

# PELLET<sup>time</sup>

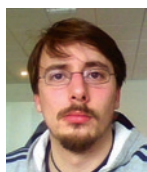
## Productivity and cost analysis of a harvester operation in Hallormsstaður, east Iceland



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## Abstract

During the next decades extension of forest area and tree growth let the timber volume removable from Icelandic forests during regular thinnings and clear cuts increase dramatically. At the same time actual removals stagnate at a low level. As technology improves forestry operations become more mechanized and nowadays harvesters are used around the world to lower costs of thinnings. The possibility of using harvesters profitably in Iceland was researched by analysing two thinnings carried out by a harvester in Hal-lormsstaður, east Iceland. Productivity and costs of mechanized thinning were determined and compared with traditional motor manual thinnings. For smaller tree sizes (0.1 m<sup>3</sup>) the harvester was twice as expensive as a forest worker, for slightly bigger trees (0.2 m<sup>3</sup>) costs were equal (excluding transportation of the harvester). The results were influenced by the low costs assessed by the harvester operator and – more importantly and acting reciprocally – his inexperience at the time. Comparisons with time studies from Austria showed that experienced operators are able to work several times faster than the operator in this study did. Thus the use of a harvester could become a viable alternative to motor manual fell-ings. This argument is strengthened taking into account that the harvester used during this study is a walking harvester specialized for operations in difficult conditions such as steep gradients that are rare in Icelandic forestry. Because of this we suggest a wheeled harvester (faster) or a harvester attachment for a tractor/excavator (cheaper) as noteworthy alternatives.

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## 0. Foreword

This report is based on two thinnings conducted in Hal-lormsstaður, east Iceland, by the forestry entrepreneur Guðjón Helgi Ólafsson, owner of the firm Græni Drekkinn ehf (Green Dragon Ltd). These two thinnings only constitute an early fragment of his experience with the harvester and shall therefore not be seen as final judgement of his work. On the contrary it is the authors' wish that this report will be seen as a contribution for future productivity analyses, e.g. that analyses in the time to come will have another benchmark to compare their results with.

## 1. Introduction

### 1.1. Forestry and harvesting in Iceland

At the time of human settlement about 1140 years ago, birch (*Betula pubescens*) forests and woodlands covered up to 40% of Iceland's land area (Wöll, 2008). The settlers cut and burned down the existing woodlands to create space for farming. After centuries of utilization for charcoal production and overgrazing by domestic animals followed by ecosystem degradation and soil erosion (Arnalds, 1987), forest cover was reduced to about 1% in 1900 (Aradóttir and Eysteinnsson, 2005). The Icelandic Forest Service (IFS) was established in 1908 in order to protect the remaining forests and did so by acquiring several of the remaining woodlands during the first decades of the

*Table 1. Assumed stem volume removal rates and clear cut ages for eight most common tree species in Iceland (changed after Eggertsson and Snorrason, 2006). Removal rate in relation to total stem volume; MAI = mean annual increment.*

Tree species	First thinning		Second thinning		Clear cut age (yrs.)	MAI (m <sup>3</sup> /ha*a)
	Removal age (yrs.)	Removal rate (%)	Removal age (yrs.)	Removal rate (%)		
<i>Larix sibirica</i>	25	60	40	35	91	3.3
<i>Pinus contorta</i>	25	35	40	35	91	3.2
<i>Picea sitchensis</i>	35	40	50	35	91	4.3
<i>Picea</i> spp.	40	35	60	30	91	2.1
<i>Betula pubescens</i>	25	35	45	35	101	1.4
<i>Populus trichocarpa</i>	20	35	40	35	61	8.2

20<sup>th</sup> century (Eysteinnsson, 2009). In the second half of the 20<sup>th</sup> century the focus shifted from conservation to afforestation. Between 500,000 and 1 million seedlings were planted annually by the IFS and forestry societies between 1950-1990 (Gunnarsson et al., 2005). Main species planted at the time were *Picea abies*, *Picea sitchensis*, *Pinus sylvestris*, *Pinus contorta* and *Larix sibirica*. After 1990 seedling numbers increased. Today between five and six million seedlings are planted annually being tantamount to 1500 ha (personal estimation). At present the main species are native *Betula pubescens* and *Larix sukachewii* (both about 30 %) followed by *Picea sitchensis*, *Pinus contorta* and *Populus trichocarpa* (Gunnarsson et al., 2005). The biggest share of afforestation is carried out on private land and subsidized by Regional Afforestation Projects.

The older plantation forests in Iceland, i.e. those due for second or final thinnings, are mostly publicly owned. Thinning and harvesting operations in public forests are carried out by IFS forest workers as well as private entrepreneurs. Until recently felling operations inside the IFS were mostly carried out with chainsaws and forwarding of the timber usually with tractors. Thinnings inside the regional afforestation projects are carried out by the landowners themselves or private entrepreneurs. Contractors mainly use chainsaws themselves but one contractor purchased a harvester recently.

### 1.2. Development of timber harvest in next decades

Ólafur Eggertsson and Arnór Snorrason (2006) estimated growing stock of and stem volume removals from plantation forests for the next 100 years based on seedling production statistics and growth measurements. For each of the most common planted tree species they assumed certain removal rates for first and second thinnings and certain rotation periods (Table 1).





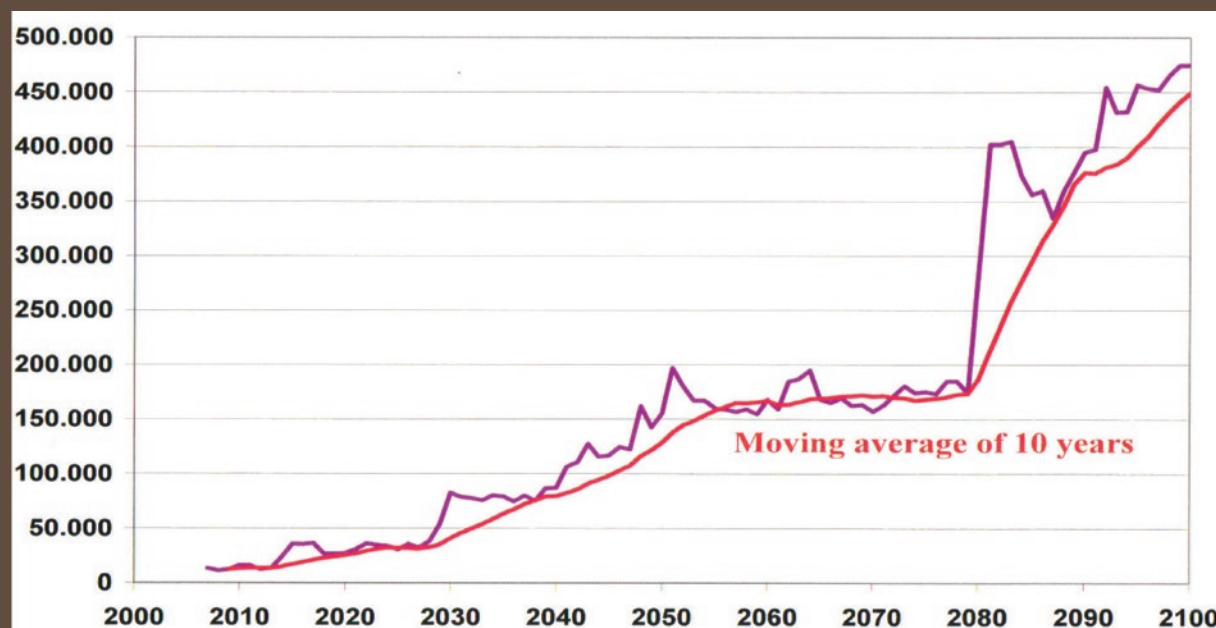


Fig. 1. Predicted annual stem volume removals from plantation forests in Iceland 2007-2100 (in m<sup>3</sup>). Image source: Eggertsson and Snorrason (2006).

Thus they predicted that annual removals should amount to app. 13,500 m<sup>3</sup> in 2007, 30,000 m<sup>3</sup> in 2025, 200,000 m<sup>3</sup> in 2050 and 500,000 m<sup>3</sup> in 2100 (Fig. 1). Actual annual removals, though, have been much lower than predicted. The amount of timber sold from forests owned by the IFS has been about 1,000 m<sup>3</sup> in 2008 (Bröstur Eysteinnsson, written communication). Adding unsold timber and timber from forests outside the IFS this number can be roughly doubled (personal estimation). Although Eggertsson's and Snorrason's (2006) estimations are based on simplifying assumptions, e.g. that thinnings have no effect on growing stock or that 20 % of all plantation forests will be protected or inaccessible, they show two important trends. Firstly, that timber stock will increase rapidly in the next decades requiring an expansion of annually thinned forest area and secondly, that forests in Iceland today are heavily under-thinned (comparing predicted annual removals of 13,000 m<sup>3</sup> with actual removals of about 2,000 m<sup>3</sup>).

### 1.3. The harvester used in the thinning

Guðjón Helgi Ólafsson, owner of forestry firm Græni Drekkinn ehf (GD), based in south Iceland, acquired the harvester A91 of Swiss producer Menzi Muck in 2006 (Fig. 2). The A91 is a "walking" harvester, meaning that its wheels are on "legs" that can be controlled separately, making it able to step over ditches and work in gradients in excess of 45° inclination (Menzi Muck Ltd, 2008). The range of the crane is 9 m. The felling head (Woody H50 of Austrian producer Konrad Forsttechnik Ltd) can fell trees up to a diameter of 65 cm and delimb trees from 7 to 50 cm

diameter. The feed rate is up to 4 m/s and sawing speed is 40 m/s. Harvester and felling head cost 26 mil. ISK at the time (converted 300,000 €, exchange rate from 10/2006 when harvester was purchased). The harvester can also be used in construction work. Suðurlandsskógar (South Iceland Afforestation Project) bought a planting head from the Swedish company Bräcke for 6 mil. ISK (app. 70,000 €). Guðjón was given a practical training over some days by the manufacturer in how to use the harvester. Technical data for the A91 is shown in Table 2.

Table 2. Basic technical data for harvester Menzi Muck A 91. Data source: Menzi Muck Ltd, 2008.

John Deere diesel engine 4 cyl- inders	104 Kw / 140 PS
Governed to	2,000 rpm
Displacement	4,500 ccm
Electrical system	24 V
Battery capacity	2 x 95 Ah
Starter	7.2 kW
Maintenance intervals	500 h
Diesel fuel tank capacity	130 + 200 l
Hydraulic system	Soziales Load Sensing
Working hydraulics	220 l/min.
Driving hydraulics	160 l/min.
Powerline	170 l/min.
Swivelling speed	up to 10 t/min.



Fig. 2. A Menzi Muck A91 harvester at work. Image source: Menzi Muck Ltd, 2008.

## 2. Methods

### 2.1. Thinned larch stands

The harvester was used in the thinning of two larch stands in Hallormsstaðaskógur in east Iceland. The first stand was 48 year old Siberian larch (*Larix sibirica*) and will be called Hafursá from now on (Fig.3). The second stand consisted of 41 year old Russian larch (*Larix sukachewii*) and will be called Mjóanes from now on (Fig. 4). Additional stand information based on measurements made by Annukka Pesonen and Hanna Parviainen during an inventory of larch in Hallormsstaðaskógur in 2006 is shown in Table 3 (Pesonen, written communication; called Finnish measurements from now on).

Table 3. Stand information for two larch stands in Hallormsstaðaskógur based on Finnish measurements (Pesonen, written communication).

	Planting yr	Area <sup>1</sup>	N/ha	BHD	Height
Mjóanes	1966	1.37	2625	15.9	9.2
Hafursá	1959	2.10	1030	21.8	13.0

<sup>1</sup> For Mjóanes: most of stand 195-3 (excluding unthinned area); for Hafursá: sum of three adjacent stands (304-7, 304-7A and 304-8).

### 2.2. Measurements

In order to establish the amount of timber harvested in both stands the measurements during this study (made in April 2008) were compared to the Finnish measurements (made in late summer 2006). Therefore the plot measurements of Pesonen and Parviainen were retrieved (Pesonen, written communication). The Finnish dataset consisted of six sample plots in Hafursá and four plots in Mjóanes. All trees inside a plot were counted and their diameter at breast height was measured. The diameters were used to calculate the mean basal area. The tree whose basal area was closest to the mean basal area was defined as mean tree. The height of the mean tree was measured. During this study the same amount of plots were chosen randomly in both stands and identical measurements were carried out. The volume of the mean tree was calculated using a model by Norrby (1990):

$$V = e^{-2.5079} * d^{1.7574} * h^{0.9808} \quad (1)$$

The volume of each mean tree was multiplied with the tree number of the plot. The sum of all plot volumes was divided by the number of plots and multiplied with 100 and resulted thus in the volume per hectare.

Since one growing season (2007) had passed since both the Finnish measurements (late summer 2006) and the thinning (March 2007) had taken place, the preceding year's volume increment was established. Therefore each plot's mean tree was





Fig. 3. Aerial map of Siberian larch stand in Hafursá (courtesy of IFS) and view of the forest.

cored and its height increment during 2007 measured. Diameter and height before the 2007 growing season were used to calculate last year's stand volume (using the same procedure described above). The harvested timber volume per hectare was calculated thus:

$$V_{\text{yield}} = V_{2007} - (V_{2008} + \text{Increment}_{2007}) \quad (2)$$

The stand in Mjóanes covers 1.67 ha, but the harvester did not finish thinning the entire stand. The remaining area was tracked with a GPS and subtracted from the stand area. The area in Hafursá consisted of three stands: 304-7, 304-7A and 304-8. There, however, the state forest service had felled 171 trees before the harvester arrived. Their volume was subtracted from calculation 2 for Hafursá. Regarding the working hours there was a discrepancy between the working diary of the harvester and the hours the harvester operator reported in the end, latter were also the basis for his payment. The volume per hour was calculated with the numbers from the working diary, since only they could be attributed separately to each stand. The yielded volume per stand was divided by the working hours and shown as function of tree volume. This function then was compared to a tree volume – yield volume per hour relationship for motor manual harvest of larch (Heiðarsson and Jónsson, 2004). After-

wards the harvesting costs per m<sup>3</sup> were calculated using both total costs (including transport of the machine from south to east Iceland and back) and pure harvesting costs. Neither costs included taxes.

## 3. Results

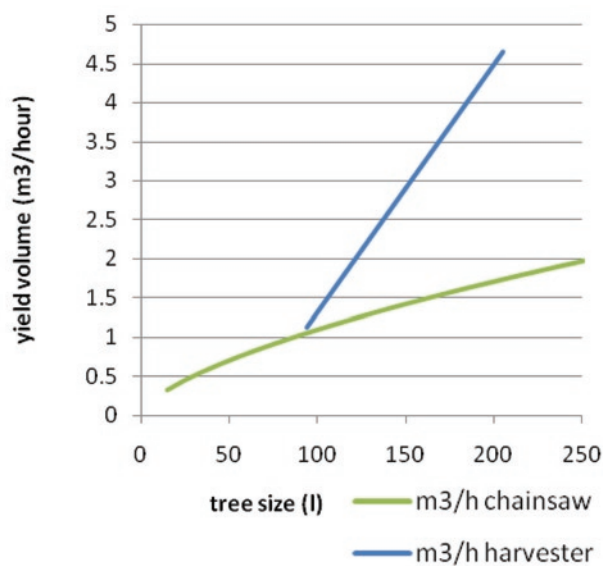
### 3.1 Productivity

In Mjóanes the mean tree volume before thinning was 94 l, in Hafursá it was 205 l. The harvester worked for 58 hours in Mjóanes and thinned 1.28 ha of larch forest. This resulted in timber volume of 1.1 m<sup>3</sup> per hour or 66 m<sup>3</sup> in total. In Hafursá it worked for 29 hours, thinned 2.1 ha and yielded a total timber volume of 135 m<sup>3</sup> (4.7 m<sup>3</sup> per hour). This means that it processed about twice as many of the larger trees per hour (23) than of the smaller ones (12). Compared to thinning with a chainsaw the harvester worked a bit faster than one forest worker with a chainsaw in the younger forest and 2.7 times as fast in the older forest (Fig. 5).





Fig. 5. Comparison of productivity for different tree sizes between a harvester (mechanized) and a forest worker (motor manual) with a chainsaw in larch stands.



### 3.2 Costs

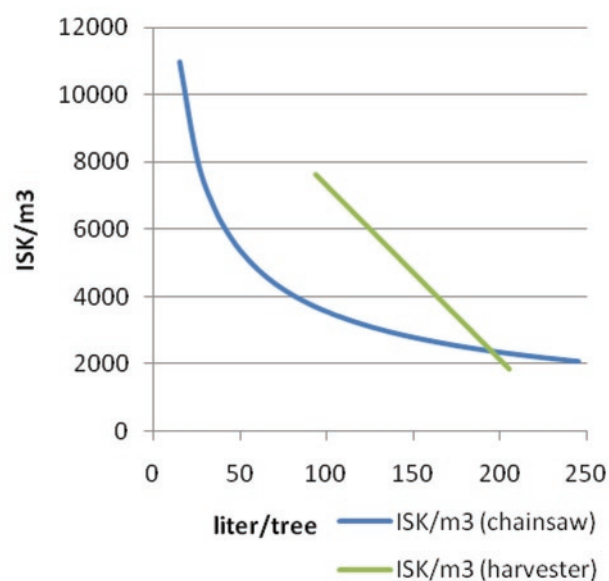
GD was paid 10,000 ISK per working hour amounting to 750,000 ISK for 75 hours of work. The harvester's working diary, however, showed 87 working hours. Hence the actual work hourly rate was only 8,620 ISK. Two thirds of the 87 hours were spent in Mjóanes. There the felling of one m³ timber cost 7,600 ISK. In Hafursá the felling of one m³ timber cost only 1,850 ISK.



Fig. 4. Aerial map of Russian larch stand in Mjóanes (courtesy of IFS) and view of the forest.

Compared to a forest worker, the thinning in the smaller stand was twice as expensive when done by the harvester. For the larger trees the harvester was 20 % cheaper per m³ than a forest worker (Fig. 6). When adding the transport costs of 150,000

Fig. 6. Comparison between harvesting costs per m³ as function of tree size for a harvester and forest worker with chainsaw (calculated with 8,620 ISK/work hour for the harvester, without transportation costs).



ISK for the harvester the costs per work hour increase by about 20 % thus making it two and a half times as expensive as a forest worker for the smaller trees, but still slightly less expensive than a forest worker for the trees with a stem volume of 0.2 m<sup>3</sup> (results not shown).

## 4. Discussion

### 4.1 Comparison of productivity

The harvester felled only half as many small as large trees per time unit. The reason for this was that the harvester operator had problems reaching the trees in Mjóanes because the stand was much denser than the one in Hafursá, where he had no problems (Guðjón Helgi Ólafsson, oral communication). It takes an operator about 500 to 1,000 working hours to be able to operate a wheeled or tracked harvester efficiently and even more to operate a walking harvester – due to the complicated driving motions (J. N. Stampfer, written communication). Therefore it is debatable whether the relationships in thinning productivity and costs for small trees between harvester and forest worker should be generalized. A time study of tracked harvesters (which are also specialized in difficult conditions) with experienced operators in Austria gives a scope of per time productivity (K. Stampfer, 2001). The productivity (harvested m<sup>3</sup> per working hour including breaks up to 15 min) of the small tracked Harvester MHT Robin for a tree size of 0.1 m<sup>3</sup> was 5.4 m<sup>3</sup>, for a tree size of 0.2 m<sup>3</sup> it was 6.9 m<sup>3</sup>. The medium sized tracked harvester Neuson 11002 HV had a productivity of 5.3 m<sup>3</sup> and 8.3 m<sup>3</sup> for comparable tree sizes, respectively. The comparison with the present study (Fig. 7) shows the following: in the Austrian study the tracked harvesters were about 1.5 times

as productive for the bigger sized trees but five times as productive for the smaller sized trees. There are some restrictions comparing the Austrian results with this study, above all the comparison between tracked harvesters and walking harvesters and differences in data collection. The comparison nevertheless shows the impact the inexperience of the operator had on productivity and indicates that this impact increased with the difficulty of the working conditions. This trend is confirmed by the comparison with another Austrian time study (Frick et al.) which analysed the productivity of the walking harvester Menzi Muck A71. This harvester is a smaller version of the Menzi Muck A91. For a tree size of 0.1 m<sup>3</sup> this harvester had a productivity of 5.5 m<sup>3</sup> or five times as much as the A91 in this study. For a tree size of 0.2 m<sup>3</sup> it had a productivity of 14 m<sup>3</sup> or three times as high as this study's.

### 4.2 Comparison of costs

In the stand with larger trees, the harvester was slightly cheaper than a forest worker. This is partly due to the low work hour costs assessed by GD. 10,000 ISK per hour is too low to be sustainable (Ólafsson, oral communication). This would become even more evident, if the high financial costs caused by the purchase of the harvester were taken into account and interest charges were calculated with the actual base rate in Iceland (18%, January 2008). Additionally there are numerous variable costs: repair, maintenance, fuel, lubricants, transportation etc. The harvester operator subsequently charged 13,000 ISK (Ólafsson, oral communication). When comparing thinning costs per m<sup>3</sup> between motor manual and highly mechanized method using 13,000 ISK as hourly rate it becomes apparent, that the harvester is also more expensive than a forest worker with a chainsaw in stands with a mean tree size of 200 l (Fig. 8).

Fig. 7. Productivity of harvesters from different studies.

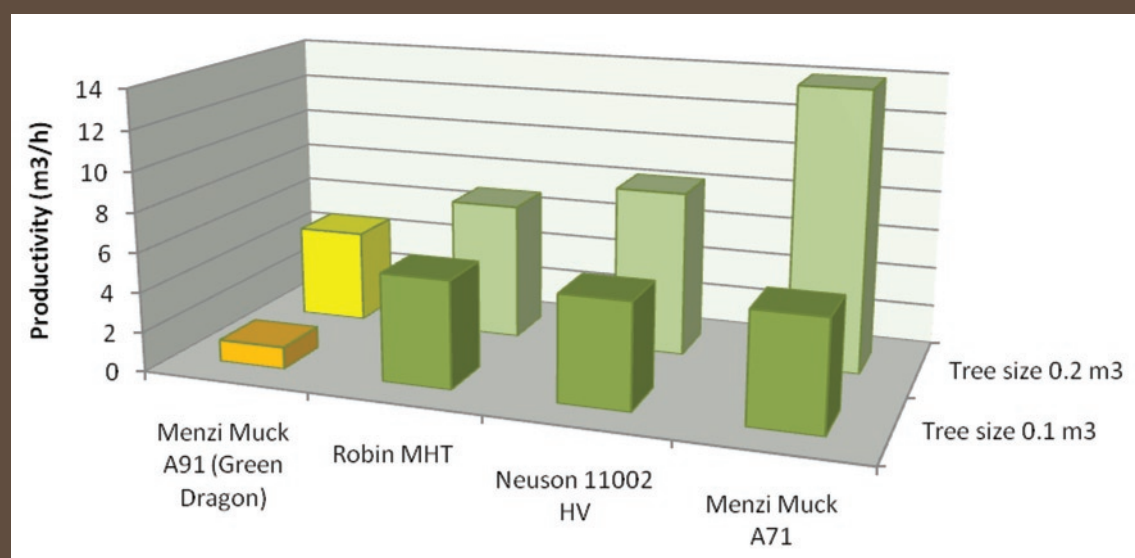
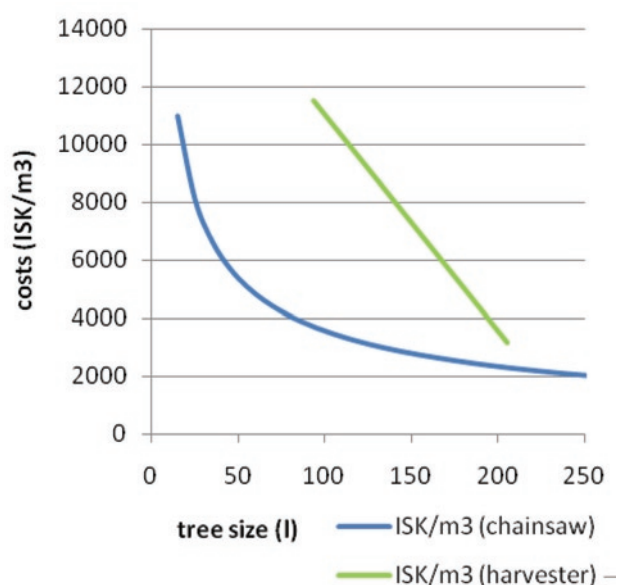




Fig. 8. Comparison between harvesting costs per m<sup>3</sup> as function of tree size for a harvester and forest worker with chainsaw (calculated with 13,000 ISK/hour for the harvester without transportation costs).



GD is based in Hveragerði, south Iceland. The two stands in Hallormsstaðaskógur, east Iceland, are about 650 km travel distance away. Thus, transportation becomes a significant cost factor. Guðjón calculated that, would he have bought the transportation from a transport company he would have paid about 380,000 ISK (without tax). He transported the harvester himself and charged only 150,000 ISK. A great share of older plantation forests, i.e. the ones due for thinning, are situated in north and east Iceland (Traustason and Snorrason, 2008), thus over 500 km away from south Iceland, GD's base. Therefore only larger sized biddings are profitable for the harvester operator, who estimates a minimum stand size of 10 ha for a profitable assignment (Ólafsson, oral communication).

Costs and benefits of thinning with a harvester in Iceland depend very much on the skills of the operator. One other factor, though, has not been taken into account yet: the question whether the harvester used is the right one for Icelandic circumstances. Thereto only one remark: the Menzi Muck A91 is a harvester custom built for extremely difficult circumstances, i.e. areas with difficult access and very steep slopes. It is accordingly expensive and the high financial costs have to be recouped by many working hours. Most of Iceland's economic forests are neither very hard to access nor very steep. Therefore a "normal" wheeled harvester might be a viable alternative given a sufficient work load. Recalling statements made in chapter 1.2. a sufficient work load for a harvester is currently not given in Iceland. Although the annual amount of stem volume due for thinnings is somewhere between 10,000 and 20,000 m<sup>3</sup> (according to Eggertsson and Snorrason, 2006), commissioned

removals are around 2,000 m<sup>3</sup> (Eysteinnsson, written communication and personal estimation). On the off chance that the harvester was given all commissioned thinnings, 2,000 m<sup>3</sup> still would be far from using it to capacity. Restrictively it has to be added that a good deal of the forests that are thinned today are small and scattered over the country so that allocation costs for a harvester would be very high. Hence, another possibility would be an attachment for an already existing tractor/excavator which would cause less financial costs. This option puts less financial pressure on the owner since the costs are much lower and the tractor/excavator can be used otherwise when there is no thinning work.

### 4.3 Damages

All statements regarding costs made above only account for instant profit. By including future profits in the calculation, any changes to the value of the remaining stand have to be included. The value of the remaining stand can be reduced if it is severely damaged during thinnings. If it is used in the right way and under the right circumstances the use of a harvester does not cause extensive damages to the remaining forest. E.g. controls the harvester head the tree after felling and can thus restrict felling damages to a minimum. And if the harvester

Fig. 9. Tree in Hafursá damaged by driving.







Fig. 10. Tracks of harvester going in three directions (to left, right and in center) in Hafursá.

stays on previously appointed strip roads driving damages to the remaining stand can be minimized. Thus compression of soil would also be restricted to certain areas, which are (theoretically) not part of the production area. No felling and driving damages are achieved only if the harvester is operated by an experienced operator. If operated by an inexperienced operator, though, damages to the remaining stand are likely to be more severe than in motor manual forest work (Fig. 9). When the harvester leaves appointed strip roads its weight of 10 tons compresses the soil (Fig. 10). Whether soil compression by heavy machines in Icelandic forests is permanent has not been researched, yet. Damage to forest soils is worsened if the harvester is used in wet conditions.

## 5. Epilogue

Today (January 2009), two and a half years after the purchase of the harvester and almost two years after the thinnings researched in this study took place, there are new developments regarding the harvester and its use.

First of all did the operator Guðjón Helgi Ólafsson of course gain experience in the use of the harvester. Consequently there are less damages to remaining trees during work (Böðvar Guðmundsson, oral communication). Furthermore did productivity increase significantly. In the right circumstances, i.e. easy terrain and without breaks caused by mechanical problems, Guðjón can thin up to roughly  $10 \text{ m}^3/\text{h}$  (Ólafsson, oral communication). Productivity is still very dissimilar and decreased by difficult conditions such as slopes, very branchy stands or windbreakage.

GD went on to charge 13.000 ISK per hour thinnings forests, which was higher than the rate used in the thinnings in Halformsstaður. He calculated that this rate was sustainable given a sufficient workload. In central Europe harvesters work between 1500 and 2000 hours, in individual cases up to 3000 hours (Pröll, 2005). In Scandinavia harvesters are sometimes run in shifts and in this case machine hours are even higher. The



high work loads are necessary in order to divide the high financial costs caused by the acquisition of the harvester among as many machine hours as possible. Thus the financial costs' share of total costs can be lowered and losses reduced or profits increased. The impact of high acquisition costs increases with increasing interest rates, a fact that is especially noteworthy as interest rates in Iceland today have reached a historical height. GD owned the harvester for two and a half years and was able to obtain thinnings for only about 450-470 hours (about 200 hours/year). Moreover the complementary use of the harvester in plantings did not work out as planned, because the planting head purchased by Suðurlandsskógar did not work as in-

tended. When planting on old fields or drained wetlands the planting head was not able to put the plants deep enough and was therefore not used anymore (Böðvar Guðmundsson, oral communication). GD used the harvester in digging operations but altogether it reached only 750 machine hours after its purchase.

Because of the lack of contracts GD has decided to sell the harvester abroad. Had there been enough work, Guðjón would have kept it.

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## 6. References

- Aradóttir, Á.L. and Eysteinnsson Th. (2005). Restoration of birch woodlands in Iceland. In: Restoration of boreal and temperate forests (Stanturf, J.A. and Madsen P. eds.), pp. 195-209. CRC Press, Boca Raton.
- Arnalds, A. (1987). Ecosystem disturbance in Iceland. Arctic Alpine Research 19: 508-513
- Blöndal, S. and Gunnarsson, S.B. (1999). Íslandsskógar - Hundrað ára saga. Mál og mynd, Reykjavík. In Icelandic.
- Eggertsson, Ó. Written communication
- Eggertsson, Ó. and Snorrason A. (2006). Forecasting of growing stock and the removals in plantation forests during the next 100 years in Iceland. The Northern Woodheat symposium, August 21-23 2006, Hallormsstadur, Iceland. 15.
- Eysteinnsson, P. Written communication.
- Eysteinnsson, Þröstur (2009). Forestry in a treeless land 2009. Updated from: Lustgården 2004: 27-34.
- Frick, J., Glatz, M., Sturm R. Maturaprojekt aus Arbeitstechnik und Arbeitslehre. Zeitstudie einer vollmechanisierten Durchforstung mit einem Universalharvester Menzi Muck A71 und Woody H50.
- Guðmundsson, Böðvar. Oral communication
- Gunnarsson, K. S., Eysteinnsson, Th., Curl, S., Thorfinnsson, Th. (2005). Iceland. In: Acta Silv. Hung. Special Edition, pp. 335-346.
- Heiðarsson, L. Written communication.
- Heiðarsson, L. and Jónsson, L. P. (2004). Ákvæðisvinna við grisjun í lerkiskógum. Rit Mógilsár Rannsóknastöðvar Skógræktar, Nr. 18.
- Norrby, M. (1990). Volum- och formtalsfunktioner för Larix sukaczewii och Larix sibirica på Island. Institutionen för skogsskötsel. Sveriges lantbruksuniversitet. Examensarbete i ämnet skogsskötsel. 35 p. (In Swedish).
- Ólafsson, G. H. Oral communication
- Pesonen, A. Written communication
- Pröll, W. (2005): Harvestereinsatz steigt. Forstzeitung 116. Jg, 12, Arbeit im Wald IV-V
- Stampfer, J. N. Written communication
- Stampfer, K. (2001). Harvester Leistungsdaten. FPP-Schriftenreihe, Kooperationsabkommen Forst-Platte-Papier, Wien.
- Traustason, B. and Snorrason, A. (2008). Stærð skóglendis á Íslandi byggt á CORINE flokkun
- Wöll, C. (2008). Treeline of mountain birch (*Betula pubescens* Ehrh.) in Iceland and its relationship to temperature. Technical University Dresden, Department of Forestry, diploma thesis in Forest Botany.
- <http://www.menzimuck.com/en/produktgruppe/forst.html>



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