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The Research Agency of the Forestry Commission

TECHNICAL DEVELOPMENT

INTERNAL PROJECT INFORMATION NOTE 15/06

Title: Wood Fuel Trial Rivox, Ae Forest District

Number: 1000A/57/06 & FR06042

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SUMMARY

A trial was carried out in a 44 year old Sitka spruce stand in Ae FD to look at the effect of fuelwood production and residue removal on harvesting out puts. Four different treatments were compared which involved various combinations of chipper pole and brash residue removal, in addition to harvesting of conventional log and pole products.

Results showed the harvester outputs from the four treatment types were similar and ranged from 11.26 m³/shr ob to 12.63 m³/shr ob with harvesting costs of £5.40 to £4.80/m³ ob.

The harvester cut 89 m³ of chipper poles per hectare from this trial. However it should be noted that the cut off diameter of the fencing material was 9 cm and the remaining part of the tree was being placed into the brash mat. If conventional smaller diameter roundwood was being cut, the volume of chipper poles produced would be significantly reduced.

Forwarder outputs ranged from 20.70 m³/shr ob to 5.61 m³/shr ob. The highest extraction rates were achieved with large sawlog material at high product density rates per hectare and the lowest extraction rates were achieved with small sawlog material at low product density rates per hectare. Smallwood extraction rates were between 8.81 m³/shr ob and 13.61 m³/shr ob. Extraction costs were between £2.10/m³ ob and £7.70/m³ ob. The forwarder output for green tops was 3.06 m³/shr. Extraction costs based on stemwood volume were £14.10 m³ ob. The volume of green tops was estimated at 8.00 m³/ha which is relatively low when compared to the chipper pole volume.

Cutting specifications for woodfuel production should be considered in terms of expected yield, revenue and site impact, considering extraction and environmental constraints. Managers will be able to use the guidelines *Site Selection for Brash Removal* (currently under development) when assessing sites for woodfuel harvesting.

INTRODUCTION

Over the last 15 years, the forest industry has reviewed the potential of small diameter timber and brash for fuel wood.

Following the introduction of the government's Energy Policy and the use of renewable sources, the Royal Commission on Environmental Pollution identified that heat and energy from biomass was the missing link in the 'Renewable Policy'.

This issue was taken forward by government and a number of biomass combined heat and power (CHP) plants have been constructed in the UK. One of these developments is now under construction at Stevens Croft, Lockerbie, south Scotland.

The fuel for this CHP plant will be sourced from forestry and agricultural businesses in southern Scotland and northern England. Many forestry companies are now looking at their harvesting operations to identify methods, techniques and machinery for cost effective woodfuel production.

Euroforest, a private forestry company, identified a trial area for potential woodfuel production in agreement with Ae Forest District and senior operations managers in FES. Because there were no updated guidelines on brash removal and site impact, advice was sought from Bill Rayner, Forest Research before the trial commenced. Technical Development was commissioned by Forestry Commission Scotland (FCS) to study the production of potential wood fuel from this area.

OBJECTIVES

(1) Time study identified woodfuel production methods describing:

- Woodfuel volumes obtained.
- Harvesting and extraction outputs and costs.
- Total amount of timber and residue from trial area.

(2) Time and method study (with costs) brown and green brash extraction on an older clearfell site.

SITE and CROP CONDITIONS

The site at Rivox, Greskine forest, Ae FD is at grid reference NT 008 044 and was harvested by a forestry contractor for the purchaser. Previously managed by Forest Research, the site had been thinned with 50% of the crop removed. Table 1 gives site and the crop details.

Table 1: Trial Site and Crop Information

Site Conditions	
Elevation (m)	465
Slope range (%)	0 – 25
Soil	Mineral, ironpan on the drier sloping areas with peaty gley and deep peat on the flat areas
Previous ground preparation	Single furrow plough
Crop Information	
Species	Sitka spruce
Planted (year)	1962
Age (years)	44
Average DBH (cm)	17
Average volume (m^3)	0.24
Volume range (m^3)	0.015 – 1.02
Average trees per hectare	1600
Trees per hectare range	1200 – 1800
Average volume per hectare (m^3)	380
Volume per hectare range (m^3)	192 – 437

MACHINERY

The crop was felled by a Timberjack 1270D, 6 wheeled harvester fitted with a Timberjack 758 harvester head and a John Deere 1410D 8-wheeled forwarder was used for extraction. Table 2 gives a brief outline of machine specifications.

Table 2 Machinery Description

	1270D Harvester	1410D Forwarder
Weight (e)(kg)	19 500	18 000
Length (m)	7.70	5.50
Width (m)	3.10	2.90
Load capacity (kg)		14 000
Engine	John Deere 6081 HTJ, 6 cylinder, 8.1 litre turbo	John Deere 6088 HTJ, 6 cylinder, 6.8 litre turbo
Power output (kw)	160 @ 1400 – 2000 rpm	139 @ 1400 – 1900 rpm
Fuel capacity (l)	480	165
Transmission	Hydro-mechanical	Hydro-mechanical
Tractive force (kN)	160	175
Speed (km/h)	0 – 25	0 – 22
Axles	Balanced gear bogie axles, hydro-mechanical diff locks	Balanced gear bogie axles, hydro-mechanical diff locks
Hydraulics	Load sensing, compensated pressure	Load sensing, with power control
Working pressure (Mpa)	24 – 28	21.5
Hydraulic tank capacity (l)	220	140
Boom	210H 9.0 m reach	CF7, 8.5m reach.
Cab	Rotating 50º, side tilt 15º, fore/aft tilt 11º Full ROPS, FOPS & OPS	Standard cab complying with ROPS, FOPS, OPS
Traction Aids	700 x 50 x 26.5 Nokian tyres, with water ballast and Clark 'Lite' bandtracks on the front bogie. 700 x 55 x 26.5 Nokian tyres and chains on rear wheels.	750 x 50 x 26.5 all round, Clark 'Lite' bandtracks fitted to rear bogies, Offa wheel chains on the rear wheel of the front bogie.

Table 3 gives a brief outline of the harvester head specification fitted to the 1270 harvester.

Table 3 Harvester Head Specification

Make	John Deere
Model	H758
Weight (kg) (including rotator)	1 150
Height (cm)	167
Width (knives open) (cm)	165
Width (knives closed) (cm)	120
Felling & Cutting	
Max fell diameter (cm)	65
Chain type (inch)	0.404
Chain speed (m/s)	40
Feed type	Four serial connected hydraulic motors fitted with steel rollers.
Feed force (kN)	2 @ 630, 2 @ 800
Max roller opening (cm)	70
Delimbing system	Four movable hydraulic operated knives, one fixed
Max delimbing diameter (cm)	48

Table 4 shows cost assumptions for new machines including running costs and operator rates.

Table 4 Harvesting Machinery 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	8.00	5.00
Insurance	3.00	3.00
Operator (including oncosts)	20.00	20.00
Operating Costs	36.00	33.00
Total hourly charge (£)	**60.48**	**43.64**

TRIAL SPECIFICATIONS

Discussions with the contract manager, machine owner and driver prior to starting the study indicated that they were not producing any chipwood or pulpwood from the site. Fencing material was cut to 9 cm top diameter. The original specification was to process the fencing material to 7 cm but due to product quality issues, it was decided to increase the cut off diameter. Brash was placed on the ground to produce a route for machine travel. The trial site was split into four areas and the following products cut in each treatment.

Treatment One

Logpoles	7.00 m to 14.00 m x 16+ cm top diameter
Sawlogs	3.70 m x 18+ cm top diameter
	3.10 m x 16+ cm top diameter
	2.20 m x 18+ cm top diameter
Bars	2.50 m x 12+ cm top diameter
	1.90 m x 14+ cm top diameter
Fencing	1.70 m x 9+ cm top diameter
Chipper poles	2.90 m x 3+ cm top diameter

Treatment Two

Fencing material was removed from the cutting matrix and replaced with chipper poles to determine if cutting chipper pole material affected recovery, output and costs. Chipper poles were processed from deadwood, un-merchantable material and stem wood. The snedded chipper poles were cut to a set specification (2.90 m x 3 cm top diameter) to improve harvester and forwarder handling.

Treatment Three

All the products in Treatment One were cut and in addition 'green tops' were produced, which are live random lengths of small diameter stemwood with branches, cut from the top of the tree after chipper poles. This material is usually placed into the brash mat to form the extraction route for the machine to travel on and to protect the underlying soils. The green tops were placed on the opposite side of the brash mat from the timber zone.

Treatment Four

All the products in Treatment Two were cut except set length 2.9 m chipper poles where random length chipper poles with a length of 2.50 m to 6.00 m were cut.

Brown and Green Brash

If sufficient brash had been available, it would have been extracted using a conventional forwarder with a bunk modified for brash haulage, and the forwarder loaded using a tracked excavator fitted with a suitable brash grab.

The data from the total volume of the products cut and green brash can be compared with Technical Development Technical Note 17/97 *Clambunk System - Timber Residue Availability*.

OUTPUTS AND RESULTS

Harvesting

Table 5 shows felling outputs and costs for the four treatment types. The tree size did vary through the treatment types and the data were processed using an analysis program, so that cost comparisons using an average tree size of 0.20 m³ could be made. Costs are based on a charge of £61.00 per hour (rounded) for the harvester as shown in Table 4.

Table 5 Outputs and Costs

Treatment		Move (%)	Fell (%)	Process %	Aside Top %	Trim Butt %	Treat Dead %	Total Time (SM) *	Tree Vol (m³)	Standard output Vol (m³)	Cost (£/m³/shr) (rounded)
1	Sawlog, fencing and chipper poles	3.5	25	56	10	2	3.5	149.20	0.20	12.63	4.80
2	Sawlog and chipper poles	3	26	56	10	1.5	3.5	64.17		11.91	5.10
3	Sawlog, fencing, chipper poles and green tops	5	24	57	6	2	6	156.37		12.03	5.10
4	Sawlog, and random length chipper poles	2	22	56	11	7	2	71.14		11.26	5.40

* An allowance of 18% for rest and 20% for other work has been used to convert basic time to standard time

Discussion

Using treatment one as a base line, output differences of between -5% and -11% were recorded against the other treatments. Treatments 1, 2 and 3 have similar outputs.

It should be noted that the time study data collected for Treatment Four was limited and therefore the results should be viewed with some reservation. The results indicated an output difference of -11% between Treatment One and Treatment Four and it would appear that the difficulties experienced with cutting random length chipper poles has an adverse effect on output. The time study was stopped on Treatment Four because the harvester operator encountered problems with the diameter measuring system, cross cut activation and volume calculation by the computer. Problems were encountered when longer length narrow material dropped out of the harvester head, preventing the delimbing knives and feed roller sensors recording the volume of the narrow diameter produce in the head. When the operator tried to re-feed the long narrow stem back through the head, the rollers would not move, stopping cross cut saw activation and produce recording. The operator had to drop the produce on the ground and reposition the harvester head on the larger diameter part of the stem, then feed the stem back through the head and cross cut the material into shorter sections.

EXTRACTION

Table 6 shows product and volume in the forwarder extraction area (average tree size 0.16-0.18 m³) using Treatment 3 as a large scale extraction area. The volume per hectare was calculated using the products cut (recorded by harvester computer) and the area felled. This indicated a volume of 402 m³/ha.

Table 6 Product Assortment and Yield

Product	Product Assortment (%)	Volume (m³/ha)
Logpoles 7.00m to 14.00m x 16+ cm top diameter	37	149
3.70 m sawlog x 18+ cm top diameter	–	–
3.10 m sawlog x 16+ cm top diameter	11	44
2.20 m sawlog x 18+ cm top diameter	2	8
2.50 m bars x 12+ cm top diameter	6	24
1.90 m bars x 14+ cm top diameter	11	44
1.70 m fencing x 9+ cm top diameter	11	44
2.90 m chipper poles x 3+ cm top diameter	22	89
Green tops *	Not included in assortment	8
Total	100	402

*Green top volume is not included in the product assortment

Discussion

The harvester cut 89 m³ of chipper poles per hectare from this trial. However it should be noted that the cut off diameter of the fencing material was 9 cm and the remaining part of the tree was being placed into the brash mat. If conventional smaller diameter roundwood was being cut, the volume of chipper poles produced would be significantly reduced.

Further investigations into product assortment using the conventional harvesting method and including wood fuel needs to be carried out against a selection of cutting matrixes.

This may be feasible using the 'Optimiser' Computer Systems that are installed in the on board computers of the John Deere (Timberjack), Ponsse and Valmet machines. Further investigation into this work needs to be carried out with consultation with the machine owner and John Graves, Forestry Training Services.

The set length 2.90m chipper pole was easier for the harvester operator to process compared to random length chipper pole. It was also easier for the forwarder operator to load and two bays could be carried, maximizing forwarder capacity.

The green tops stem volume was calculated using length and mid diameter and does not include branch wood volume.

Discussion

Table 7 shows the output and cost for each product extracted per m³ per 100 metres. The costs are based on an hourly forwarder charge of £43.00 as calculated in Table 4.

Table 7 Forwarder Outputs and Costs

	Forwarder - John Deere 1410	
Product	Output (m³/100/shr)	Rounded Cost (£/m³)
Logpole	20.70	2.10
3.1 Sawlogs	12.31	3.50
2.2 Sawlogs	5.61	7.70
2.5 Bars	8.08	5.30
1.9 Bars	11.19	3.80
1.7 Fencing	8.81	4.90
2.9 Chipper poles	13.61	3.20
Green tops	3.06	14.10

During the study, the forwarder operator extracted single product loads because full bunk capacity could be achieved and two bays were used with shorter material. Depending on the product density and extraction distance, two bays of different material can also be extracted.

TOTAL HARVESTING COSTS AND REVENUES

The total cost to harvest and extract the products is shown in Table 8. The harvesting cost is based on Treatment 3.

Table 8 Total Harvesting Costs

	Cost (£/m³)		Total harvesting cost (£/m³)	Revenue (£/m³)	Surplus (£/m³))
Product	Harvester	Forwarder			
Logpole	5.10	2.10	7.20	30.00	22.80
3.1 Sawlogs		3.50	8.60	30.00	21.40
2.2 Sawlogs		7.70	12.80	30.00	17.20
2.5 Bars		5.30	10.40	25.00	14.60
1.9 Bars		3.80	8.90	25.00	16.10
1.7 Fencing		4.90	10.00	26.00	16.00
2.9 Chipper Poles		3.20	8.30	20.00	11.70
Green Tops		14.10	19.20	–	–

Revenue is based on Forest Enterprise (Scotland) information (Summer 2006) with logpole and sawlog revenue based on average revenue for 'green and red' logs. The chipper pole revenue is based on pulpwood/chipwood revenue following consultation with FE(S) harvesting managers. Income from the green tops is unknown.

Roundwood harvesting costs ranged from £7.20/m³ to £12.80/m³. The highest costs were associated with 2.20 m sawlogs and 2.50 m bars. Historical data and study work carried out by Technical Development indicates that low product density and small piece size does adversely affect extraction; increasing the cost and reducing the outputs. Green tops had low product densities and they had poor weight to volume ratios, i.e. they are bulky to transport. The harvester stacked the tops on the opposite side of the brash mat to the timber which incurred a small time penalty.

OTHER POINTS OF CONSIDERATION

Environmental Issues

The woodfuel market could increase the removal of small diameter roundwood and brash which could have a negative impact on some sites in terms of nutrition and soil disturbance caused by machine travel. Research carried out over the past 10 – 15 years has identified that the removal of residues can be detrimental on certain site types. There are three main concerns; physical damage, soil impoverishment and acidification. Guidance for the forest industry on site selection for brash removal is currently being written by Dr. Tom Nisbet, Forest Research, Alice Holt.

The following list identifies current FC guidance and further sources of information for woodfuel harvesting operations:

- *Forest and Water Guidelines* 4th Edition, ISBN 085538 615 0.
- Technical Note, FCTN 010 *Extraction Route Trials on Sensitive Sites*. ISBN 085538 682 7.
- Technical Note, FCTN 011 *Protecting the Environment during Mechanised Harvesting Operations* ISBN 085538 683 5.
- Practice Guide *Whole-tree Harvesting: A Guide to Good Practice*. ISBN 085538 360 7.

Discussion

On the majority of sites there will be a need to balance the degree of brash removal against maintaining adequate brash mats to prevent harvesting damage.

Within the trial area there was evidence that the operators had at times got the balance wrong. During extraction the forwarder broke through the brash mat and created ruts up to 90 cm deep in the soft peaty gley areas. On the sloping ground the brash mat was showing signs of compaction with ruts up to 30 cm deep.

OBJECTIVE 2 BRASH EXTRACTION

Brown and Green brash extraction

This was not carried out during the period of the initial study. This is due to be reviewed at a later date following consultation with the forest manager, harvesting supervisor, contractor and machine owners.

CONCLUSIONS

The harvester outputs from the four treatment types were similar and ranged from 11.26 m^3/shr ob to 12.63 m^3/shr ob with harvesting costs of £5.40 to £4.80/m^3 ob.

Cutting random length chipper poles had the greatest detrimental effect on harvester outputs and costs due to handling difficulties within the harvester head. Random length chipper poles were also less efficient for forwarder extraction in this case study.

Cutting set length chipper poles increased roundwood recovery by 89 m^3/ha ob when this product type was introduced to the cutting specification which previously had a fencing product as the only non sawlog product. It is important to note that the cut off diameter of the fencing material was 9 cm and the remaining part of the tree was being placed into the brash mat. If conventional smaller diameter roundwood was being cut, the volume of chipper poles produced would be significantly reduced.

Forwarder outputs ranged from 20.70 m^3/shr ob to 5.61 m^3/shr ob. The highest extraction rates were achieved with large sawlog material at high product density rates per hectare and the lowest extraction rates were achieved with small sawlog material at low product density rates per hectare. Smallwood extraction rates were between 8.81 m^3/shr ob and 13.61 m^3/shr ob. Extraction costs were between £2.10/m^3 ob and £7.70/m^3 ob.

The forwarder output for green tops was 3.06 m^3/shr and this volume calculation is based on main stemwood volume and not branch volume. Extraction costs based on stemwood volume were £14.10 m^3 ob. The volume of green tops is estimated at 8.00 m^3/ha which is relatively low when compared to the chipper pole volume.

The development of the woodfuel market could increase the recovery of small diameter roundwood and brash which has usually been left on site. This raises a number of environmental concerns which cover physical soil damage, soil impoverishment, acidification and fresh water eutrophication.

RECOMMENDATIONS

Managers and supervisors should use the environmental guidelines *Site Selection for Brash Removal*, currently in draft, to assess the suitability of sites for brash removal.

Cutting specifications for woodfuel production should be considered in terms of expected yield, revenue and site impact, considering extraction and environmental constraints.

On sites with a sawlog element, a set length woodfuel product should be considered for maximum harvester and forwarder efficiency.

Investigations should be carried out to determine woodfuel yields from a conventional shortwood harvesting operation where the minimum cut off diameter for white-wood is 7 cm.

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