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INTERNAL PROJECT INFORMATION NOTE 30/07

Title: Woodfuel Production from a Thinning Operation

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Work Study 1957
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celebrating 50 years of work study in British forestry

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WOODFUEL PRODUCTION FROM A THINNING OPERATION

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SUMMARY

This Internal Project Information Note (IPIN) describes a mechanised thinning operation in a crop of P84 Sitka spruce (*Picea sitchensis*) in Wales. Two different cutting specifications were produced, one of which included woodfuel.

The line and selective thinning was carried out using a John Deere 1270D harvester with a 758HD harvesting head in a crop with an average tree size of 0.073 m^3.

Time study data gathered for the harvesting of four products, logs, bars, chipwood and stakes showed an output of 2.44 m^3/shr and the output for harvesting logs, bars and woodfuel was 2.91 m^3/shr. The cost to roadside for the four products was £3.30/m^3 higher than for the woodfuel specification, which was £25.13/m^3.

INTRODUCTION

A range of current UK policies and strategies aim to increase the use of woodfuel, a renewable resource to generate energy. To support this policy, the forest industry is investigating harvesting methods to bring additional volumes of both brash and stemwood (not currently harvested as part of the conventional products) to market.

Technical Development has supported this development by providing time study and operational information from several woodfuel harvesting trials. Recent work has included a study of woodfuel production trials from a mechanised clearfell operation in Rivox, Ae Forest District (IPIN15/06). In summary the results showed an additional volume of 89 m^3/ha was recovered as chipper poles, a woodfuel product which was previously unutilised and placed in the brash mat. As a continuation of the Rivox work, a similar woodfuel harvesting trial was carried out in a mechanised thinning operation in Wales. The findings of the trial are described in this IPIN.

OBJECTIVES

1. Time study the harvesting and extraction of products from a thinning operation producing conventional products.

2. Time study the harvesting and extraction of products from a thinning operation producing conventional and woodfuel products.

3. Compare the two methods.

SITE AND CROP CONDITIONS

The trial site was in Dyfnant forest, Coed y Gororau Forest District. Tree spacing throughout the trial area was very variable. The crop consisted of both planted trees and regeneration which tended to be in close groups of three to five stems. It was difficult to identify planting lines and, as a consequence, some of the racks created by the harvester for machinery access were not straight.

Table 1 Trial site and crop information

Dyfnant Forest	
Grid reference	SJ 005165
Site Conditions	
Elevation (m)	340 – 360
Slope range (%)	11 – 32
Soil	Surface water gleys
Previous ground preparation	None could be identified
Crop Information	
Species	Sitka spruce
Average number of trees per hectare	2344
Planted (year)	1984
Age (years)	23
Average DBH (cm)	13
Average volume per tree (m^3)	0.073
Average volume per hectare (m^3)	171
Basal area per hectare (m^3)	45

MACHINERY

The harvesting was carried in November 2007out using a John Deere 1270D Eco 3 harvester with a 758 HD harvesting head and a John Deere 1110D forwarder, refer to Appendix 1 and 2 respectively for the technical specifications. Both machines were less than twelve months old and were operated by experienced Wales Harvesting and Marketing (WHaM) operators.

TRIAL SPECIFICATION

A WHaM thinning programme in the forest provided the opportunity for the trial to take place. The thinning type was a first thinning in a second rotation crop. One line was removed every 20 m to create access racks for the machinery and selective thinning carried out on both sides of the racks. The selective thinning was at the discretion of the operator who was instructed by the works supervisor to select trees suitable for the stake and log specifications.

To compare the harvesting of different products from the thinning operation it was important that the trial areas had comparable site and crop characteristics. For each of the two areas, the distribution of stem diameter was statistically assessed and no significant difference was found between them (maximum absolute difference of 0.175 for a maximum difference allowed of 0.304 with 95% confidence).

Study data were collected from:

- harvesting the stake, bar, chip and log product specifications provided by WHaM
- a cutting specification in which no stakes were cut and the chipwood was replaced with a woodfuel specification as given in Table 2.

Table 2 Product specification

WHaM standard specification			Woodfuel specification		
Product	**Length (m)**	**Diameter range (mm overbark)**	**Product**	**Length (m)**	**Diameter range (mm overbark)**
Stakes	1.7	Min 70 Max 130			
Bars	2.4	Min 140 Max 225	Bars	2.4	Min 140 Max 225
Chipwood	2.8	---------	Woodfuel	3.0	----------
Logs	3.7	Min 190 Max 320	Logs	3.7	Min 190 Max 320

For each study, the product specifications were programmed into the Timbermatic 300 computer system in the harvester before the work commenced. Measurements of extracted products confirmed the accuracy of the measuring device on the harvester with variations in length being within 0.05 m.

OUTPUTS AND COSTS

Results

Table 3 Harvesting and extraction outputs and costs

Outputs and Costs	WHaM Standard Specification	Woodfuel Specification
Harvesting output (m^3/shr)	2.44	2.91
Harvesting hourly cost (£/hr)	58.48	
Harvesting cost (£/m^3)	**23.97**	**20.10**
Extraction output per 100m (m^3/shr)	13.19	12.06
Extraction hourly costs (£/hr)	43.64	
Extraction costs (£/m^3/100m)	3.31	3.62
Extraction costs (£/m^3) per site	**4.46**	**5.03**
Total costs to roadside (£/m^3)	**28.43**	**25.13**

- Harvesting output - Standard hour (shr) includes a rest allowance of 18% and an allowance for other work of 20%.
- Extraction output – Standard hour (shr) includes a rest allowance of 15% and an allowance for other work of 17%.

The detailed calculation of the hourly costs shown in Table 3 is described in Appendix 3.

Discussion

Harvesting

The harvesting output was 19% (0.47 m^3) greater with the woodfuel specification. It is likely that the reduced number of products contributed to increased output.

From observations during the harvesting of both specifications, the majority of the trees were harvested from the racks created by the machine. Selective thinning in the matrix was restricted to a maximum of 4 m either side of rack. This was due to the close spacing of the crop, which restricted the operator view and manoeuvrability of the harvesting head.

Difficulty was also encountered processing the smaller sections of stems where the diameter was less than 5 cm. The configuration of the feed rollers on the 758 HD head meant that contact between the rollers and small diameter stem (<5 cm) was lost and the stems could not be reversed through the head past the delimbing knives to remove the side branches. Length and diameter measurements of the products were also lost due to the measuring wheel and diameter sensors on the rollers not being in contact with the stem. This is considered to have impacted on the recovery of woodfuel.

Extraction

Extraction output per 100 m was 9% (1.13 m^3) greater with the WHaM specification. There appeared to be no obvious reason for this although from observations there were greater volumes per grapple loaded than with the woodfuel specification.

Each product had been stacked by the harvester separately and perpendicular (lengthways) next to the rack. Each cutting specification was extracted as a single product. The volumes of each product stacked did not make a full load on the 1110 D forwarder (12 000 kg load rating).

Due to the slope on the site, the forwarder loaded the front bunk (next to the headboard) first and reversed uphill out of the rack. The close spacing of the remaining trees restricted visibility for the operator and to avoid damaging the crop the loader and grab had to be positioned carefully to grab the stacks in the narrow spaces between the trees. The rubber sections of hydraulic hoses around the knuckle of the boom were at risk of damage from the upper branches of standing trees during loading. The operation required a high level of skill and concentration.

All the brash produced by the harvester was placed in the rack. The trees had narrow crowns because of their close spacing and this had reduced the amount of green brash available for the brash mat. Thatching would have been beneficial in a small wet section in one of the extraction racks however this would have had to have been imported from another rack.

CONCLUSIONS

The results show that it is feasible to produce woodfuel as part of conventional thinning operations in conifer stands using standard harvesting machinery. The time study data gathered from the two cutting specifications showed a harvesting output of between 2 – 3 m^3/shr. The harvesting head used in the trial was capable of felling trees with a stem diameter of 650 mm. It was more suitable for operating in crops with bigger average tree sizes such as late thinnings and clearfell operations.

Where woodfuel is to be comminuted into woodchips, the diameter of the material can be lower than the conventional 7 cm accepted as the minimum for merchantable timber. The 758 HD harvesting head could not process stemwood lower than 5 cm and therefore potential woodfuel was placed in the brash mat. It is expected that greater recovery of small diameter material could have been achieved using a smaller harvesting head.

These observations suggest that a harvesting head with a smaller capacity fitted to a specialised base unit would have been more appropriate both for the conventional and woodfuel harvesting.

The volumes of the separate products per rack did not reach the maximum capacity of the forwarder. Extracting all the product specifications per rack on a load would have improved output performance despite there being greater time spent unloading the different products at roadside. Additional volume could have been produced from the matrix if the harvesting head had been able to reach further into the crop, the close spacing prevented this from happening. This would have produced more brash for the brash mat and greater protection for the soil from machine movement damage. The increased volume would have made extraction more efficient and would also have silvicultural benefits to the trees within the matrix.

The choice of cutting specification is influenced by current market prices for products. An investigation into the current market prices revealed a high price (*c*. £40.00/m^3)[1] for the stake specification. This was higher than the log material which was £32.00/m^3. Estimated prices for the woodfuel specification could expect to be between £20.00 and £25.00/m^3. However straightness is not critical for woodfuel and therefore a woodfuel specification in crops with poor form would be appropriate.

Restricted visibility for both operators was observed during the trial. This was caused by the closely grown trees. Operators were frequently required to adjust their seating position either to guide the head to the base of a tree being selected or manoeuvre the grab towards a stack of produce without debarking trees next to the stacks.

[1] This relates to the market price current at the time of the trial.

When compared to the Rivox trials the harvesting costs were considerably higher in the thinning operation ranging from £20.10 to £23.97. The same costs in the Rivox trials were £4.80 to £5.40. Harvesting outputs from the Rivox trial were considerably higher with the volumes ranging from 11.26 to 12.63m^3/shr. In the smaller tree sizes of the thinning operation which had a proportion of small trees which couldn't be processed the outputs ranged from 2.44 to 2.91m^3 .

The extraction output with the greater number of products from the Rivox trials was 5.61 m^3 to 20.10m^3 compared to a range of 13.91 m^3 to 12.06 m^3 in the thinning trial. The range of costs for forwarding products from the Rivox trials and thinning operation were £2.10 to £7.70 and £4.46 to £5.03 respectively.

The recovery of small diameter roundwood as an additional product from both clearfell and thinning operations can increase the supply of woodfuel to this emerging market.

RECOMMENDATIONS

The use of a smaller thinning harvester and forwarder in crop of this age with a similar thinning prescription should be considered and the operation studied to provided comparison with the larger machines used in this trial.

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APPENDIX 1

Harvester Technical Data

John Deere 1270D Harvester	
Diesel Engine	John Deere 6081HTJ
Volume power output (kW @ rpm)	160 @1400–2000
Torque (Nm @ rpm)	1100 @ 1400
Fuel tank (l)	480
Transmission	Hydrostatic – mechanical, 2-speed gearbox
Speed, mode 1 (km/h)	0 – 8
mode 2 (km/h)	0 – 25
Tractive force (kN)	160
Steering	Proportional frame steering
Steering angle (± °)	42
Brakes	Service and working brakes are hydraulically actuated, oil-immersed multi-disc brakes. Spring-actuated parking and emergency brakes. ISO 11169
Axles/Bogies	Hydro-mechanical differential lock at front and the rear
Front	Balanced gear bogie axles
Rear	Rigid axles
Electrical System	
Voltage (V)	24
Batteries (Ah)	2 x 140
Alternator (A)	140
Working lights	14 twin power and 4 single lamps on boom 30 lux in the working area of the boom
Hydraulics	Load-sensing, pressure compensated
Pump volume (cm^3)	190
Working pressure (MPa)	24/28
Hydraulic tank (l)	220
Boom	210 H
Maximum reach lengths (m)	9.7
Gross lifting torque (kNm)	178
Slewing torque (kNm)	43.6
Tilt angle (°)	-13/ +25
Slewing angle (°)	220
Cab	Safe and in conformity with ISO standards. Rotating and levelling cab
Sideways tilt (°)	15
Forward/backward tilt (°)	11
Turning angle (°)	50
Measuring and control system	PC/Windows-based Timbermatic 300
Harvester head	758 HD
Measurements (mm)	
Length	7580
Rear section	3900
Wheelbase	4050
Ground clearance	625
Estimated transport length	11600
Width, front – 700 Tyres	2766 – 2956 (band tracks fitted to front bogies, ballasted with water/antifreeze)
Width, rear – 700 Tyres	2860 (wheel chains on rear wheels)
Height	3850
Weight (kg)	17500

Harvesting Head	
Type	John Deere H758
Dimensions (mm)	
Knives open	1650
Knives closed	1200
Height	1670
Weight incl. rotator and link (kg)	1150
Felling /Cutting	Chainsaw – hydrostatic drive. Automatic chain tensioning
Maximum felling/cutting diameter (mm)	650
Chain type (inch)	0.404
Chain speed (m/s)	40
Feed force (motors cm^3 @ kN)	Four serial connected hydraulic motors 630/400 @ 22.0 800/500 @ 27.0
Opening upper knives (mm)	680 max.
Opening lower knives (mm)	710 max.
Opening feed rollers (mm)	700
Delimbing (mm)	Tip to tip 480
Hydraulic System	
Operating pressure (MPa)	25

Refer to www. JohnDeere.com for further machine information.

APPENDIX 2

Forwarder Technical Data

John Deere 1110D Forwarder	
Diesel Engine	John Deere 6068HTJ
Power output (kW @ rpm)	120 @2000
Torque (Nm @ rpm)	719 @ 1400
Fuel tank (l)	150
Transmission	Hydrostatic – mechanical, 2 speed gearbox
Speed, mode 1 (km/h)	0 - 8
mode 2 (km/h)	0 - 23
Tractive force (kN)	150
Steering	Proportional Frame Steering
Steering angle (± °)	44
Brakes	Service and working brakes are hydraulically actuated, oil-immersed multi-disc brakes. Spring-actuated parking and emergency brakes. ISO 11169
Axles/Bogies	Hydro-mechanical differential lock at front and the rear Balanced gear bogie axles. Hydro-mechanical differential lock at the front and the rear
Electrical System	
Voltage (V)	24
Batteries (Ah)	2 x 145
Alternator (A)	100 (28V)
Working lights	8 x 140 W twin power
Hydraulics	Load-sensing, with power control
Pump volume (cm^3)	125
Working pressure (MPa)	21.5
Hydraulic tank (l)	140
Boom	CF5
Maximum reach lengths (m)	8.5
Gross lifting torque (kNm)	102
Slewing torque (kNm)	24
Slewing angle (^{0})	380
Cab	Safe and in conformity with ISO standards.
Measuring and Control System	TMC or PC/Windows-based Timbermatic 700
Measurements (mm)	
Length	9425
Ground clearance	605
Minimum transportation height	3700
Width – 700 tyres	2800, band tracks fitted to rear bogies, wheel chains on front wheels
Weight (kg)	15370

Refer to www. JohnDeere.com for further machine information.

APPENDIX 3

Machine Costs

Machine	**Harvester**	**Forwarder**
Capital cost (£)	230 000	100 000
Residual value (£)	23 000	10 000
Life in years	5	5
Hours per year	2000	2000
Interest (%)	5	5
Discount factor	0.7835	0.7835
Equivalent annual cost	0.2310	0.2310
Capital cost (£/hr)	**24.48**	**10.64**
Operating Costs (£/hr)		
Repair and maintenance	5.00	5.00
Fuel	6.00	5.00
Insurance	3.00	3.00
Operator (including oncosts)	20.00	20.00
Total hourly charge (£)	**58.48**	**43.64**