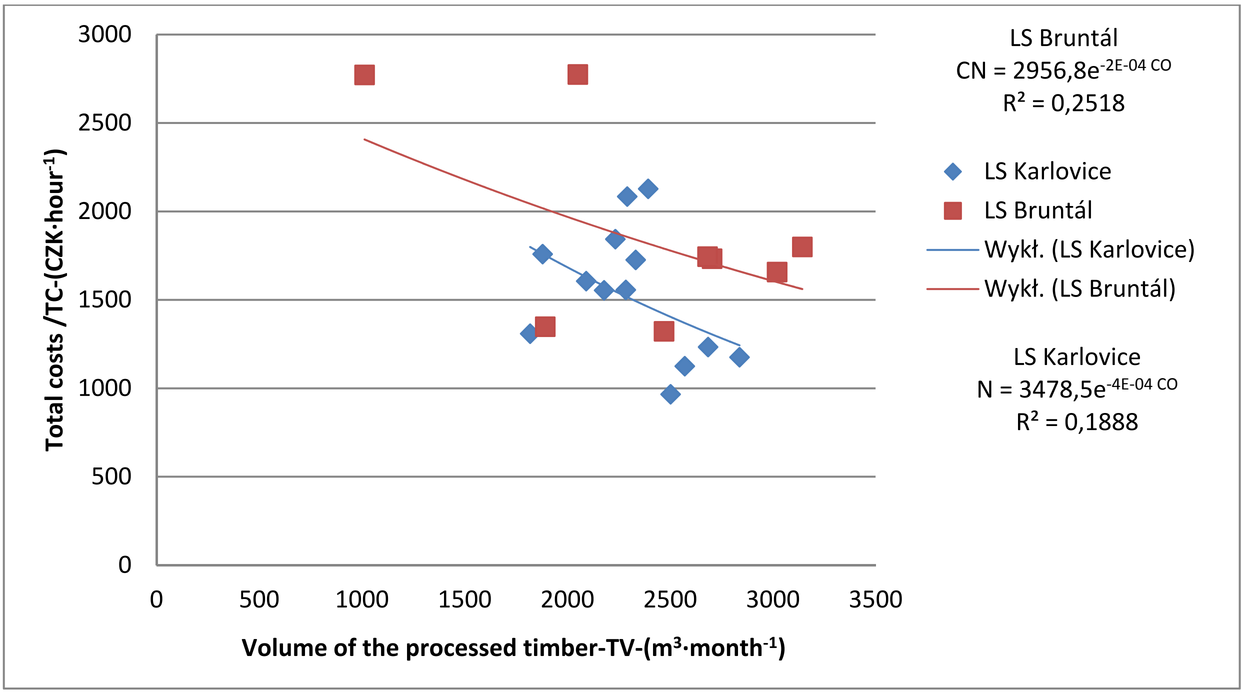

Fig.4: Dependence of the total costs on the volume of the processed timber

When total costs are compared, the costs of the Bruntál Forest District are much more irregular. This is caused by the composition of total costs which also include the costs for transport, repairs and maintenance of the harvester, among others. These costs influence the total costs, but their time distribution need not agree with the deployment of the harvester in a certain area. This fact is well seen in the bar charts given in the next part of the thesis – the overall evaluation of the harvester operation.

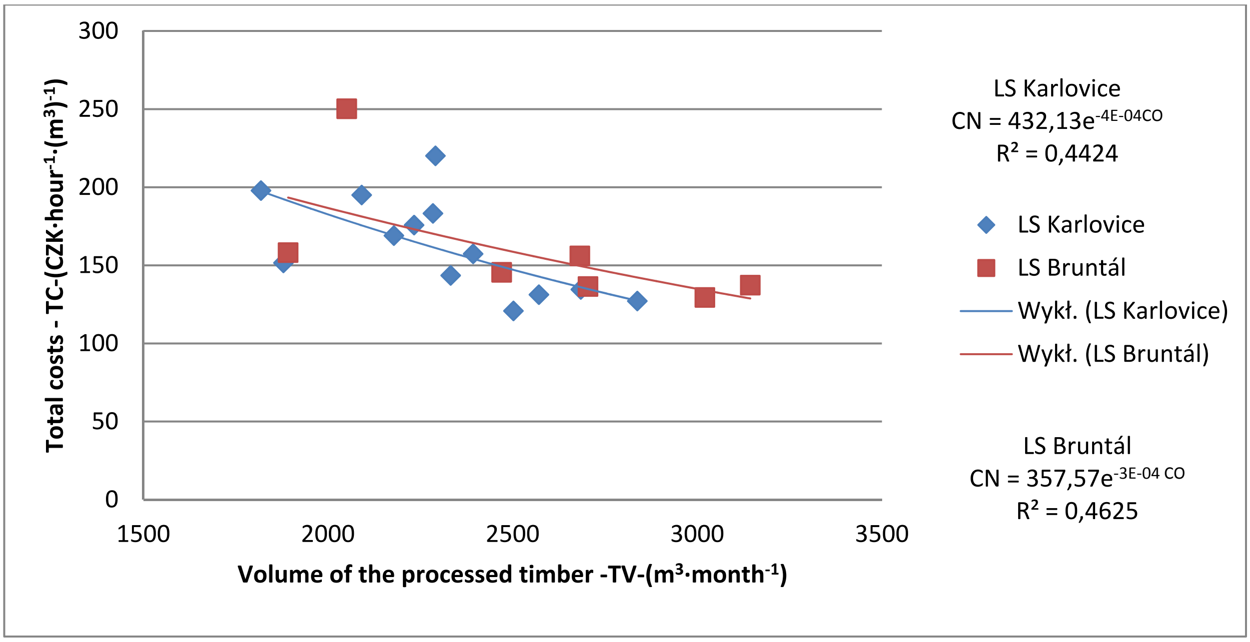

Fig.5: Dependence of the total costs on the volume of the processed timber

Total costs (in CZK·(hour·m^{-3})$^{-1}$) depend on the total processed timber volume.

Specific Detailed Descriptions with Examples of Harvesting Technology Usage

A) Harvester technology

Growth: 708 B7

Economic set: 2541

Target economy: fertile sets of higher elevations

Growth type: spruce

Growth group area: 14, 15 ha

Tree species representation: spruce 90, beech 10

Characteristics: spruce stem-wood with decay, group-mixed beech.

Nursing intervention: release of target trees

Site description: The growth group is situated on a slight slope with southern exposure with the terrain slope of 23%. It is bordered on the lower base of the slope by a 1L-type paved bituminous road; the upper border of the **growth group is formed by a 2L-type paved road.**

Technologies: Harvester technology was used. An approximately identical quantity of timber was taken to both the aforementioned forest roads. This resulted in a reduction in the forwarding distance which did not exceed 300 m. The finished qualities of timber were delivered directly to the end customer.

The costs per 1 m³ of produced timber at the collection point by sales qualities of timber in the growth group 708 B7

Parameters of the applied technology:

- Average weight of the harvested trees: spruce – 0.68 m³, beech – 0.48 m³
- Harvesting and forwarding the qualities of timbers to the collection point: up to 300 m

Determination of pricelist costs:

Total harvest: 1300.54 m³

Of which (tree species):

- spruce, the total harvest of 1271.20 m^3, the average weight of 0.68 m^3 - CZK 360 /m³
- beech, the total harvest of 29.34 m^3, the average weight of 0.48 m^3 - CZK 380 /m³

Note: Production prices of the qualities of timbers gained by the harvester technology are taken from pricelists of supplier companies common on the market.

Thanks to the possibility to forward the processed qualities of timber to two collection points which are situated at the transport roads described above, the transport distance shortened to 300 m. This resulted in the reduction in the costs for timber production. If one of the roads did not exist, the costs would increase by approximately CZK 10 per 1 m^3 of the produced quality of timber. (Prices: at the stated average stem weights – transport along the distance of 300 - 800 m = CZK 370/ m^3, tree species: spruce, or CZK 390 /m^3, tree species: beech).

Shortening the transport distance also accelerates the process of transporting which results in the elimination of delays in the transport process before the harvest by means of the harvester. This always occurs at longer skidding distances. This is also influenced by the lengths structure of the processed qualities of timbers (the shorter qualities, the longer loading time). It is usually necessary to combine two harvesters with three forwarding sets in the most common parameters of forwarding distances (300 – 800 m) and the common structure of the produced quality of timber (the lengths of 2-5m). This ratio of machines ensures timely transport of timber at the stated average parameters which are most often represented in the Czech Republic without the common delay of 3-5 days. The adequate density of the forest road network is a must.

B) Harvester technology

Growth: 622 C5, 622 C7

Economic set: 2721

Target economy: acidic sites of mountainous elevations

Growth type: spruce

Growth group area: C5: 9.03 ha C7: 3.12 ha

Tree species representation: C5: SM 100 C7: SM 100

Characteristics: thickness-varied spruce pole timber.

Nursing intervention: sanitary selection

Site description: The growth group is situated on the slope with western exposure with the terrain gradient of 31%. The lower base of the growth is formed by a 1L forest bituminous road. Clearing tracks are situated in such a way that they gravitate to the only depot on the junction of 1L-type roads.

Technologies: The harvester technology was used (at the threshold of usability). The only possibility for the storage of transported qualities of timber caused a relatively long forwarding distance and thus higher production costs. The processed qualities of timbers were delivered directly to the end customer.

The costs per 1 m^3 of produced timber at the collection point by sales of the qualities of timbers in the growth groups of 622 C5 and 622 C7:

Parameters of the applied technology:

- -Average stem volume of a harvested tree and the harvested timber volume:
- Growth: 622 C5, tree species: spruce, the average stem volume of 0.19 m^3, the harvest of 174.23 m^3
- 622 C7, tree species: spruce, the average stem volume of 0.29 m^3, the harvest of 100.39 m^3

Harvesting and transporting the qualities of timber to the collection point – the determination of price costs: the distance of 900 m

Growth 622 C5: SP, the average stem volume of 0.19 m^3, price per 1 m^3= CZK 475

Growth 622 C7: SP, the average stem volume of 0.29 m^3, price per 1 m^3= CZK 440

Production prices of the timber qualities by harvester technology are taken from pricelists of supplier companies and are common on the market. The forwarding distance of 900 m at this location is influenced by the terrain configuration and the only possible depot. Both of the growths gravitate to the 1L-type forest bituminous road. A steep section of the slope approximately 50 m long from the road to the growth and the impossibility of storage did not allow the forwarding system to skid in optimum places to the transport road. The forwarding system has to choose a longer track. This is the reason for higher production costs per 1 m^3 of the produced timber. Otherwise, the forwarding distance would be reduced below 800 m and thereby the price costs per 1 m^3.

C) Motor-manual technology

Growth: 725 H4

Economic set: 2701

Target economy: exposed sites of mountainous elevations

Growth type: spruce

Growth group area: 6.68 ha

Tree species representation: spruce 90, beech 10

Characteristics: height-varied spruce pole timber, beech at the base of the slope.

Nursing intervention: Sanitary selection

Site description: The growth group is situated on the steep slope with northern exposure with the terrain gradient of 43%. It is bordered by a paved bituminous 1L-type road at the base of the slope. The upper border of the growth group is formed by a 2L-type paved ground road.

Technologies: Cableway skidding technology was used which was partially supplemented by a team which collected raw stems to the forwarding line of the cableway. The total length of the cableway track was 350 m, the width of working fields reaching up to 60 m and it depended on the possibility and suitability to anchor the rope on the counter slope. Timber was deposited at the base of the slope and continuously, due to the lack of space, delivered to the customer.

The determination of costs per 1 m^3 of produced timber at the collection point by sales of qualities of timber in the growth group 725 H4:

- - Track length: 350 m, 4 constructions
- - Horse team to the forwarding place

- The average weight of the harvested stem: 0.13 m^3

Total costs: CZK 875.00

Of which: Harvesting: CZK 225 / m^3, team, the block of wood location – the forwarding place (up to 50m): CZK 110, cableway forwarding - transport place: CZK 540.00

The manner of skidding by means of the cableway was chosen downwards to the forest valley bituminous road. Thanks to the connection of the lower bituminous road with the upper solidified ground road the construction of the cableway was facilitated because all the necessary material including assembly ropes could be easily transported to the upper anchoring trees. The assembly and the running ropes were relatively easily taken down on cleared skidding tracks to the lower driving cableway station. It would be impossible if the upper contour road did not exist and the time exigency for the construction of the cableway would increase by approximately 30%, which would result in higher total costs per forwarded 1 m^3 of timber to the collection point (the total amount depends on the volume of the skidded timber on the track).

These three examples showed in practice various alternatives of timber harvesting in the conditions of the Karlovice Forest District. To a great extent, these examples are typical possibilities for addressing timber harvesting in mountainous conditions. In one case, the necessity to use the cableway optionally is proven, or in another one, the advantage of delivering the timber to the customer from the collection point and thus addressing the problems of timber storage without other continuing operations.

Total Evaluation of the Work of the Harvester in 2008 - 2010

The harvester operated in other conditions besides the aforementioned Karlovice Forest Management Area and Bruntál Forest Management Area. The data from the Hanušovice, Týniště and Nižbor Forest Management Areas are also available, the total evaluation and comparison of which is very extensive and would exceed the scope of this article. Therefore, we only give the harvester output in individual bar charts during 30 months (2008 – 2010) regardless of individual sites. The charts show monthly outputs (except for February 2009 when the harvester did not operate).

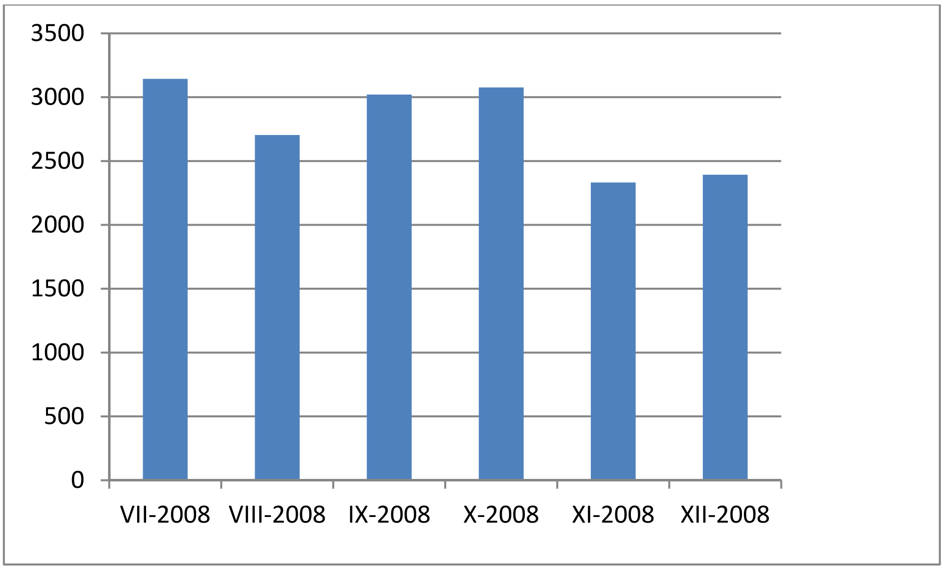

Fig.6. Monthly harvester outputs (m^3) in 2008

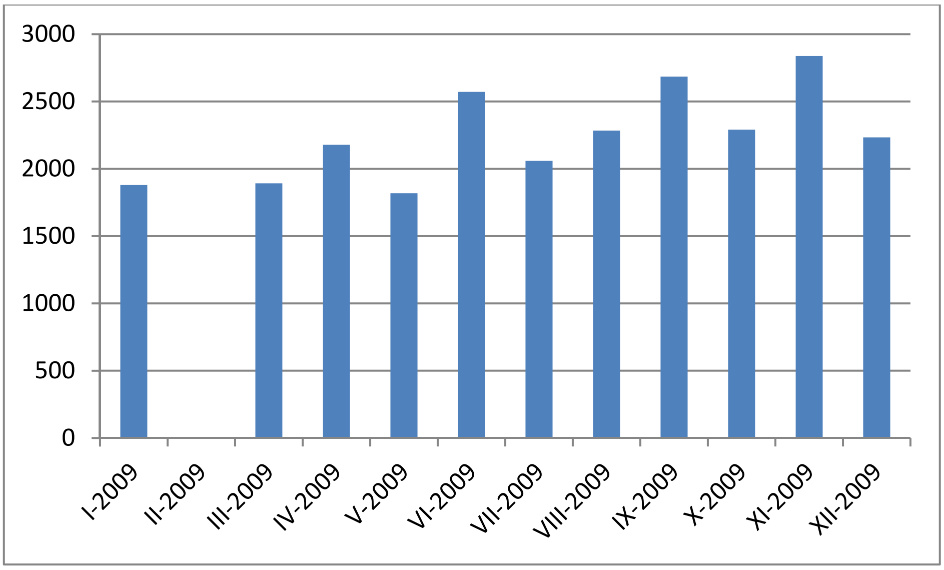

Fig.7. Monthly harvester outputs (m^3) in 2009

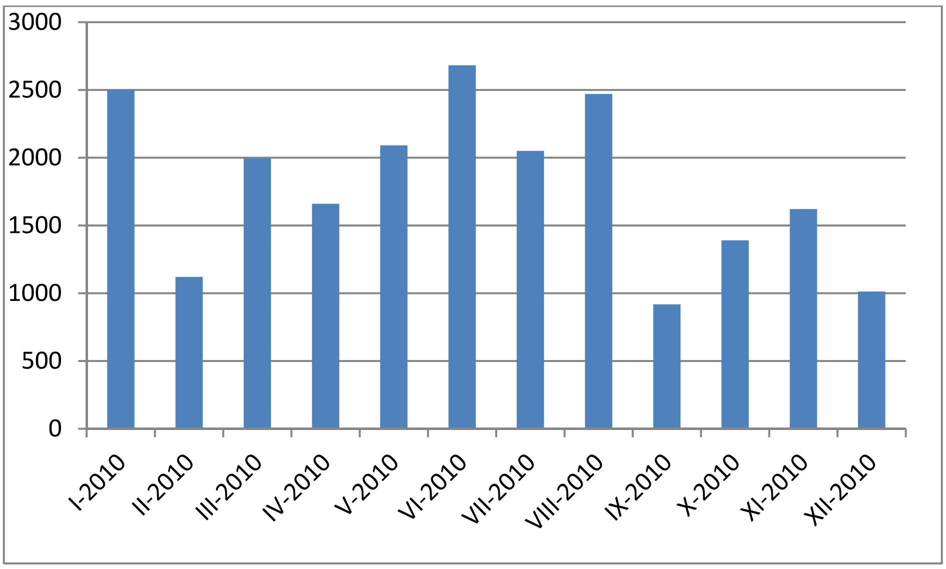

Fig.8. Monthly harvester outputs (m^3) in 2010

The charts clearly show an increasing irregularity of monthly outputs, particularly in 2010. This is caused by the following circumstances: Except for January, May through August, the harvester was often transferred to operate at sites outside the main area of Karlovice and Bruntál – time delays caused by the transfer of course significantly influence the total monthly output. Despite this fact, we consider it suitable to give the overview of monthly outputs to point out the difficulties which occur if extensive transfers are necessary (Karlovice – Týniště – Nižbor etc.).

It follows from the analysis of the given monthly output charts than monthly outputs above 2500 m^3 were achieved four times in 2008 (in six months), eight times in 2009 and only twice in 2010 (which is particularly caused by extensive transfers of the harvester).

CONCLUSION

The application of harvester technologies in timber harvesting is entirely common in our conditions at present. The impact of heavy machinery on the ground surface [3] or damage to standing trees [1,4] are often monitored. These issues are not the subject of this article.

The place of research is situated in the forest management areas of Karlovice and Bruntál. The goal of the thesis is to evaluate the three-year set of data (2008 – 2010) on John Deere 1070 DT3 harvester operation in mountainous terrain conditions. The subject of the analysis was to illustrate the dependence of total financial costs broken down into material, wage and overhead costs including leasing on the total harvester output in m^3 according to time intervals at two forest management areas, Karlovice and Bruntál.

The results of the financial analysis are illustrated by dependencies of:

- wage costs on the total processed timber volume (in CZK/hour/m^3/month)
- total costs on the total processed timber volume (in CZK/hour and CZK/hour/m^3/month)

and processed to scatter charts with regression lines with the stated determination coefficients (R^2).

In the case of the wage costs dependence on the total processed timber volume the R^2 Karlovice value was 0.2193 and R^2 Bruntál value was 0.6019. The low value of R^2 Karlovice is caused by a high dispersion of wage costs at the monthly output interval of 2000 – 2500 m^3 which is influenced by the stem volume of harvested trees.

In the case of dependence of total costs on the total processed timber volume R^2 Karlovice and R^2 Bruntál values are in the difference interval of 0.063 to 0.0201.

The comparison of the harvester deployment and the classical motor-manual technology with cableway skidding in the forest Karlovice Management Area proves the cost difference when the progressive harvester technology is used in classical mountainous conditions (although at the threshold of usability) with the advantage of direct delivery of sales qualities of timber having the length from 2 to 5 m. The advantage of direct delivery of sales of qualities of timber having the length from 2 to 5 m from the location to the collection point is expressed by the financial evaluation of the secondary timber transport in shortened raw stems to the conversion depot and handling. The saving reaches CZK 200 per m^3 in the local conditions. The financial data on of the local forest road network density which affects the forwarding distance and thus reduces the costs of this operation is CZK 10 per m^3.

We have proven on the example of the Karlovice Forest District that the harvester wheel technology can be used in classical mountainous conditions under the condition of thorough technological preparation and transport accessibility of growth, i.e. the quality forest road network.

These technologies have an important influence on the storage of harvested timber, which is the conclusion Mr. Ulrich also came to [10].

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Accepted for print: 30.03.2012