Forest Research
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TECHNICAL DEVELOPMENT BRANCH

INTERNAL PROJECT INFORMATION NOTE 19/98

Project: Random Length Smallwood Chipping Recovery Compared to Conventional Shortwood Systems

Number: 1000A/58/97

Location: Newton Stewart Forest District

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Project Leader: I R Murgatroyd

Ref: 1000A/58/97 Title: RANDOM LENGTH SMALLWOOD CHIPPING RECOVERY COMPARED TO CONVENTIONAL SHORTWOOD SYSTEMS

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Summary

End product recovery in mixed LP and SS crops, expressed as a percentage of standing volume was greater (except in one study, from a total of 14 studies) when random length smallwood to 3 cm tdob (designated unconventional) was cut compared with 2 m or 3 m length smallwood to 6 cm tdob (designated conventional).

Total unconventional system working costs were higher due to smaller forwarder smallwood loads being carried compared to conventional extraction (2 bays x 2 m) and the cost of chipping at roadside. Unconventional harvester costs were lower than those for conventional working due to increased output (c 10%). Total revenue from unconventional working was higher due to increased smallwood recovery and a higher estimated revenue for chips at roadside.

Rates of taper for SS and LP sawlog material were significantly greater than the average values used in Booklet 39 (Forest Mensuration Handbook). LP smallwood rates of taper were similar to Booklet 39 values and SS smallwood rates of taper were less than Booklet 39 values. Site specific rates of taper were used with crops of poor form.

Sufficient brash was available to aid forwarder extraction when random length tops were cut. No significant difference was noted between brash mats formed from random length tops or conventional smallwood working. Thatching was required to maintain Key Routes which degraded in the soft deep peat conditions after rainfall. Windblown areas were incorporated in Key Routes. Flotation aids such as double wheels, 700 mm wide tyres and flotation bandtracks were required for forwarder extraction.

Forwarders with standard bunk configurations extracted random length smallwood tops to a landing area for subsequent disk chipper processing.

The disk chipper processed all material extracted and loaded chips into standard rear door opening articulated residue trailers. The chipper had an output of 34.87 m^3 (overbark)/shr and was under utilised on site.

Harvester outputs were greater (except 1 study) when cutting random length tops (unconventional) compared to outputs when cutting traditional smallwood lengths (conventional). The average increase was 10%.

When extracting sawlogs there was little difference in output between the conventional and the unconventional systems over a 300 m average extraction distance. In similar conditions the difference between unconventional chipwood extraction rates and conventional 2 m smallwood extraction rates was more significant. The extraction output of random chipwood lengths was 77% of 2 m smallwood extraction. Terminal times and travelling times were similar, but the 2 m load size was c 47% greater.

Introduction

There are extensive areas of forestry in SW Scotland consisting of SS/LP mixtures, which are due for harvesting (clearfell) over the coming years. These areas have been difficult to market in the past and there is a feeling that some of the lower value chipwood is cut to waste as there is often a nett loss on the product, the contractor maximising on the higher value products. Increasingly these areas are being sold on a weight basis and as such the FE are losing revenue form such a practice. Euroforest have developed a system which harvests the small wood element in random lengths and chips at roadside for sale as "white" wood chips (some bark content, but practically no brash content). It is claimed that the system is more cost effective than conventional harvesting because of higher utilisation, lower harvesting costs and higher recovery.

Technical Development Branch (TDB) was commissioned by Forest Enterprise to compare conventional shortwood working with a modified system (unconventional) where some or all small roundwood (depending on crop quality and ground conditions) is extracted to a disc chipper.

The following crops and conditions were to be studied where possible:

- Intimate mix SS/LP softer ground.
- Intimate mix SS/LP windblown.
- Pure LP.

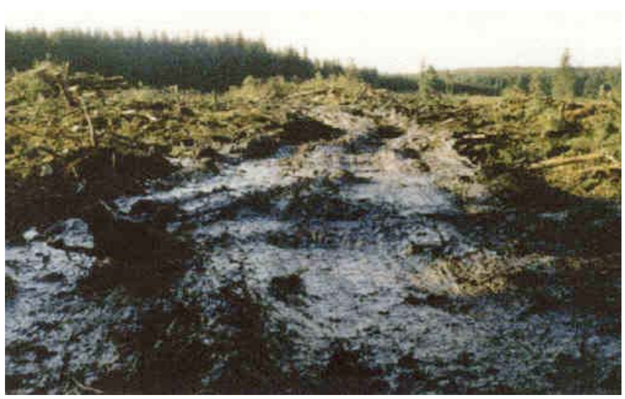
The study was designed to quantify:

- Systems outputs and costs (harvesters, forwarders, chippers).
- Product recovery from the 2 systems - per unit area and as a % of the standing crop.
- Brash mat weight per running metre.
- Assessment of environmental impact.
- Safety considerations.

In 1997 a system initially used a feller clambunk skidder (8 wheeled Hemek with bandtracks) to fell and extract whole trees to a flail delimber supported by a front end loader to clear brash. Delimbed whole poles were then chipped by a Morbark disc chipper. A conventional harvester and forwarder system (6 wheeled forwarders with double tyres and super flotation bandtracks) was used to recover sawlog material in appropriate crop conditions. The lack of brash during whole tree extraction resulted in machine boggings and extensive site disturbance with pronounced machine ruts (Plate 1). The Forestry Authority Whole Tree Harvesting, 'A Guide to Good Practice' recommends that operations should be suspended or reorganised if ruts deeper than 10 cm and longer than 5 m occur. The system was modified during working and the 1998 system is a direct descendant of this earlier trial.

Plate 1

Whole Tree Harvesting Ground Damage



The present unconventional system uses a single grip harvester to fell and delimb trees. Sawlog material is presented in the conventional manner and random length smallwood cut for chipping. Small trees with no sawlog material may be converted into 2 lengths, so that random tops are in the 3 m to 7 m length range. Generally one smallwood length per stem is cut from trees with sawlog material. There is no restriction on top diameter and coarse branch sprags are acceptable. A brash mat is formed for harvester and forwarder travel. In soft or problem areas the harvester operator can increase the strength of the brash mat, by placing more stem wood in the brash mat. This flexible approach ensures that recovery is maximised. A forwarder with a standard bunk is used to extract all material. Key Routes need to be thatched early using brash from extracted areas and at regular intervals until they stabilise. If smallwood cannot be stockpiled or if the chipper is delayed, less brash is available from incompletely extracted areas for Key Route maintenance.

A timber zone with 3.7 m sawlog material, random pallet lengths (to 12 cm tdob) and random length smallwood tops stacked for extraction is shown in Plate 2. The brash mat from this timber zone is on the right of the picture.

Contractor and Forest Enterprise support and co-operation with TDB was excellent and enabled the trial to proceed to TDB's data collection requirements.

Plate 2

Timber Zone with Random Length Smallwood Tops and Pallet Wood

Working Areas

Studies to compare conventional and unconventional working methods were made in compartments 600(a) and 601(a) of Newton Stewart Forest District.

Three working areas were used.

Area A — Terrain Classification 3:2:1.
Peaty gley.
The crop was planted in alternating 3 row bands of SS & LP.
A 5 m unploughed and unplanted strip crossed the drifts at right angles.
Recovery was expected to be high as little brash would be required for machine flotation on the firm ground.

Area B — Terrain Classification 5:2:1.
Deep peat.
The crop was an intimate in row mixture of alternating 3 tree groups of LP & SS.
The average tree size of the LP was greater than the SS although the LP had more broken tops and windblow.

Area C — Terrain Classification 5:2:1.
Deep peat.
The crop was an intimate mixture of a alternating 3 tree groups of LP and SS.
Areas with poor crop form and windblow were separated from better areas and comparison studies made in each type. An area in pronounced check was also studied.

Machines Used

Areas A and B

Two similar harvesters with Keto 150 heads mounted on JCB 814 Super tracked excavators with 700 mm wide tracks were studied. A Kockums 84-35 six wheeled forwarder equipped with double 23.1 by 26 tyres (wheel chains on inner wheels) and Clark's Super Apex Lite (900 mm wide) bandtracks on the bunk bogies was used for extraction. Study data for the Kockums is not used in this Report because the drift lengths were short.

Area C

The harvester studied was a Logset 555 mounted on a JCB 814 Super tracked excavator with 700 mm wide tracks (Plate 3). The forwarder was a Logset Challenger 8 wheeled machine fitted with 700 mm wide tyres. The tracks on the rear bunk bogies were old design Clark flotation tracks (F Series). The forwarder was fitted with a long reach Log Lift 71 FT hydraulic loader. The forwarder is seen off loading random smallwood lengths at the chipper stacking area in Plate 4.

Operators were asked by the harvesting machinery owner to work as normal with regard to the conditions. TDB over rode these instructions on one occasion and asked for 2.0 m long smallwood to be cut to a diameter closer to the minimum specification in good soil conditions in area A.

Plate 3

JCB 814S and Logset 555 Tracked Harvester

Plate 4

Logset Challenger Forwarder at Chipper Stacking Area

Chipper

The chipper used was a Morbark Model 23 Chiparvestor which is powered by a turbo charged Cumins diesel engine with a quoted output of 550 hp. The knives were set to cut chips between 19 mm and 38 mm. The infeed speed was set at a high rate and the machine equipped with a relatively new Foresteri 701 hydraulic loader.

The disk chipper guard has been lifted with a hydraulic ram to show one of the cutting knives in Plate 5.

Plate 5
Disc Chipper Knife

Measurement Techniques

Standing Volume

Twenty volume sample trees were felled to compare the Tariff number obtained from volume by mid girth related to dbh, to the Tariff number obtained from top height measurements. The mean Sitka spruce Tariff number obtained from volume sample trees was equal to the mean Tariff number obtained from top heights.

The mean Lodgepole pine Tariff number obtained from top height measurements was 12% greater than the mean Tariff number obtained from volume sample trees.

All trees were measured at diameter breast height before felling and top height samples taken to calculate standing volume for each species to 7 cm top diameter overbark. Lodgepole pine tariff numbers were reduced by 12%.

The standing volume of dead trees was recorded when dead trees were processed into end product. Few or no dead trees were processed into end product with conventional shortwood working.

End Product Volume

Standard rates of taper were used in area A (crop of good form) growing on a peaty gley. Forestry Commission Booklet No 39 uses a 1:120 rate of taper for sawlogs and 1:84 rate of taper for smallwood.

Individual rates of taper were calculated for the other areas for each species and product type. The rates of taper used in end product volume calculations are shown in Table 1.

Table 1

Rates of Taper

	3.7 m Sawlog	3.1 m Sawlog	2.5 m Pallet	Random Pallet	Random Chipwood	3 m Smallwood	2 m Smallwood
Sitka Spruce	1:72	1:72	1:90	1:90	1:98	1:98	1:98
Lodgepole Pine	1:51			1:72	1:80	1:80	1:80

Increasing the rate of taper increases piece size. There was a high proportion of butt sawlogs with increased rates of taper compared to Booklet 39 average values. Lodgepole pine smallwood had a rate of taper similar to Booklet 39 and Sitka spruce smallwood had a decreased rate of taper.

An intensive sample of converted produce was measured to calculate average piece size from average top diameter and average length. Measurements for SS and LP were recorded and calculated for each species.

Cutting Specifications

Details of products cut are given in Table 2.

Table 2

Cutting Specifications

Area	Conventional & Unconventional			Conventional	Unconventional
	Sawlog	Fixed Pallet	Random Pallet	Chipwood	Random Tops
A	4.3 m x 16 cm★	2.5 m x 14 cm	Random to 12 cm	2 m x 6 cm	Random to run out
B	3.7 m x 16 cm	None	Random to 12 cm	2 m x 6 cm	Random to run out
C	SS 3.1 m x 16 cm LP 3.7 m x 16 cm	None	Random to 12 cm	3 m x 6 cm	Random to run out

★Top diameter all measured over bark.

Comparison Results

In each of the working areas paired drifts of unconventional and conventional working were compared for recovery. Paired drifts were chosen to give the closest match of tree size, characteristics and terrain type. There was some variance of mean tree sizes within paired drifts.

Detailed data on crop form can be found in each comparison section.

Area A

Unconventional System (Good crop and ground conditions)

The recovery results are shown in Table 3 for the unconventional shortwood system.

Table 3

Unconventional Recovery

Species	4.3 S\L ($m^{3)}$	2.5 m Pallet (m^3)	Random Pallet (m^3)	Random Chipwood (m^3)	Total End Product (m^3)	Number Trees	Average Tree Size (m^3)	Standing Volume (m^3)
LP	0	0.13	1.08	7.61	8.82	80	0.080	6.40
SS	5.19	4.62	3.80	6.88	20.49	84	0.202	16.97
TOTAL	5.19	4.75	4.88	14.49	**29.31**	164	0.143	**23.37**

Tree characteristics for trees processed into end product are shown in Table 4.

Table 4

Tree Characteristics in Unconventional Drift

Species	Alive & good form for crop type (%)	Dead (%)	Broken Top (%)	Forked, Blown, Coarse (%)
LP	37.5	37.5	12.5	12.5
SS	65.0	17.0		18.0

Only 5 dead trees were not processed in the LP crop (disintegrated), with 37.5% of LP processed stems being dead. Only 4 dead trees were not processed in the SS crop with 17% of processed stems being dead. Dead trees were measured at dbh before felling.

Conventional System (Ground conditions were good and minimal brash required for machine flotation)

The recovery rates for the conventional shortwood system are given in Table 5.

Table 5

Conventional Recovery

Species	4.3 S\L (m³)	2.5 m Pallet (m³)	Random Pallet (m³)	2.0 m Chipwood (m³)	Total End Product (m³)	Number Trees	Average Tree Size (m³)	Standing Volume (m³)
LP	0	0	0.81	3.44	4.25	47	0.096	4.51
SS	8.23	2.88	5.54	6.29	22.94	90	0.267	24.03
TOTAL	8.23	2.88	6.35	9.73	**27.19**	137	0.208	**28.54**

Tree characteristics for trees processed into end product are shown in Table 6.

Table 6

Tree Characteristics In Conventional Drift

Species	Alive & good form for crop type (%)	Dead (%)	Forked, Broken tops, coarse, dead (%)
LP	81	9	10
SS	90		10

Less dead trees were processed in this system compared to the unconventional drift. Fourteen LP stems being placed in the brash mat and 9% of stems processed were dead. No dead stems should be processed for markets such as pulpwood. Fifteen dead SS stems were not processed and placed in the brash mat.

Discussion

In area A end product recovery, as a percentage of standing volume, was 95% in conventional working compared to 125% in unconventional (Table 7). Most of this increase would come from the extra volume obtained by cutting smallwood to a lower diameter, 56% of SS and 47% of LP random lengths had a top diameter less than 6 cm. The number of Lodgepole pine stems in the unconventional system is greater than in the conventional system, because dead stems are utilised in unconventional working.

Table 7

Comparison of Conventional and Unconventional Systems

Method	Harvested trees/ha			Mean Tree	Volume (m³/ha)		End Product % Standing
	LP	SS	Total	(m³ Standing)	Standing	End Product	
Conventional	684	1310	1994	0.208	416	396	95
Unconventional	1165	1223	2388	0.143	340	427	125

Area B (Plate 6)

Unconventional System (Poor crop and deep peat conditions)

Plate 6

Crop in Area B

The recovery results are shown in Table 8, all volumes are in m^3 ob.

Table 8

Unconventional Recovery

Species	3.7 m S\L (m^3)	Random Pallet (m^3)	Random Chipwood (m^3)	Total End Product (m^3)	Number Trees	Average Tree Size (m^3)	Standing Volume (m^3)
LP	7.00	4.83	5.61	17.44	89	0.200	17.80
SS	1.86	1.34	2.96	6.16	57	0.089	5.07
TOTAL	8.86	6.17	8.57	**23.60**	146	0.157	**22.87**

Tree characteristics for trees processed into end product are shown in Table 9.

Table 9

Tree Characteristics

Species	Alive and good form for crop (%)	Dead (%)	Broken Top (%)	Windblown (%)	Forked & Coarse (%)
LP	42	8	24	20	6
SS	79	0	7	12	2

Approximately 21 LP broken tops and 13 dead trees were not processed into product and were placed in the brash mat.

Approximately 4 SS broken tops and 25 dead trees were not processed into product and were placed in the brash mat.

The majority of dead and broken tops were placed in the brash mat to aid machine flotation in the deep peat conditions.

Conventional System

The recovery rates are shown in Table 10 all volumes are in m^3 ob.

Table 10

Conventional Recovery

Species	3.7 m S\L (m^3)	Random Pallet (m^3)	2.0 m Chipwood (m^3)	Total End Product (m^3)	Number Trees	Average Tree Size (m^3)	Standing Volume (m^3)
LP	6.24	7.81	2.93	16.98	76	0.240	18.24
SS	1.16	1.47	1.00	3.63	29	0.122	3.54
TOTAL	7.40	9.28	3.93	**20.61**	105	0.207	**21.78**

Tree characteristics for trees processed into end product are shown in Table 11.

Table 11

Tree Characteristics

Species	Alive and good form for crop (%)	Dead (%)	Broken Top (%)	Windblown (%)	Forked & Coarse (%)
LP	42	0	24	18	16
SS	72	0	17	7	4

Approximately 14 dead LP stems and 18 LP tops were placed in the brash mat with circa 12 dead SS stems and 5 SS tops being placed in the brash mat.

In this comparison, conventional working end product volume was 95% of standing volume compared to 103% in unconventional working. A detailed comparison is given in Table 12.

Table 12

Comparison of Methods

Method	Harvested trees/ha			Mean tree	Volume m³/ha		End Product % Standing
	LP	SS	Total	(m³ standing)	Standing	End Product	
Conventional	1003	383	1386	0.207	287	272	95
Unconventional	1143	732	1875	0.157	294	303	103

Area C (Plate 7)

Conventional System (Reasonable varying crop form and variable size on deep peat)

Plate 7
Crop in Area C

Table 13

Conventional Recovery

Species	3.7 m SL	3.1 m SL	Random Pallet	3 m Chipwood	Total End Product	Number Trees	Average Tree Size	Standing Volume
LP	2.91		2.22	1.47	6.60	32	0.236	7.55
SS		1.06	1.10	1.19	3.35	25	0.139	3.48
	2.91	1.06	3.32	2.66	**9.95**	5.7	0.193	11.03

Unconventional System (Reasonable Crop Form)

Table 14

Unconventional Recovery

Species	3.7 m SL	3.1 m SL	Rando m Pallet	Random Chipwood	Total End Product	Number Trees	Average Tree Size	Standing Volume
LP	1.89		3.19	1.75	6.83	28	0.235	6.58
SS		2.90	1.43	1.93	6.26	35	0.170	5.95
TOTAL	1.89	2.90	4.62	3.68	**13.09**	63	0.199	12.53

A comparison of methods is given in Table 15.

Table 15

Comparison of Methods

Method	Harvested trees/ha			Mean tree	Volume m³/ha		End Product % Standing
	LP	SS	Total	(m³ standing)	Standing	End Product	
Conventional	1022	799	1821	0.193	352	318	90
Unconventional	648	810	1458	0.199	290	303	104

Conventional Recovery (Poor Crop form)

Table 16

Recovery Rates

Species	3.7 m SL	3.1 m SL	Random Pallet	3 m Chipwood	Total End Product	Number Trees	Average Tree Size	Standing Volume
LP	2.75		2.32	3.40	8.47	58	0.236	13.69
SS		2.26	1.47	2.24	5.97	41	0.177	7.26
TOTAL	2.75	2.26	3.79	5.6	14.44	99	0.212	20.95

Unconventional Recovery (Poor crop form)

Table 17

Recovery Rates

Species	3.7 m SL	3.1 m SL	Random Pallet	Random Chipwood	Total End Product	Number Trees	Average Tree Size	Standing Volume
LP	3.18		4.62	4.27	12.07	58	0.280	16.24
SS		1.66	1.96	1.86	5.48	50	0.133	6.65
TOTAL	3.18	1.66	6.58	6.13	17.55	108	0.212	22.89

A comparison of methods is given in Table 18.

Table 18

Comparison of Methods

Method	Harvested trees/ha			Mean tree	Volume m³/ha		End Product % Standing
	LP	SS	Total	(m³ standing)	Standing	End Product	
Conventional	946	669	1615	0.212	342	236	69

Unconventional	847	730	1577	0.212	334	256	77

Unconventional (Reasonable crop and deep peat)

Table 19

Recovery Rates

Species	3.7 m SL	3.1 m SL	Random Pallet	Random Chipwood	Total End Product	Number Trees	Average Tree Size	Standing Volume
LP	2.33		3.53	2.48	8.34	37	0.233	8.62
SS		0.18	0.52	1.39	2.09	26	0.075	1.95
TOTAL	2.33	0.18	4.05	3.87	10.43	63	0.168	10.57

Conventional (Reasonable crop)

Table 20

Recovery

Species	3.7 m SL	3.1 m SL	Random Pallet	Random Chipwood	Total End Product	Number Trees	Average Tree Size	Standing Volume
LP	3.03		3.34	2.22	8.59	34	0.239	8.13
SS		0.26	0.32	0.69	1.27	14	0.109	1.53
TOTAL					9.86			9.66

A comparison of results is given in Table 21.

Table 21

Comparison of Methods

Method	Harvested trees/ha			Mean tree	Volume (m³/ha)		End Product % Standing
	LP	SS	Total	(m³ standing)	Standing	End Product	
Conventional	1063	438	1501	0.201	302	308	102
Unconventional	1317	925	2242	0.168	376	371	99

This is the only example where the conventional end product volume exceeds the unconventional end product volume when compared to standing volume.

Unconventional (Checked Crop)

Table 22

Recovery Rates

Species	3.7 m SL	3.1 m SL	Random Pallet	Random Chipwood	Total End Product	Number Trees	Average Tree Size	Standing Volume
LP	0.38		2.24	1.94	4.56	38	0.120	4.56
SS		2.40	3.73	2.52	8.65	68	0.140	9.52
TOTAL	0.38	2.40	5.97	4.46	13.21	106	0.133	14.08

Conventional (Checked Crop)

Table 23

Recovery Rates

Species	3.7 m SL	3.1 m SL	Random Pallet	3 m Chipwood	Total End Product	Number Trees	Average Tree Size	Standing Volume
LP	0.57		1.41	2.21	4.19	39	0.118	4.60
SS		1.96	1.92	3.43	7.31	60	0.155	9.30
TOTAL	0.57	1.96	3.33	5.64	11.50	99	0.140	13.90

A comparison of methods is shown in Table 24

Table 24

Comparison of Methods

Method	Harvested trees/ha			Mean tree	Volume m³/ha		End Product % Standing
	LP	SS	Total	(m³ standing)	Standing	End Product	
Conventional	961	1478	2439	0.140	342	283	83
Unconventional	821	1469	2290	0.133	304	285	94

Recovery Rates Summary

The recovery rate for each system expressed in end product volume as a percentage of standing volume is shown in
Table 25. Except for one case, unconventional recovery rates exceeded conventional recovery rates.

Table 25

End Product Recovery as a Percentage of Standing Volume

Area	Crop & Ground Conditions	Recovery (%)	
		Conventional	Unconventional
A	Good crop & soil	95	125
B	Poor crop & deep peat	95	103
C (I)	Reasonable crop and deep peat	90	104
(ii)	Poor crop & deep peat	69	77
(iii)	Reasonable crop & deep peat	102	99
(iv)	Checked crop & deep peat	83	94

The mean recovery rate for the unconventional system was 101% and the mean recovery rate for the conventional system 90%, based on recovery rates weighted by study size. The unconventional system gave a 12% increase in recovery expressed as a % of conventional recovery over the crop types and product types studied. This equates to an extra 12 m^3 ob/ha with a mean conventional smallwood recovery of 100 m^3 ob/ha based on study data.

End product recovery in mixed LP & SS crops, expressed as a percentage of standing volume was greater (except one study) with random length smallwood tops (to 3 cm tdob) than with 2 m or 3 m smallwood specifications (to 6 cm tdob). Dead material unconventionally processed into random length chipwood was significant in study area A and less significant in other wetter study areas

Roadside Chipping

Random length smallwood tops stockpiled at the Morbark Chiparvestor stacking area were chipped directly into articulated bulk residue trailers.

The Morbark Chiparvestor, a self powered disc chipper unit was mounted on a road legal articulated trailer. The trailer can be unhitched and left at a suitable stacking area that has adequate space for:

- forwarders to stockpile smallwood and
- lorries to turn and reverse trailers for rear end chip loading.

The stacking area should be stable relatively flat, free drained, adequately surfaced and able to support the weight of the Chiparvestor and loaded lorries. Lorry tractor units with single drive axles and less aggressive grip tyres (used for sawmill residue transport) can have difficulties reversing empty trailers on muddy, sloping stacking areas.

Morbark manufacture a range of chippers and some machines can be equipped with integral flail delimbers. The Morbark Model 23 Total Chiparvestor used at Newton Stewart is an older second hand model. The unit has a 550 hp Cummins 6 cylinder diesel engine which drives a disc chipper through a belt drive system with 8 belts. The chipper is able to produce chips between 19 mm and 38 mm square. The target chip size at Newton Stewart was 25 mm square. The unit has a debris separator designed to remove a high percentage of dirt, twigs, bark and foliage.

The current Model 23 has a maximum quoted chipping diameter of 58 cm and weight of 26.3 tonnes.

The Chiparvestor was equipped with a weather proof cab which allowed 1 operator to control, product infeed with a hydraulic loader and chip outfeed, via a hydraulically adjusted chute, into the lorry trailer.

Environmental Impact Assessment

The combination of whole tree harvesting and conventional shortwood working used at Newton Stewart in 1997 on soft conditions caused significant site disturbance in some areas (Plate 1). No erosion was noted (relatively flat site) by TDB during a brief site visit, but water ponding in deep machine ruts was seen. The level of site disturbance seen in the 1997 working could lead to erosion and watercourse pollution on sloping sites and would not meet the criteria of the Forestry Authority, Whole Tree Harvesting, 'A Guide to Good Practice'.

The system studied at Newton Stewart in 1998 enabled the harvester to create a brash mat to match the changing conditions. Brash was also available for Key Route maintenance by the forwarder.

Harvester operators were instructed to maximise smallwood recovery in good soil and crop conditions. In areas of windblow, checked crop and soft ground, the operators had the option of placing more stem wood in the brash mat to aid machine flotation. Two extremes were noted during the trial. In studies, area A soil conditions were firm and recovery was maximised with little stemwood in the brash mat. In an extensive windblown pure Lodgepole pine crop (not studied) for a distance of 20 m almost only sawlog material was recovered. The combination of windblown stumps, exposed saturated peat (after heavy rain) and paucity of timber gave rise to difficult working conditions. Despite reduced recovery, this area still had to be extensively thatched by forwarders to maintain the Key Route.

In side by side extraction comparisons there was no significant difference in brash mat qualities between unconventional and conventional working. The longest brash mats running over checked and windblown conditions (155 m) did not require thatching in the conventional or unconventional systems.

Machine ruts were within Forestry Authority Guidelines. The total % of exposed peat for the unconventional brash mat was 5% and for the conventional brash mat 8%. An unconventional brash mat after extraction is shown in Plate 8 and Plate 9 shows a conventional brash mat after extraction. In area B the unconventional brash mat can be seen in Plate 10 and the conventional brash mat in Plate 11.

Plate 8

Unconventional Brash Mat after Extraction

Plate 9

Conventional Brash Mat after Extraction

Plate 10

Unconventional Brash Mat

Plate 11

Conventional Brash Mat

Measurements of compacted brash depth and exposed stumps/peat after extraction did not reveal any significant differences in brash mat characteristics.

It was decided that brash mats would not be weighed, because no significant differences could be seen.

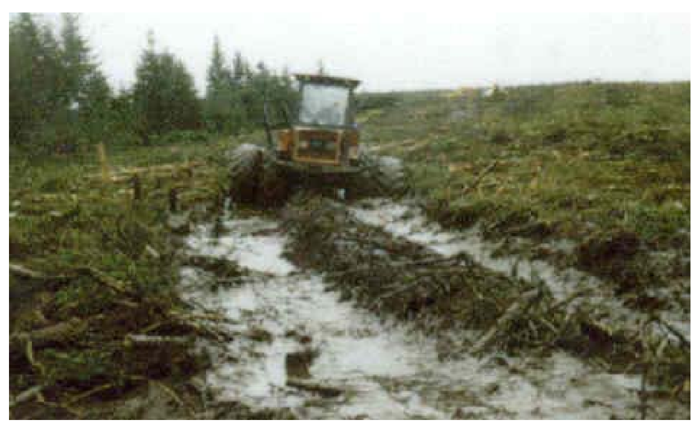
Some trial area brash mats were linked up to Key Routes which had been maintained by thatching. The degree of Key Route brash mat thatching that was carried out by a Kockums 84-35 forwarder during Logset Challenger forwarder studies was significant (Plate 12). Following heavy rainfall on an area with extensive windblow and soft conditions the Key Route (380 m long) in the Logset Challenger studies began to deteriorate (Plate 13).

Plate 12

Kockums 84-35 Key Route Maintenance

Plate 13

Key Route Deterioration



The Key Route brash mat had been built up on soft spots and was being pushed into the upper peat layers in some areas, exposing peat at the brash mat edge. In areas the mat was deflected down under the forwarder and rose after the forwarder passed. In localised areas (not extensive) the mat was broken and peat was exposed. These exposed areas were covered with brash, to prevent bogging. The action of mat deflecting under load, peat being exposed and precipitation gathering on the mat resulted in a potential pollutant "mud" accumulating on the Key Route. In this case the "mud" was not able to enter water courses. There could be a risk of water pollution on other sites and the following actions would be required:

- Suspend operations in affected area, until conditions improve.
- Significantly upgrade Key Route with brash.
- Divert pollutant into safe areas[1].

The possibility or significance of peat being compacted under these conditions is not understood. Amelioration during ground preparation will be essential.

This type of Key Route degradation can occur on conventional shortwood sites. Supervisors should assess ground disturbance during extraction and take appropriate action.

Outputs

Details of outputs for harvesting, extraction and chipping operations are given in Table 26. Standard outputs include the following allowances:

	Rest %	Other Work %
Harvester	18	20
Forwarder & Chipper	15	17

Table 26

Machine Outputs

Area	Method	Operation	Machine	Product	Output (m^3/shr)
A	Conventional	Harvest	JCB 814+Keto 150	Logs+2.0 m chipwood	9.8
	Unconventional	Harvest	JCB 814+Keto 150	Logs+random chipwood	12.0
B	Conventional	Harvest	JCB 814+Keto 150	Logs+2.0 m chipwood	10.48
	Unconventional	Harvest	JCB 814+Keto 150	Logs+random chipwood	9.83
C	Conventional	Harvest	JCB 814+Logset 555	Logs+3.0 m chipwood	10.94
	Unconventional	Harvest	JCB 814+Logset 555	Logs+random chipwood	12.53
A&B	Conventional	Extract	Logset Challenger	2 m chipwood	12.62
A B&C	Conventional	Extract	Logset Challenger	Random pallet	18.48
	Unconventional	Extract	Logset Challenger	Random pallet	19.07
A&B&C	Unconventional	Extract	Logset Challenger	Random chipwood	9.73
A&B&C	Conventional	Extract	Logset Challenger	sawlogs	15.47
	Unconventional	Extract	Logset Challenger	sawlogs	16.17
A&B&C	Unconventional	Chip	Morbark Chipper	Delimbed tops	34.87

1 Forestry Commission (1993). Technical Development Branch, Report 7/93, Oil and Chemical Spillages. Forestry Commission (1995). Technical Development Branch, Technical Note 20/95, Application of Bunded Tank Systems in Forestry.

An average extraction distance of 300 m has been used for forwarder extraction. Forwarder outputs have been reduced by 11% (estimate) to allow for Key Route maintenance.

The disk chipper processed all material extracted for chipping and loaded standard rear door opening residue articulated trailers. The chipper had an output of 34.87 m^3/ob per s/hr and was under utilised on site.

Harvester outputs were greater (except 1 study) when cutting random length tops compared to outputs when cutting traditional smallwood lengths. The average increase in output with the unconventional system was 10%.

When extracting sawlog material forwarder outputs were similar for the unconventional and conventional systems, over a 300 m average extraction distance. In similar conditions the difference between unconventional chipwood extraction rates and conventional 2 m smallwood (2 bays) extraction rates was more significant. The extraction output of random smallwood lengths was 77% of 2 m smallwood extraction. Terminal times/m^3 and travelling times/load were similar, but the 2 m load size was c 47% greater.

Costs

Data for machine costing is shown in Table 27. The following machine and management costs are excluded:

- Machine transportation on site.
- Operator accommodation.
- Profit margin on machine use.
- Machine/site contract supervisor cost.
- Road/chipping area upgrading.
- Buyer management costs.

Table 27

Machine Costing Data

Formulae Explanation	★JS 200 LC Tracked Excavator	Logset 555 Harvester Head	Logset Challenger Forwarder	Morbark Model 23 Chipper
C is Capital Cost	70000	45000	155000	128000
RV is Residual Value	7000	4500	15500	15000
PH is Productive hours/year	1780	1780	1780	1400
L is Life in hours	10680	5340	10680	8400
n is Life in years	6	3	6	6
r is Interest Rate r= R/100	0.6	0.6	0.6	0.6
Dn is Discount Factor Dn=1/(1+r)n	0.7050	0.8396	0.7050	0.7050
An is Equivalent Annual Cost An= r/1-Dn	0.2034	0.3741	0.2034	0.2034
Capital Cost (£/hr)= [C-(RV x Dn)]An / PH	7.43	8.66	16.46	17.06
Labour cost (£/hr/man)	10.00	See JS 200	10.00	10.00
Fuel & Oil Costs (£/hr)	3.00	See JS 200	1.50	5.50
Repair & Maintenance Costs (£/hr)	13.00	See JS 200	10.00	10.00
Total Running	**33.43**	**8.66**	**37.96**	**42.56**

★ JCB 814 S is no longer available and cost is based on a JS200 LC

Costs are shown for new machines with high attainable utilisation rates based on current MES data.

The hourly cost of the Morbark chipper unit will be affected by the productive hours in use. At the Newton Stewart site, the target number of lorry loads per day was eight, which equates to 192 m^3 ob. This would require 5.5 Standard hours operation of the chipper per day and c 1 200 hours per year. The capital cost of the chipper when used for a 1 000 hours per year is £23.88. If the operator has no alternative work labour costs could rise to c £17/effective hour resulting in a total hourly rate of £56.38/hour. Chipping costs will be influenced by machine utilisation which is affected by harvester and more critically by forwarder output and lorry availability. The Morbark Chipper was under utilised at Newton Stewart.

Unit working costs (Table 28) are based on output data from Table 26 and machine costing data from Table 27. All costs relate to EP over bark volumes worked in each system and assume 270 m^3/ha for conventional working and 306 m^3/ha for unconventional working.

Table 28

System Unit Working Costs End Product Volume

Operation	Total Hourly Cost (£/hr)	Unconventional Output (m^3/shr)	Conventional Output (m^3/shr)	Unconventional Unit cost (£/m^3)	Conventional Unit Cost (£/m^3)
Motor Manual Pre-Brash **(estimated)**	7.50	10.0	8.80	0.75	0.85
Harvest JCB/Logset 555 Harvester	42.09	12.53	10.94	3.36	3.85
Extract Logset Challenger Forwarder	37.96	14.17	15.02	2.68	2.53
Chip Morbark Model 23 Chiparvestor	42.56	34.87	N/A	(1.22)★ 0.51	N/A
TOTAL SYSTEM WORKING COST TO ROADSIDE				**7.3**	**7.23**

★ £1.22/m^3 is cost of the actual chipping of 127 m^3. The system cost of £0.51 relates to the total 306 m^3 extracted.

Studies in area C have been used for conventional and unconventional harvester outputs.

Forwarder outputs have been weighted proportionally by the volume of each product cut by the harvester for forwarder extraction for an average extraction distance of 300 m.

Revenue and Surpluses

An indication of the surplus which could be obtained from conventional and unconventional working methods is shown in Table 29.

The product assortment percentage is based on the mean end product ob volumes from studies in Area C.

Revenue costs were supplied by Newton Stewart FD.

Working costs which will affect indicated surpluses but are excluded are shown in notes on Table 27.

Table 29

Product Revenues, Working Costs & Surpluses

	Conventional			Unconventional		
Standing Volume (m^3/ha)	300			300		
Recovery (%)	90			102		
End Product (m^3/ha)	270			306		
Income	m^3/ha	£/m^3	£/ha	m^3/ha	£/m^3	£/ha
3.1 m SL	35.1	22.52	790	35.1	22.52	790
3.7 m SL	37.8	27.27	1031	37.8	27.27	1031
Random Pallet	105.3	20.81	2191	105.3	20.81	2191
Smallwood	91.8	13.62	1250	-	-	-
Random Chipwood	-	-	-	127.8	24.41	3120
Total Income	270	19.49	5262	306	23.31	7132
Costs (E P)						
Brash	270	0.85	230	306	0.75	230
Harvest	270	3.85	1040	306	3.36	1028
Extract	270	2.53	683	306	2.68	820
Chip	-			127.8	1.22	156
Total System Cost★	270	7.23	1953	306	7.30	2234
Surplus	270	12.26	3309	306	16.01	4898

★ The system costs relate to the total system volumes of 270 m^3 and 306 m^3 respectively.

Working costs (excluding chipping) per unit of end product roundwood extracted to roadside are c 6.5% higher for conventional working (£7.23/m^3) compared to unconventional working (£6.79/m^3). Working cost per ha was 6% lower in conventional working (£1 953) compared to unconventional (£2 078) as c 12% less volume was produced.

When the chipping cost and value of chips are included the surplus from unconventional working is estimated as £4 898/ha compared to £3 309/ha for conventional working an increase of 48%.

The overall surplus is £12.26/m^3 for conventional compared to £16.01/m^3 for unconventional working, an increase of 30.5% but on a larger end product volume/ha (13.3%).

Conclusions

End product recovery in mixed LP and SS crops, expressed as a percentage of standing volume was greater except in one study, when random length smallwood to 3 cm tdob (designated unconventional) was cut compared with 2 m or 3 m length smallwood to 6 cm td ob (designated conventional).

Total unconventional system extraction costs were higher due to smaller forwarder smallwood loads compared to conventional extraction (2 bays 2 m). Unconventional harvester costs were lower compared to conventional working due to increased output (c 10%). Revenue/ha from unconventional working was higher due to increased smallwood recovery and a higher estimated revenue for chips at roadside.

In one study a surplus of c £4 900/ha was indicated from unconventional working compared to £3 300/ha from conventional. This reflects an increased end product recovery of c 13% from random tops cut to 'run out' and increased value of chipped material.

Rates of taper for SS and LP sawlog material were significantly greater than the average values used in Booklet 39 (Forest Mensuration Handbook). LP smallwood rates of taper were similar to Booklet 39 values and SS smallwood rates of taper were less than Booklet 39 values. Site specific rates of taper were used with crops of poor form.

Sufficient brash was available to aid forwarder extraction when cutting random length tops. No significant difference was noted when comparing brash mats formed from random length tops and conventional smallwood working. Thatching was required to maintain Key Routes which deteriorated in the soft deep peat conditions after rainfall. Windblown areas were incorporated in Key Routes.

Standard forwarders were able to extract random length smallwood tops to a landing area for subsequent disk chipper processing.

The disk chipper was able to process all material extracted for chipping and load standard rear door opening residue articulated trailers. The chipper had an output of 34.87 m^3ob/shr and was under utilised on site.

Harvester outputs were greater (except one study) when cutting random length tops (unconventional) compared to outputs when cutting traditional smallwood lengths (conventional). The average increase in output was10% with the unconventional system.

When extracting sawlog material forwarder outputs were similar for the unconventional and conventional systems. In similar conditions the difference between unconventional chipwood extraction rates and conventional 2 m smallwood (2 bays) extraction rates was more significant. The extraction output of random smallwood lengths was 77% of 2 m smallwood extraction. Terminal times and travelling times were similar, but the 2 m load size was c 47% greater.

Recommendations

It is recommended that:

- Random length smallwood working and subsequent roadside chipping should be considered as a viable working system with surplus benefits.
- The unconventional system developed at Newton Stewart, with substantial brash Key Routes, should be considered in preference to the whole tree harvesting system used on soft ground in 1997.
- The availability of markets and suitable contractors and machinery should be explored by FE managers when considering the use of random length smallwood and chipping systems.
- Managers should ensure that Key Routes are maintained at an early stage during extraction and as required during extraction in soft conditions.

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