Forest Research
The Research Agency of the Forestry Commission

TECHNICAL DEVELOPMENT

INTERNAL PROJECT INFORMATION NOTE 07/07

Title:	**Rumster Forest Northern Wood Heat Woodfuel Cutting Trial**
Number:	**1400S/48/07 & FR07035**
Date:	**August 2007**
Project leader:	**Paul Webster and Martin Price**

Work Study 1957
2007 Technical Development

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Rumster Forest Northern Wood Heat Woodfuel Cutting Trial

SUMMARY

A comparison between clearfell production of conventional products and woodfuel was carried out in unthinned stands of Lodgepole pine (*Pinus contorta* Dougl.) and Sitka spruce (*Picea sitchensis* (Bong.) Carr.).

The Lodgepole pine stand had an estimated volume of *c*. 355 m^3/ha, a mean tree volume of *c.* 0.19 m^3 and a top height of 18 m. The Sitka spruce stand had an estimated volume[1] of *c*. 590 m^3/ha, a mean tree volume of *c*. 0.41m^3 and a top height of 25m.

Cutting of woodfuel was found to increase volume recovered by *c*. 20% in Lodgepole pine and *c*. 35% in Sitka spruce.

Harvester productivity was found to increase when cutting woodfuel by 59% from 7.8 to 12.4 m^3/standard hour in Lodgepole pine and by 26% from 12.8 to 16.1 m^3/standard hour in Sitka spruce.

Indicative forwarder productivity study values suggest working is more efficient in woodfuel working by *c*. 20% in Lodgepole pine and *c*. 19% in Sitka spruce.

The harvester and forwarder fuelwood outputs are greater than conventional harvesting outputs in both comparisons and this is reflected in lower total harvesting costs for fuelwood harvesting.

Mensuration assessment of the stands found discrepancies in volume estimation suggesting that the structure and tree form within this stand type does not conform well to management tables published in Matthews & Mackie (2006)[2]. Stand volume estimations should be used with caution.

INTRODUCTION

Some British upland plantations contain poor quality stands liable to produce a high proportion of non-sawlog material such as chipwood and palletwood. The remote locations of these plantations often mean the haulage costs of transport to mill are equal to or exceed the revenue gained from small-roundwood (SRW), making harvesting financially unattractive.

The burgeoning woodfuel sector presents an alternative to conventional SRW markets. Prices for woodfuel are generally lower than those for conventional SRW products. However, where woodfuel markets are a more local alternative to conventional mills the price differential may be offset by the decreased transport costs.

The objective of this study was to compare the conventional harvesting of typical plantation crops with an alternative prescription where woodfuel is cut instead of SRW.

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[1] Tree volumes were calculated from mean tariff number as this seemed to offer a more realistic volume estimate compared with form height. Volume per hectare calculated as in 4.2.11 Matthews & Mackie (2006). The volume takes planting breaks into consideration but not any net-gross assumptions of rides and other open ground.

[2] Matthews & Mackie 2006. *Forest mensuration handbook*.

SITE DESCRIPTION

Rumster Forest covers *c.* 1200 ha and is situated 20 km to the southwest of Wick in Caithness, Scotland. The forest is mainly coniferous, consisting predominantly of Sitka spruce and Lodgepole pine of various provenances. The trial plots were typical of most of the Rumster block, being reasonably level but with soft ground conditions and coarse crops. Site conditions are summarised in Appendix 1. Soils were wet gleys and peaty-gleys requiring a high density of drains which have not been maintained and have blocked leading to local water-logging. Original site establishment consisted of ploughing at a mean of 1.6 m between ridges with subsequent planting at 1.6 m spacing leading to an initial stocking density of 3906 trees per hectare.

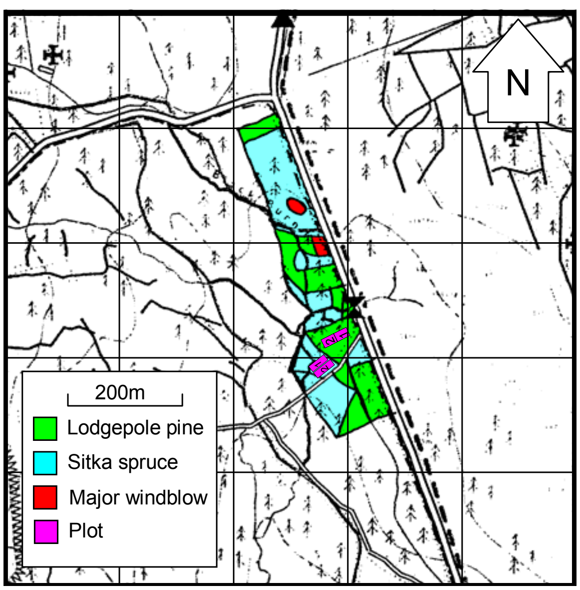
CROP DESCRIPTION

The study crop was about 53 years old, unthinned and consisted of around 1650 live trees per hectare in areas of Sitka spruce and 2100 live trees per hectare in areas of Lodgepole pine. Crop form was good for Lodgepole pine, the crop being a north coastal provenance and not south coastal which is more prone to serious sweep. Small pockets of windblow were common throughout the stand with larger areas of windblow centred on wetter areas and progressing east from the clearfelled area bordering the west of the stand.

Areas of homogeneous unblown Sitka spruce and Lodgepole pine were identified within the stand and four plots installed; two in each species. In each pair of plots, one was used to assess conventional working and the other cutting woodfuel. Size of plots was based on the minimum number of trees needed for a time study as specified in the Time Study Instructions[3] i.e. 40 trees. The four trial plots are summarised in Table 1 and their position within the stand shown in Figure 1. The western edge of the mapped stand borders continuous windblow.

Standing deadwood was also measured as it is potentially exploitable for woodfuel. Dead tree density was around 1100 trees per hectare in Sitka spruce and 615 trees per hectare in Lodgepole pine.

Figure 1 Map of standing crop and trial plots. Map top left hand corner OS grid: NH200390



[3] TSI HM4 Grapple harvesters in thinning and clearfell

An independent samples t-test was carried out to compare diameter distributions of plot LP1 with LP2 and SS1 with SS2. No significant differences ($p<.05$) were found between Lodgepole pine live trees [$t(138)=1.022$, $p=.309$] or dead trees [$t(39)=.483$, $p=.632$] or between Sitka spruce live trees [$t(78)=1.243$, $p=.217$] or dead trees [$t(52)=.941$, $p=.351$].

This indicates that the diameter distributions of the plots are comparable (with a probability >95%, which is the accepted standard for biological studies), and that any significant difference observed in the results of the study will be very unlikely to come from differences in the crop diameters.

Table 1 Trial area plot summary

Plot	Plot Area (ha)	Cpt	Sub Cpt	P. Year	WHC	Strata	Trees Per Plot	Trees Per Ha.	Mean DBH (cm)	Std. Dev. DBH (cm)	Top Ht. (m)	GYC
Lodgepole 1	0.0315	3019	A	1954	5	Live	70	2222	18.1	5.31	18.1	8
						Dead	18	571	12.4	2.75	11.1	
Lodgepole 2	0.0349	3019	A	1954	5	Live	70	2007	17.2	4.94	17.7	8
						Dead	23	660	12.0	2.92	12.7	
Sitka 1	0.0258	3019	B	1954	5	Live	37	1432	22.7	6.92	24.8	14
						Dead	36	1394	11.8	6.71	15.0	
Sitka 2	0.0231	3019	B	1954	5	Live	43	1862	20.4	9.42	25.3	14
						Dead	18	780	10.3	1.96	13.9	

The standard deviation (Table 1) in the dbh expresses the dispersion of the diameters around the mean dbh. It means that assuming a normal distribution of dbh within the stand, 68% of the trees will be between mean dbh ± 1 standard deviation. For instance for the live trees in LP1, 68% of the trees will be between 18.1+ 5.31 = 23.41 cm dbh and 18.01 – 5.31 = 12.61 cm dbh.

Compared with mean values, the relatively high standard deviations observed suggest that the stand diameter distribution is rather heterogeneous.

Because of the provenance choice, the majority of pine trees would have been classed[4] as 1.1.1 with poorer individuals having sweep, branching or stem deviation classed as 2. Plot condition and form can be seen in Plates 1 and 2.

Forking and double or triple stems was common. Within plots LP1 and LP2, 14% and 11% respectively of stems were forked and 4% and 13% respectively were joined below breast height.

Crop form in the Sitka spruce was poor, although representative of many stands in the Rumster block, based on personal and FD staff observation. Plot condition and form can be seen in Plates 3 and 4.

Forking and double or triple stems was also quite common within the Sitka spruce plots. Within SS1 and SS2, 7% and 1% respectively of stems were forked and 10% and 17% respectively were joined below breast height.

CROP VOLUME ESTIMATION

Crop volume was initially estimated using stand form height based on top height[5]. Volume estimates, as can be seen from Table 2, were higher than might be expected for such crops.

In order to investigate this further, tariff numbers were derived for both spruce and pine from measured sample trees felled from areas adjacent to the plots, 12 for each species and covering the stand diameter range.

[4] Refers to work study branch report 11/91 *Classification of tree characteristics in lodgepole pine*
[5] Matthews & Mackie 2006. *Forest mensuration handbook.*

Table 2 Summary of standing volume estimates

Plot	Strata	Form Height	Mean Tree Volume (m^3OB)	Standard Deviation (m^3OB)	Crop Volume (m^3/ha)	Tariff No.	Mean Tree Volume (m^3OB)	Std. Dev. (m^3 OB)	Crop Volume (m^3/ha)
Lodgepole 1	Live	8.22	0.23	0.14	509.1	23	0.18	0.12	396.7
	Dead	4.56	0.06	0.03	32.9	19	0.07	0.04	39.0
Lodgepole 2	Live	7.96	0.20	0.11	401.4	23	0.16	0.10	318.0
	Dead	5.34	0.06	0.03	41.8	21	0.06	0.05	41.5
Sitka 1	Live	10.81	0.48	0.30	683.6	30	0.38	0.26	549.0
	Dead	6.36	0.09	0.12	127.3	24	0.10	0.18	144.8
Sitka 2	Live	10.81	0.43	0.42	793.2	30	0.34	0.36	632.1
	Dead	5.91	0.05	0.02	39.5	23	0.05	0.03	38.8

The standard variations (Table 2) show that the distribution of the volumes is very heterogeneous in the stand

As can be seen in Table 2, volume calculated from tariff numbers is considerably lower than that from form height, suggesting that there was some stratification of crop, probably due to its unthinned nature.

Using the estimates derived from tariff trees, standing volume was around 590 m^3/ha live and 97 m^3/ha dead in Sitka spruce and 355 m^3/ha live and 40 m^3/ha dead in Lodgepole pine.

It should be stressed that conventional volume estimates are for over-bark commercial volume to 7cm top diameter. Trees will have a higher useable volume when cut for woodfuel as there is a lower product specification which will accept produce smaller than 7cm.

The discrepancy in volume estimation between form height and tariff number suggests that the structure and tree form within this stand type does not conform well to management tables published by Matthews & Mackie (2006)[6]. Measured produce volumes suggest that standing volume is equivalent to or slightly higher than values derived from tariff calculations and certainly less than those derived from stand form height calculations.

The studied stands were the most homogeneous within the block and so it is likely that this problem will only be exacerbated by increasing heterogeneity from factors such as windblow. Stand volume estimations can vary either way and should be used with caution.

PRODUCTS CUT

Four products were cut in the study; log, pallet, chipwood and woodfuel, the specifications of which are summarised in Table 3. Conventional products were log, pallet and chipwood, the chipwood cut to Norbord specifications. Woodfuel was a random length product with no set diameter limits which is chipped for fuel. Table 3 denotes the products cut within each plot with an asterisk. The product mix studied was the same as was normally cut by the contractor for woodfuel or conventional harvesting and so represents normal working practice.

[6] Matthews & Mackie 2006. *Forest mensuration handbook*.

Table 3 Product specifications

Product Number	Product Type	Length (cm)	maximum base diameter (cm)	minimum top diameter (cm)	Cut in LP1	Cut in LP2	Cut in SS1	Cut in SS2
1	Log	370 (±5)	60	18			*	*
2	Palletwood	250 (±5)		14		*		*
3	Chip	300		8		*		*
4	Woodfuel	random to 500	-	-	*		*	

Table 4 presents the volumes cut within each plot with the equivalent values per hectare and the volumes as a percentage of live standing volume and live and dead combined standing volume.

Very little of the dead Lodgepole pine yielded woodfuel, the trees often being too brittle to process. Seven pieces of woodfuel were processed from dead trees with an estimated volume[7] of $0.46m^3$ ($14.6m^3$/ha). This is only 37% of the estimated standing deadwood volume[8] within the plot. The majority of the dead tree volume in both plots was added to the brashmat.

In contrast, 48 pieces of woodfuel were processed from dead Sitka spruce with an estimated volume of 2.88 m^3 (111.6 m^3/ha). This volume represents 77% of the estimated standing deadwood volume within the plot. Much of the dead tree volume in SS1 utilised instead of being processed into the brashmat was un-measurable and un-merchantable .

A proportion of pieces were rejected as they were cut outside length specifications. These consist of 4 of 44 pallet in plot LP2, 1 of 51 logs in plot SS1 and 2 of 32 pallet in plot SS2.
Errors in cutting are likely to have been due to the coarse nature of the harvested trees causing the head measuring wheel to skip or over-measure as it passed over large branch stubs.

Errors were seen to be more likely in palletwood as pieces were often cut from small portions of clear stem adjoining lengths of defect. Feed traction and grip control were often lost to the likely detriment of measurement accuracy as the head moved from the clear stem but had not yet cross-cut the piece. There appeared to be more of a tendency to re-measure in logs if measurement had become suspect. Volumes of products cut as recorded by the harvester are presented in Appendix 2 as a comparison to the values derived through hand measurement.

[7] Both SS & LP dead woodfuel volumes are based on mean piece volume. As mean dead tree volume was considerably smaller than that of live trees, mean piece size from dead trees will be proportionally smaller. Volumes of dead-tree derived woodfuel are therefore likely to be smaller.

[8] Based on tariff volume

Table 4 Summary of product volumes cut

LP1	Fuel			Total	LP2	Pallet	Chipwood		Total
Count	187				**Count**	40	109		
Mean	0.066				**Mean**	0.086	0.044		
Standard Deviation	0.060				**Std. Deviation**	0.026	0.022		
Minimum	0.002				**Minimum**	0.017	0.014		
Maximum	0.359				**Maximum**	0.133	0.113		
Sum (plot)	12.37			12.37	**Sum (plot)**	3.45	4.81		8.26
(m^3/ha)	392.79			392.79	**(m^3/ha)**	98.74	137.91		236.65
Cut as % of live volume (tariff)				99%	Cut as % of live volume (tariff)				74%
Cut as % of live & dead volume (tariff)				90%	Cut as % of live & dead volume (tariff)				66%
Cut as % of live volume (form height)				77%	Cut as % of live volume (form height)				59%
Cut as % of live & dead volume (form height)				72%	Cut as % of live & dead volume (form height)				53%
SS1	**Log**	**Fuel**		**Total**	**Ss2**	**Log**	**Pallet**	**Chip**	**Total**
Count	50	164			**Count**	27	30	103	
Mean	0.176	0.060			**Mean**	0.203	0.073	0.048	
Standard Deviation	0.090	0.053			**Std. Deviation**	0.091	0.031	0.026	
Minimum	0.093	0.005			**Minimum**	0.104	0.050	0.018	
Maximum	0.488	0.392			**Maximum**	0.471	0.202	0.187	
Sum (plot)	8.79	9.79		18.57	**Sum (plot)**	5.48	2.19	4.95	12.61
(m^3/ha)	340.50	379.38		719.88	**(m^3/ha)**	237.01	94.63	214.37	546.02
Cut as % of live volume (tariff)				131%	Cut as % of live volume (tariff)				86%
Cut as % of live & dead volume (tariff)				104%	Cut as % of live & dead volume (tariff)				81%
Cut as % of live volume (form height)				105%	Cut as % of live volume (form height)				69%
Cut as % of live & dead volume (form height)				89%	Cut as % of live & dead volume (form height)				66%

Based on tariff estimation of stand commercial volume (live stems, O.B. to 7cm), cutting of woodfuel can be seen to increase the volume recovery by 25% in Lodgepole pine and 45% in Sitka spruce.

The greater utilisation is due to the minimal specifications for woodfuel. Plates 6 to 10 show the typically coarse timber cut. Woodfuel can incorporate more volume as defect is not cut out. Plate 8 shows a heavy fork which would normally be cross-cut to separate the forks for individual processing. The piece was instead roughly run-out to and cut at 5 m so including the normally trimmed inclusion growth. Plate 7 shows a triple-forked piece which would probably have been unusable for any conventional product type. Plate 10 shows large diameter butt timber trimmed from below a 3.7 m log which would have to be included in the brash mat in conventional felling.

Bends in the stem often led to the top knife digging in and either cutting through the stem or causing it to snap. Whilst this was not a problem for woodfuel it often caused pieces to be rejected in the conventional treatments so reducing volume utilisation.

HARVESTER STUDY

Harvester outputs are expressed in m3 OB (end product through the harvester) per standard hour (shr) which includes an allowance of 18% for personal needs & rest and 20% for other work (a factor[9] of 1.416 is used)

[9] Technical Development “Other work and rest allowances reference list” KD7

Table 5 Summary of plot harvester productivity

Plot	Treatment	Live / Dead	Output m^3/shr
LP1	Fuelwood	All Trees	12.4
LP2	Conventional	All Trees	7.8
SS1	Fuelwood	All Trees	16.1
SS2	Conventional	All Trees	12.8

An estimate of live and dead trees productivity is presented in Table 6, using mean piece volumes to calculate total volume cut. These figures should be taken as indicative for dead trees as the minimum requirement of 40 study dead trees was not achieved in any plot (the TSI requires that 40 normal trees should be studied) and as noted before, mean piece volume from live and dead trees are likely to differ from the plot mean.

Table 6 Summary of indicative live and dead tree harvester productivity

Plot	Treatment	Live / Dead	Output m^3/shr
LP1	Fuelwood	Live Trees	14.3
LP1	Fuelwood	Dead Trees	2.7
LP2	Conventional	Live Trees	9.0
SS1	Fuelwood	Live Trees	17.9
SS1	Fuelwood	Dead Trees	10.2
SS2	Conventional	Live Trees	12.8

There were equivalent amounts of standing deadwood in LP1 & LP2. Cyclic time consumption associated with felling dead trees in plot LP1 was 7.41 mins (3.92 hours/ha), providing an output of 3.9 m^3/PMH. This compares to 5.79 mins (2.77 hours/ha) of cyclic time consumption in LP2 associated with felling dead trees to waste.

Plot SS2 had less standing deadwood volume than SS1. Cyclic time consumption associated with felling dead trees in plot SS1 was 11.9 mins (7.69 hours/ha), providing an output of 10.2 m^3/PMH. If deadwood volume in SS2 is increased to SS1 levels from 5.36 mins then cyclic time consumption associated with felling dead trees to waste would be *c*.18.5 mins (13.35 hours/ha).

The higher productivity in woodfuel treatments is due to the higher volume recovery achieved with less processing. As noted before for Plates 7 and 8, forks did not need to be singled out and multiple stems were cross-cut together.

The cross-cut that severs the last piece from the tree was also often avoided as the diameter was often run out to around 4 cm and the piece simply snapped off, so saving time.

FORWARDER STUDY

Forwarder outputs are expressed in m^3 OB (end product forwarded) per standard hour (shr) which includes an allowance of 15% for personal needs & rest and 17% for other work (a factor[10] of 1.3455 is used). Forwarder productivity is presented in Table 7. Basic time (BM) is included as it is useful for comparison of loading and travelling elements.

[10] Technical Development "Other work and rest allowances reference list" KD7

The forwarder outputs are only indicative figures as only two full loads were studied for each Sitka spruce plot and only one in each Lodgepole pine crop as opposed to the 10 loads required for a full study. Further details of the forwarder study can be found in Appendix 5. The limited forwarder study was due to time constraints.

Table 7 Summary of plot forwarder productivity

Plot	Treatment	Total Terminal Time per Load (BM)	Terminal Time per m^3 (BM/m^3)	Total Travelling Time per Load (BM)	Total Basic Time per m^3 per 100 m Extracted	Total Standard Time per m^3 per 100 m Extracted	Output per Hour (m^3/shr per 100 m Extracted)	Site Output (m^3/shr)
LP1	Fuelwood	21.80	2.82	4.85	3.60	4.84	12.39	12.92
LP2	Conventional	30.77	3.68	6.03	4.33	5.83	10.29	10.14
SS1	Fuelwood	22.46	2.46	6.83	2.90	3.91	15.36	13.92
SS2	Conventional	18.03	2.79	6.83	3.45	4.65	12.91	11.58

Comparison of basic times for loading and unloading (terminal time) shows that the rate is higher for woodfuel by 30% in Lodgepole pine and 13% in Sitka spruce. Movement time per cubic metre was also found less in woodfuel by 20% in Lodgepole pine and 19% in Sitka spruce. Load volumes were found to be larger when extracting from woodfuel plots as was handling time.

These preliminary figures suggest that forwarder productivity is higher in woodfuel cutting for both species.

MACHINE COSTS AND HARVESTING COSTS

Cost Element	**Harvester**	**Forwarder**
	TJ 1270 C	**Rottne SNV Rapid**
Capital Cost (£)	145000	70000
Residual Value	14500	7000
Life in Hours	5	5
Hours/year	2000	2000
Interest rate	0.05	0.05
Discount Factor	0.7835	07835
Equivalent annual cost	0.2310	0.2310
Capital cost/hour (£/hr)	15.43	7.45
Operating costs (£/hr)		
Repair/maintenance	3.50	1.50
Fuel	7.20	5.40
Operator costs	15.00	15.00
Insurance	3	3
Total Operating costs	28.70	24.90
Total cost (£/hr)	**44.13**	**32.35**

Note: Both the harvester and forwarder were purchased as reconditioned machines and therefore the capital cost reflects the second hand price paid by the contractor.

Outputs and Costs

Harvester outputs ranged from 7.80 m^3/shr ob to 16.1 m^3/shr ob with harvesting costs from £2.74 to £5.66/m^3.

Study Ref	Harvester Output (m^3/shr)	Harvester Cost (£/m^3/shr)	Forwarder Output (m^3/shr) extracted	Forwarder Cost (£/m^3/shr) extracted	**Total Harvesting cost** (£/m^3)
LP1	12.4	3.56	12.92	2.50	6.17
LP2	7.8	5.66	10.14	3.19	8.80
SS1	16.1	2.74	13.92	2.32	4.85
SS2	12.8	3.45	11.58	2.79	5.95

The harvester and forwarder fuelwood outputs (though indicative for the forwarder) are greater than conventional harvesting outputs in both comparisons and this is reflected in lower total harvesting costs for fuelwood harvesting.

CONCLUSIONS

Cutting of woodfuel was found to more effectively utilise the volume held within a stand by *c*. 20% in Lodgepole pine and *c*. 35% in Sitka spruce. This is due to utilising standing deadwood, stem diameters of less than 7 cm and normally unmarketable portions of stem defect. Yield from deadwood is less in Lodgepole pine as it becomes more brittle than Sitka spruce.

Harvester productivity was found to increase when cutting woodfuel by 59% from 7.8 to 12.4 m^3/shr in Lodgepole pine and by 26% from 12.8 to 16.1 m^3/shr in Sitka spruce. Higher productivity is achieved due to woodfuel requiring less processing input to cut and lesser quality standards.

Indicative forwarder productivity study values suggest working is also more efficient in woodfuel working by *c*. 20% in Lodgepole pine, rising from *c*. 10.3 m^3/shr to *c*. 12.4 m^3/shr and *c*. 19% in Sitka spruce rising from *c*. 12.9 m^3/ shr to *c*. 15.4 m^3/shr.

The harvester and forwarder fuelwood outputs are greater than conventional harvesting outputs in both comparisons and this is reflected in lower total harvesting costs for fuelwood harvesting.

Mensuration assessment of the stands found discrepancies in volume estimation suggesting that the structure and tree form within non-thin stands differ from predictions in published management tables. This is thought to be due to stratification within the stand due to its unthinned nature. Stand volume estimations should be supported by field measurements where feasible.

ACKNOWLEDGEMENTS

Thanks go to the machine operators Scott Drennan & Mark Baillie and the staff of Dornoch Forest District who helped in this study.

Martin Price
for Technical Development

Appendix 1 Summary of trial site

SITE DETAILS			
Plot	SS1 & SS2	LP1 & LP2	
Terrain Class.	5.3.1		
Ground Conditions	Very Poor (5)		
Soil type	gley / peaty gley	peaty gley	
Soil moisture	wet		
Rainfall	c. 1000mm per year		
Ground Roughness	Uneven (3)		
Rocks	none		
Stumps	none		
Plough Furrows	0.3 - 0.4m ridge to furrow @1.6m spacing		
Drains	c. 1m deep running SW		
Slope	level (1)		
%	<1%	3%	
Form	even		
Ground Vegetation	none	moss, *D. flexuosa* , ferns	
Brash Cover	none		
Direction of working	with furrow 265º	with furrow 255º	
Weather Conditions	fine		

Appendix 2 Summary of volume cut as recorded by the harvester

Product Number	Product Type	Cut in LP1	Cut in LP2	Cut in SS1	Cut in SS2
1	log			10.5	6.2
2	palletwood		3.9		2.6
3	chip		6.3		5.2
4	woodfuel	12.5		9.2	

Appendix 3 Summary of harvester

MACHINE SPECIFICATION	
Make and Model	Timberjack 1270C
Boom	8.3m parallel (1620kg@8.3m, 2425kg@6.0m, 4000kg@4.0m)
Measuring System	Epic 4W30
Feed Rollers	Tracks (feed to approx 60cm)
Urea System	Fitted but not used
Tracks/Chains	Tracks on front bogey
Any Non STD Mods	Keto 500 head
Other	L: 7.4m, W: 2.95m, H: 3.7m, CL: .65m
Tyres	Trelleborg Foristry 700/55/34 & 700/55/26.5
MACHINE OPERATIONAL DETAILS	
Hours on Clock/Age	c. 9000 base, c. 200 head
Auto Measuring?	yes
Knife Quality	good
OPERATOR	
Name	Scott Drennan
Experience	19 years

Appendix 4 Summary of forwarder

MACHINE SPECIFICATION	
Make and Model	Rottne SNV Rapid
Measuring System	Trip distance
Grab Make	Rottne generic boom, 6.5m reach
Grab Size	0.28 m^2
Tracks/Chains	None fitted
Bunk Capacity	22.6 m^3 or 24.3 m^3 (moveable headboard)
Any Non STD Mods	No
Other	L: 8.51m, W: 2.41m, H: 3.35m, CL:
Tyres	Nokia 500/55/26.5 TRS LS-2
MACHINE OPERATIONAL DETAILS	
Hours on Clock/Age	*c.* 16000
OPERATOR	
Name	Mark Baillie
Experience	1.5 years

Appendix 5 Forwarder output summaries

Lodgepole pine 1: Woodfuel

Average Load Size	7.722		
(No. of Pieces in load)	117		
Average Piece Size,	0.066		
Average No. Grabs to Load	28		
Average No.of Piles			
Average No. of Grabs to Unload	18		
No. of Loads	1		
Terminal Time per Load	**BM**	**Mean Distance**	
Manoeuvre inWood (K)			
Loading per Load (L)	10.15		
Move to Load (J)	0.28	15	
Adjust Load (A8)	1.33		
Manoeuvre on Road (A3)			
Unloading per Load (U)	6.27		
Adjust/Butt Up Stack (A5)	1.99		
Stow/Unstow Grapple/Turn Seat/Adjust Headboard (A6)	0.69		
Move to Unload (A2)	0.10	3	
Manoeuvre on roadside ramp (A7)	0.99		
Total Terminal Time per Load	**21.8**		
Terminal Time per m3	**2.82**		
Travelling Times per Load			
Move in Road (A)	0.58	30	
Move in Ride (B)			
Move in Rack (C)	1.73	61	
Move in Wood (D)			
Move out Ride (E)			
Move out Rack (F)	1.96	46	
Move out Wood (G)			
Move out Road (H)	0.58	35	
Total Travelling Time per Load	**4.85**		
Extraction Distance		**81**	
Travelling Time per Load per 100 m Extracted	5.99		
Travelling Time per m^3 per 100 m Extracted	0.78		
Total Basic Time per m^3 per 100 m Extracted	**3.60**		
Other Work 17 %	1.17		
Rest 15 %	1.15		
Standard Time is Basic Time x OW x R	1.346		
Terminal Time per m^3	3.80		
Travelling Time per m^3 per 100 m Extracted	1.04		
Total Time per m^3 per 100 m Extracted	**4.84**		
Output per Hour (m^3 per 100 m Extracted)	**12.39**		
		Site Output	12.92

Lodgepole pine 2: Conventional

Average Load Size	8.366		
(No. of Pieces in load)	41	110	
Average Piece Size	0.086	0.044	
Average No. Grabs to Load	16		
Average No.of Piles			
Average No. of Grabs to Unload	18	28	
No. of Loads	0.5	0.5	
	PALLET	CHIP	
Terminal Time per Load	**BM**	**Mean Distance**	
Manoeuvre inWood (K)	0.12		
Loading per Load (L)	15.55		
Move to Load (J)	1.82	70	
Adjust Load (A8)	2.65		
Manoeuvre on Road (A3)			
Unloading per Load (U)	7.65		
Adjust/Butt Up Stack (A5)	1.4		
Stow/Unstow Grapple/Turn Seat/Adjust Headboard (A6)	0.68		
Move to Unload (A2)	0.00		
Manoeuvre on roadside ramp (A7)	0.90		
Total Terminal Time per Load	**30.77**		
Terminal Time per m3	**3.68**		
Travelling Times per Load			
Move in Road (A)	0.67	35	
Move in Ride (B)			
Move in Rack (C)	2.48	85	
Move in Wood (D)			
Move out Ride (E)			
Move out Rack (F)	2.15	60	
Move out Wood (G)			
Move out Road (H)	0.73	50	
Total Travelling Time per Load	**6.03**		
Extraction Distance		**110**	
Travelling Time per Load per 100 m Extracted	5.48		
Travelling Time per m^3 per 100 m Extracted	0.66		
Total Basic Time per m^3 per 100 m Extracted	**4.33**		
Other Work 17 %	1.17		
Rest 15 %	1.15		
Standard Time is Basic Time x OW x R	1.346		
Terminal Time per m^3	4.95		
Travelling Time per m^3 per 100 m Extracted	0.88		
Total Time per m^3 per 100 m Extracted	**5.83**		
Output per Hour (m^3 per 100 m Extracted)	**10.29**		
		Site Output	10.14

Sitka spruce 1: Woodfuel

Average Load Size	9.138		
(No. of Pieces in load)	140	51	15
Average Piece Size,	0.06	0.176	0.06
Average No. Grabs to Load	30	26	4
Average No.of Piles			
Average No. of Grabs to Unload	18	17	2
No. of Loads	1	1	
	Fuel	Log	Fuel 2
Terminal Time per Load	**BM**	**Mean Distance**	
Manoeuvre in Wood (K)	0.44		
Loading per Load (L)	10.96		
Move to Load (J)	0.625	25	
Adjust Load (A8)	1.085		
Manoeuvre on Road (A3)	0.00		
Unloading per Load (U)	6.23		
Adjust/Butt Up Stack (A5)	0.985		
Stow/Unstow Grapple/Turn Seat/Adjust Headboard (A6)	0.92		
Move to Unload (A2)	0.00		
Manoeuvre on roadside ramp (A7)	1.21		
Total Terminal Time per Load	**22.455**		
Terminal Time per m3	**2.46**		
Travelling Times per Load			
Move in Road (A)	1.62	47.5	
Move in Ride (B)			
Move in Rack (C)	5.29	125.5	
Move in Wood (D)			
Move out Ride (E)			
Move out Rack (F)	4.87	100	
Move out Wood (G)			
Move out Road (H)	1.87	67.5	
Total Travelling Time per Load	**13.65**		
Extraction Distance		**167.5**	
Travelling Time per Load per 100 m Extracted	8.15		
Travelling Time per m^3 per 100 m Extracted	0.89		
Total Basic Time per m^3 per 100 m Extracted	**3.35**		
Other Work 17 %	1.17		
Rest 15 %	1.15		
Standard Time is Basic Time x OW x R	1.346		
Terminal Time per m^3	3.31		
Travelling Time per m^3 per 100 m Extracted	1.20		
Total Time per m^3 per 100 m Extracted	**4.51**		
Output per Hour (m^3 per 100 m Extracted)	**13.31**		
		Site Output	11.29

Sitka spruce 2: Conventional

Average Load Size	6.4525			
(No. of Pieces in load)	16	106	11	32
Average Piece Size,	0.203	0.048	0.203	0.073
Average No. Grabs to Load	10	25	5	10
Average No.of Piles				
Average No. of Grabs to Unload	6	10	5	7
No. of Loads	1		1	
	Log	chip	log	pallet
Terminal Time per Load	**BM**	**Mean Distance**		
Manoeuvre inWood (K)	0			
Loading per Load (L)	8.955			
Move to Load (J)	0.74	25		
Adjust Load (A8)	0.89			
Manoeuvre on Road (A3)	0.00			
Unloading per Load (U)	5.21			
Adjust/Butt Up Stack (A5)	0.285			
Stow/Unstow Grapple/Turn Seat/Adjust Headboard (A6)	0.6			
Move to Unload (A2)	0.39	15		
Manoeuvre on roadside ramp (A7)	0.96			
Total Terminal Time per Load	**18.025**			
Terminal Time per m^3	**2.79**			
Travelling Times per Load				
Move in Road (A)	0.99	67.5		
Move in Ride (B)				
Move in Rack (C)	2.48	120		
Move in Wood (D)				
Move out Ride (E)				
Move out Rack (F)	2.45	100		
Move out Wood (G)				
Move out Road (H)	0.91	60		
Total Travelling Time per Load	**6.825**			
Extraction Distance		**160**		
Travelling Time per Load per 100 m Extracted	4.27			
Travelling Time per m^3 per 100 m Extracted	0.66			
Total Basic Time per m^3 per 100 m Extracted	**3.45**			
Other Work 17 %	1.17			
Rest 15 %	1.15			
Standard Time is Basic Time x OW x R	1.346			
Terminal Time per m^3	3.76			
Travelling Time per m^3 per 100 m Extracted	0.89			
Total Time per m^3 per 100 m Extracted	**4.65**			
Output per Hour (m^3 per 100 m Extracted)	**12.91**			
		Site Output		11.58

Plate 1 View of plots LP1 & LP2 and adjacent stand. Note common forking of trees (13F)

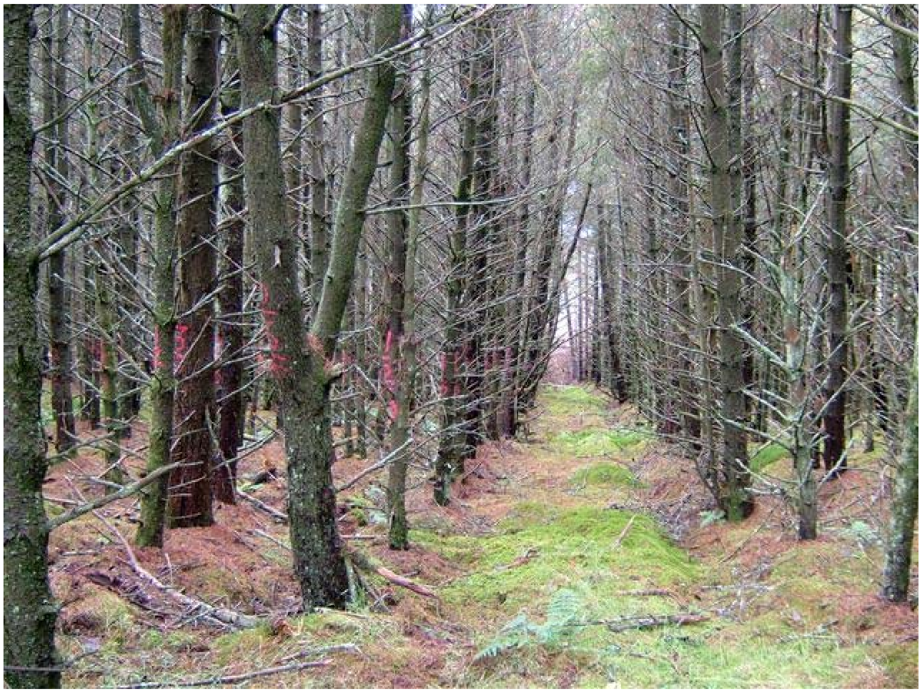


Plate 2 View of plot LP1. Note double stem (17G) and standing deadwood (17D)

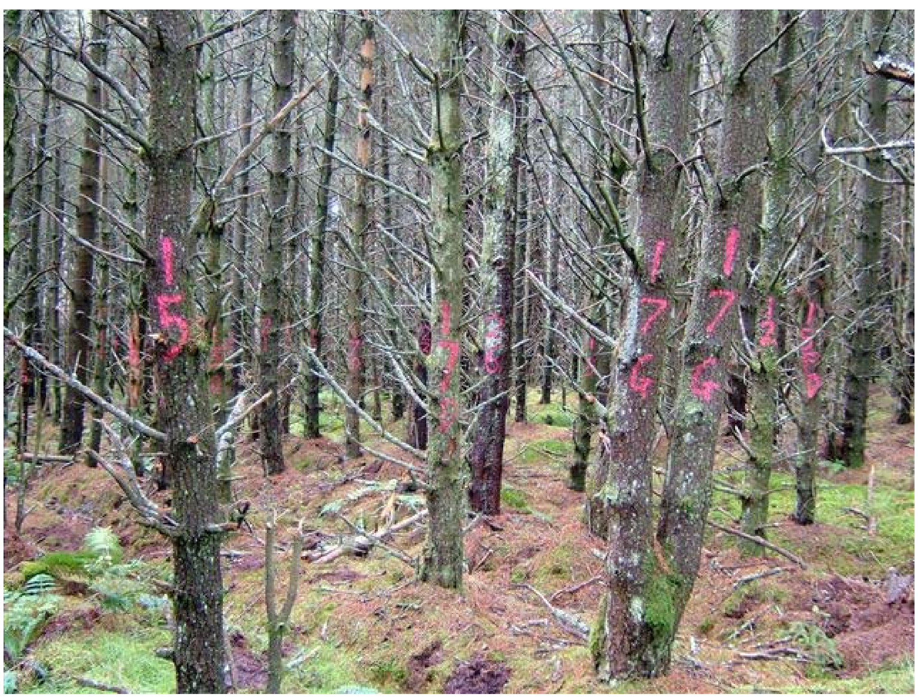


Plate 3 View of plot SS1. Note drains, standing deadwood (11D, 08D) and large double stem (20G)

Plate 4 View of plot SS1. Note standing deadwood (08D, 18D) and coarse dominant (30).

Plate 5 View of drifts in LP1 & LP2. Fuelwood plot is at front and ends at tree with red band at right. Note obvious difference in drift density and product sizes.

Plate 6 View of Lodgepole pine fuelwood length. Note coarse whirl. Spray can for scale

Plate 7 View of Sitka spruce fuelwood drift. Note piece indicated with spray can. Piece has primary and secondary forks and was run out to and cut at 5m. Spray can for scale.

Plate 8 View of Sitka spruce fuelwood drift. Note double stem run out and cut at 5m. Conventional products would require stem join to be trimmed and each stem to be processed separately. Spray can for scale.

Plate 9 View of Lodgepole pine fuelwood drift. Note fork roughly trimmed by top knife. Spray can for scale.

Plate 10 View of Sitka spruce fuelwood drift. Note portion of tree butt rejected for log as indicated by spray can. A 3.7m log was cut from the tree after removing this portion. Spray can for scale.

Plate 11 View of Timberjack 1270C. The large pile of brash by road covers an area of corduroy laid over a layer of tyres in an effort to protect a buried fibre-optic cable. This acted as stand access for this portion of the coupe. Plots LP1 & LP2 start 5m to the vehicles' left. Note also diesel bowser.

Plate 12 View of Rottne RK60. Vehicle is loading from a fuelwood drift. Note the forking on piece in grapple.