Forest Research

The Research Agency of the Forestry Commission

TECHNICAL DEVELOPMENT

INTERNAL PROJECT INFORMATION NOTE 45/08

CCF Operational Best Practice:

Final Overstorey Removal in Uniform Shelterwood




Date: December 2009

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Number: 1200A/56/08

INTERNAL PROJECT INFORMATION NOTE 45/08

Ref: 1200A/56/08

CCF Operational Best Practice

SUMMARY

This IPIN presents results from a time study of final overstorey harvesting in a Continuous Cover Forestry (CCF) uniform shelterwood of Sitka spruce. This operation used mechanised harvesting in tree sizes with a mean dbh of 42 cm amongst well developed natural regeneration. Motor manual felling was required for trees beyond the capacity of harvester felling, due to diameter and/or coarse branching. Shortwood harvesting was carried out with the aim of removing the overstorey and releasing the well developed (natural regeneration) understorey. A John Deere 1270D harvester was used for felling and timber extraction was carried out with a John Deere 1110D forwarder.

The mature overstorey included many large trees, consequently mechanised harvester outputs were high at 30.15 m^3OB/shr[1] at a cost of £2.30 per m^3OB. Motor manual felling and partial processing to assist the harvester produced an output of 8.50 m^3OB/shr at a cost of £3.07 per m^3OB (an addition of £0.35 per m^3 OB proportionally across the study area). Forwarding outputs were also high at 18.63 m^3OB/100 m for extraction to roadside at a cost of £2.88 per m^3OB/100 m. Harvesting was carried out with good integration of motor manual and mechanised techniques.

The total cost of harvesting and extraction to roadside using mechanised harvester and forwarder incorporating motor manual felling was £ 5.70 per m^3 OB over an average extraction distance of 102 m for the site.

These results are compared to outputs from a final thinning[2] in uniform shelterwood at Clocaenog in 2007 and a clearfell at Trallwm forest, mid Wales in 2004. When compared to final thinning, outputs from this final overstorey removal were lower with a corresponding increase in felling costs by harvester. Explanations for the reduction in output were the presence of larger natural regeneration which hindered visibility and larger tree sizes making harvester head placement and takedown more difficult.

The experience from this operation shows that final overstorey removal in uniform shelterwood is operationally straightforward, provided the work is well organised and carried out by skilled, experienced operators. The presence of natural regeneration caused the most significant obstacle to harvesting, but with careful harvesting techniques and motor manual assistance harvesting was achieved efficiently in a similar way to clearfelling with green tree retention.

The technique of locating the harvester head above the height of the natural regeneration then running it down the tree to securely locate the base of the tree was used to good effect to overcome the restricted visibility caused by natural regeneration.

Successful integration of mechanised and motor manual felling is dependant on a good system of communication between operators.

INTRODUCTION

This IPIN describes harvesting outputs and costs, operational techniques and site impact of final overstorey removal in a Sitka spruce stand managed as a uniform shelterwood.

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1 m^3OB : Cubic metres, over bark.

Shr = standard hour. Standard time includes built in allowances for rest and other work.

2 Final thinning in uniform shelterwood is the thinning operation which precedes final overstorey removal.

Figure 1 Stand before felling

Figure 2 Stand after felling

The purpose of the felling was to harvest the overstorey crop for timber production and increase light levels for established natural regeneration (Figure 1). A previous time study was carried out on a similar crop in Clocaenog forest in 2007 during final thinning in uniform shelterwood (Ireland, 2008). The study described in this report compares outputs and operational consequences of harvesting in a stand at final overstorey removal. The results of these two studies are compared to show operational outputs at different stages of uniform shelterwood management.

OBJECTIVES

The objectives of this case study were to:

- Measure outputs and costs of CCF transformation (harvester and forwarder) in uniform shelterwood.
- Gather operational experience of final overstorey removal in uniform shelterwood through observation and communication with local staff and operators.
- Comment on the presence of natural regeneration and the effect on harvesting, in terms of outputs, techniques and safety.
- Investigate the functionality of 'standard' harvesting and extraction machinery in uniform shelterwood with large tree sizes (pre-felling mean tree 1.78 m^3).
- Assess harvesting and extraction impact to racks and standing trees after harvesting.
- Gather operational observations to inform safe systems of working with combined mechanised and motor-manual harvesting.

This study formed part of ongoing management of CCF stands at Clocaenog so the figures should represent a typical CCF operation in these conditions.

SITE AND CROP DESCRIPTION

The study took place in a stand of Sitka spruce, managed as a uniform shelterwood during final overstorey removal in August and September 2007. Tables 1 and 2 show site and crop characteristics of the study area.

Prior to this intervention, the area had been thinned three times and this was the final overstorey removal. A naturally regenerated Sitka spruce understorey up to 5 m high was present throughout the stand at a density of approximately 50 000[3] stems per ha.

[3] Regeneration stocking density was not measured during this study, but density was comparable to that in a similar stand in Clocaenog forest at Bron Bannog where detailed plot measurements recorded a regeneration density of 50 000 trees per ha.

Table 1 Site characteristics

Planting Year	Area	Windthrow Hazard Class	Terrain Class	Slope
1950	1.22 ha (net)	5	2.2.2.	10 %

Table 2 Crop characteristics

Species	Yield Class		Basal Area m^2/ha	Overstorey Stems per ha (net)	Mean Tree Volume (m^3)	Stand Top Height (m)	Mean overstorey dbh (cm)
Sitka spruce	18	Pre fell	29.23	197	1.78	32.6	42
		Post fell	6.87	30	2.76	31.7	52

HARVESTING AND EXTRACTION MACHINERY DESCRIPTION

Felling was carried out with a six wheeled John Deere 1270D harvester (Figure 3) and extraction with an eight wheeled John Deere 1110D forwarder (Figure 4). A Husqvarna 372 chainsaw with 20 inch guide bar was used for motor manual felling.

Figure 3 John Deere 1270D harvester used for felling

Figure 4 Forwarder extraction with John Deere 1110D

Harvesting was carried out by Forestry Commission operators, with motor manual felling carried out on contract. The total thinned area was 8.6 ha (net) of which 1.22 ha (net) was used for detailed time study. Cost assumptions for the John Deere 1270D harvester and 1110D forwarder are shown in Table 3, detailed operational costs are shown in Table 20, Appendix 2.

Table 3 Costings of harvester, motor manual felling and forwarder extraction

Total machine costs		John Deere 1270D Harvester	Motor manual felling	John Deere 1110D Forwarder
	Unit			
Total cost	£/hr	69.37	26.12	53.61
Output		30.15 m^3/hr	8.50 m^3/hr*	18.63 m^3/hr/100m
Cost	£/m^3OB	2.30	3.07**	2.88

* The motor manual operator only felled and processed the first log – subsequent processing was carried out by the harvester, this output excludes complete processing of shortwood products from the remaining stem

** Cost per m^3 of the proportion of the crop that required motor manual felling. To calculate total harvesting cost per m^3 as show in Table 12 this cost has been apportioned across the total volume harvested during the study

STUDY SPECIFICATIONS

The harvester operator was asked to fell and process the crop, leaving an overstorey tree approximately every 20 m, to provide structural diversity. Five product specifications were cut (Table 4) and subsequent forwarder extraction to roadside was carried out four weeks after harvesting. Trees that were too large or too coarsely branched to pass through the John Deere H480 harvester head were felled, snedded and the first log cross cut motor manually. Processing limits of the H480 head were typically reached where dbh exceeded *c.* 55 cm or abundant branches greater than 5 cm diameter were present, usually on edge trees.

The harvester operator made an assessment of trees outwith the capability of the harvester and informed the motor manual operator of their location. Existing racks were used for access and operators were asked to minimise damage to the Sitka spruce natural regeneration during harvesting.

Table 4 Products cut

	Log	Log	Bar	Bar	Pulp
Product spec. length (m)	4.9	2.8	3.1	1.9	2.8
Product top diameter UB cut off (cm)	18	18	14	14	7
Product mean piece size ($m^{3)}$	0.572	0.202	0.103	0.050	0.046

Presence of natural regeneration

During the mechanised harvesting study the height of the adjacent natural regeneration around each felled tree was estimated to the nearest metre, using the harvester head as a guide, to provide an indicative record of the height of regeneration within the stand. Table 5 shows the results of these observations. From Table 5 for example, 76 trees felled were surrounded by adjacent regeneration of approximately 1 m in height, this represented conditions for 31 percent of trees felled.

Table 5 Height of natural regeneration around trees felled during study

Height class of natural regeneration around tree	1m	2m	3m	4m	5m
Number of trees	76	50	62	44	16
Percentage of trees felled	31	20	25	18	6

OPERATIONAL PERFORMANCE

Harvester Observations

This study was carried out in summer with good daylight available throughout the working day. However, visibility below the canopy was restricted by dense natural regeneration at approximately 50 000 stems per ha (pre-felling density) up to 5 m tall (Figures 5 and 6). A proportion of 3.7% of the harvester operator's time was spent inspecting the crop, a marginal increase compared to the 3% recorded during final thinning in uniform shelterwood (Ireland, D. (2008).

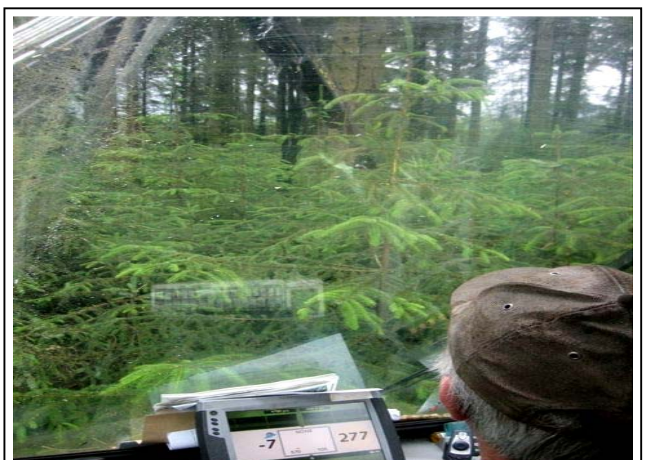

Figure 5 Operator's view from within the harvester cab

Figure 6 Restricted operator visibility from the harvester cab

Overstorey trees, 1.78 m^3 mean tree size, caused noticeable vibration within the cab when the trees hit the ground. Vibration has the potential to increase wear and tear on the machine and has implications for operator health and levels of vibration should therefore be minimised (for both harvester and motor manual operators).

During felling, the harvester operator repeatedly used the technique of locating the harvester head high on the stem and running it down to the base of the tree in the dense natural regeneration, where his vision was restricted (Figure 7). This technique enabled the operator to locate the head at the base of the tree to be felled, among the regeneration. This technique proved to be a good one, when carried out by an experienced operator, and is recommended for use in harvesting situations where the base of the tree is obscured by natural regeneration, however care must be taken to maintain a firm grip on the stem to make sure takedown is well controlled.

Figure 7 Locating the felling head high up the stem and running the rollers down to the base to accurately locate the felling cut in dense regeneration

Access to the overstorey crop trees was largely dictated by the existing rack network. Due to the density of the natural regeneration and a desire to reduce damage to the understorey, opportunities to venture off the racks were limited.

In some parts of the site access was not possible because the distance between adjacent racks was greater than twice the reach of the harvester crane. Where this was the case overstorey trees were retained or felled motor manually. This either resulted in revenue forgone or an increased harvesting cost. This observation emphasises how the layout of a regular rack network can influence the economics of harvesting.

Motor Manual Felling Observations

The motor manual operator felled trees that were beyond the limits of the harvester, where trees had large diameters, pronounced buttresses and/or coarse branches. Some trees were debuttressed, others debuttressed and felled and where necessary the coarsest branches were snedded, with the first log cross-cut (Figure 8). Subsequent processing was carried out by the harvester.

Trees requiring motor manual felling were identified by the harvester operator and communicated verbally to the motor manual operator. To improve identification of trees to be motor manually felled it is recommended they are marked by the harvester operator, either by using the head, to mark the tree at an agreed height or by paint marking.

Combining motor manual felling with the harvester allowed trees beyond the capability of harvester to be felled. These included large diameter trees *c*. 55 cm dbh particularly when combined with buttressing, coarse branching or those beyond the reach of the harvester boom from the rack. Operating in the stand did present challenges to the motor manual operator. Many of the trees felled motor manually were surrounded by dense natural regeneration and over half (18 out of 30) of the trees required regeneration to be cleared from approximately 1 m around their base before felling, taking about 4.5 % of the total time studied (Figure 9). Clearing regeneration from the base of the tree allowed the operator space to work and improved visibility in the interests of accurate felling and safety.

Figure 8 Snedding and cross cutting the first log (product) to assist mechanised harvesting

Figure 9 Clearing natural regeneration at the base of the tree prior to motor manual felling

Natural regeneration did not obscure the visibility of the motor manual feller during this study as the majority of trees felled were adjacent to racks (whose crowns presented the greatest obstacle to mechanised harvesting) and could therefore be felled into the rack. Before felling, each tree regeneration was cut and cleared from approximately 1 m around the base of the tree to allow safe working without restriction.

Forwarder Observations

Reduced visibility due to natural regeneration often prevented the operator from seeing the whole product length from the cab (Figure 10) and it was therefore difficult to distinguish between different products with similar diameters. Some productive time was lost due to misidentification of products by the forwarder operator during loading in the wood. Although inefficient, the results of the time study showed only 1% of the total study time was lost in this way however.

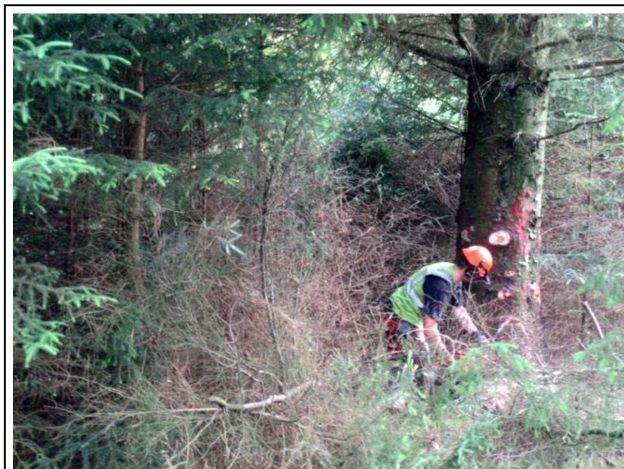

Figure 10 Restricted visibility of product lengths from the forwarder

Figure 11 Motor manual operator felling 65 cm dbh tree

A marginal increase in time was spent sorting produce in this stand compared to final thinning in uniform shelterwood (4.2% compared with 3.9% of the study time). This marginal increase in time taken to identify and sort produce at rackside was possibly caused by the greater height of regeneration restricting vision and available stacking space at rackside. Product identification could have been improved by colour marking or offset rackside stacking of different products to aid identification for the forwarder operator.

Natural regeneration in the timber zone at rackside caused constraints for loading. In order to prevent damage to the regeneration the forwarder operator loaded single billets rather than loading two or more billets in one grab (Figure 12). This method reduced outputs but preserved a greater proportion of the natural regeneration. Preserving the natural regeneration was a desired outcome of the operation and so this constraint was acceptable. It is however, important to consider the potential effect of operational constraints on outputs.

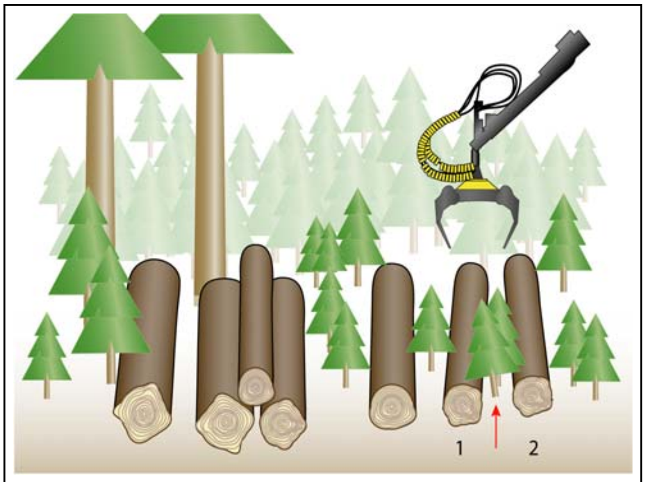

Figure 12 Natural regeneration in timber zone (as shown by red arrow) reducing loading efficiency

The forwarder operator used imported brash (from elsewhere on site) to strengthen brash mats in the racks. However, the amount of time required for brash mat thatching was lower than previously studied at Bron Bannog (2.2% compared to 11.5%). This was probably due to a combination of better site and weather conditions related to the time of year. Good use of the forwarder loader reach was made by the operator. Frequently the operator would reach through the regeneration to the adjacent rackside to pick up a product in order to make up the load volume.

RESULTS: STUDY OUTPUTS

Harvester Outputs

Time taken for each aspect of the harvesting process is shown in Table 6. Information about the trees felled, harvester output and costs are summarised in Table 7. This study was carried out as part of the ongoing management at Clocaenog so that the figures should represent a typical CCF operation in these conditions.

Table 6 Harvester elemental breakdown

Move (%)	Fell (%)	Continue to fell (%)	Process (%)	Aside felled top (%)	Trim Butt (%)	Treat Stump (%)	Clear regen (%)	Inspect (%)	Move between racks (%)	Manoeuvre (%)	Prep Route (%)	Stack Logs (%)	Total Time (Standard Hours)
20.2	21.7	2.2	35.5	5.5	3.6	0.3	1.6	3.7	0	2.7	3	0	10.34

Table 7 Harvester felling data

Output	Units	Result
Mean tree size	m^3	1.78
Mean piece size	m^3	0.210
Harvester output	m^3OB /shr*	30.15
Total machine cost, per hour	£/hr	69.37 (see Table 20 for calculations)
Cost of harvesting per m^3	£/m^3	2.30 (see Table 20 for calculations)

* A standard allowance of 18% for rest and 20% for other work has been applied to the output in the above table to convert basic time to standard time

Table 8 Motor manual felling breakdown

Walk between trees (%)	Brash (%)	Clear base (%)	Debutress (before fell) (%)	Debutress (after fell) (%)	Fell (%)	Take down (%)	Sned (%)	Mark and measure (%)	Cross cut (%)	Inspect (%)	Total Time (Standard Hours)
4.2	1.3	4.5	15.1	6.1	20.8	1.4	33.8	4.3	7.8	0.7	5.68

Table 9 Motor manual felling data

Output	Units	Result
Mean Tree size of stems motor manually felled	m^3	1.61**
Mean piece size of stems felled motor manually	m^3	Not applicable – only processed first product
Motor Manual Output	m^3/shr*	8.50
Total system cost, per hour	£	26.12 (see Table 20 for calculations)
Cost of harvesting per m^3	£/m^3	**3.07** (see Table 20 for calculations)

* A standard allowance of 23% for rest and 26% for other work has been applied to the output in the above table to convert basic time to standard time

** Mean tree size for the sample of trees felled motor manually; this was slightly smaller than the mean tree size of the stand before felling (1.78 m^3)

Forwarder Outputs

Time taken for each aspect of forwarding is shown in Table 10. Information about the products extracted during this study with the forwarder output and costs is summarised in Table 11.

Table 10 Forwarder elemental breakdown

Move in on road (%)	Move in on rack (%)	Load (%)	Move out on rack (%)	Move out on road (%)	Manoeuvre in Wood (%)	Move to load (%)	Unload (%)	Stow / Unstow Loader (%)	Stack (%)	Adjust Load (%)	Manoeuvre to Load (%)	Move to Unload (%)	Sort Produce (%)	Prep. Route (%)	Uplift log and return (%)	Total Time (Standard Hours)
3.2	9.8	38.6	3.7	2.7	1.8	13.3	14	3.2	0.8	1.2	0.2	0.1	4.2	2.2	1.0	16.87

Table 11 Forwarder data

Output	Units	Result
Mean tree size	m^3	1.78
Overall mean piece size	m^3	0.210
4.9 m log mean piece size	m^3	0.572
2.8 m log mean piece size	m^3	0.202
3.1 m bar mean piece size	m^3	0.103
1.9 m bar mean piece size	m^3	0.050
2.8 m pulp mean piece size	m^3	0.046
Average load size	m^3	14.08
Average number of pieces in load	number of pieces	60
Outputs	m^3/shr/100m*	**18.63**
Total machine cost, per hour	£	53.61 (see Table 20 for calculations)
Cost of extraction per m^3	£/m^3	**2.88** (based on extraction distance of 100m see Table 20 for calculations)

* A standard allowance of 15% for rest and 17% for other work has been applied to the output in the above table to convert basic time to standard time

Stand Characteristics after Felling

Figure 2 shows the study site immediately after felling and extraction. Plot assessment after felling showed that 30 trees per ha were left as remnant trees. The harvesting specification given to the operator was to remove the overstorey crop, minimising damage to the natural regeneration and leaving one tree approximately every 20 m to maintain structural diversity; this spacing target would have resulted in 25 remaining overstorey trees per ha. The 30 remnant trees per ha recorded in the post felling assessment plots is sufficiently close to this target to demonstrate the operator's accuracy in judging target spacing of overstorey remnants among dense regeneration.

Additional Observations

Comparison with outputs in uniform shelterwood final thinning and clear felling

Table 12 shows a harvesting cost comparison between uniform shelterwood final thinning, final overstorey removal and clear felling. The clearfell comparison figures in Table 12 should be viewed as an indicative guide only; due to differences in the crop and machinery used, (as shown in Table 19, Appendix 2). However this comparison shows similar outputs and costs can be achieved in final overstorey removal as clear felling. Based on this limited comparison the use of assisted motor manual felling during harvesting does not adversely impact considerably on the economics of the operation.

Table 12 Output comparison between uniform shelterwood final thinning, final overstorey removal and clearfelling

Site	Cost of Mechanised Harvesting (£/m^3 OB)	Harvester Output (m^3/Shr)	Cost of Forwarder Extraction (£/m^{3}OB)	Forwarder Output (m^3/ Shr / 100m)	Additional Cost of Motor Manual Felling Assistance (£/m^3)	Motor Manual Felling Output (m^3/Shr)	Total Cost of Harvesting to Roadside (£/m^3)
Bron Bannog (uniform shelterwood final thinning)	2.11	33.54	2.15	24.46	Not applicable	Not applicable	**4.26**
101 Stones (uniform shelterwood final overstorey removal	2.30	30.15	2.88	18.63	0.33*	8.50	**5.51**
Clear fell**	2.55	29.55	3.13	16.88	Not applicable	Not applicable	**5.68**

* Calculation of this figure is shown in Appendix 2 and is expressed as a proportional oncost per m^3 of total the volume studied during harvesting

** Values from a clear fell operation in similar crop conditions are shown for comparison purposes, harvesting site, crop and machine characteristics are shown in Appendix 2. Note: although similar, the mean tree size and harvesting machinery differed from this study

Ground Disturbance Assessment

Following harvester and forwarder travel, transect assessments were made to determine ground disturbance[4] after harvesting operations. Figure 13 shows ground disturbance classification after harvesting and forwarding.

The ground disturbance assessment shows very little disturbance occurred across the site as a result of harvester and forwarder movement. The low incidence of ground disturbance was probably due to a combination of site conditions, care of the operators reinforcing racks with brash where necessary and the dry summer conditions during harvesting.

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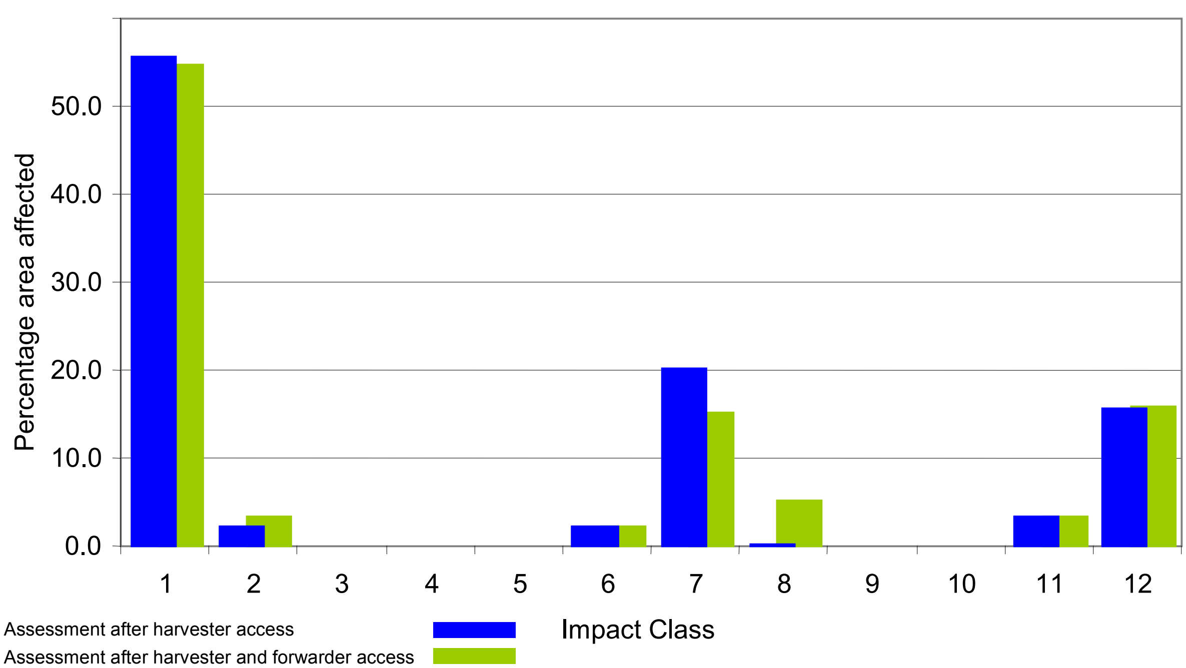
4 The ground impact assessment used in this trial is defined in Technical Development SOP: Mechanised Harvesting.

In Figure 13 Classes 11 and 12 are not damage categories but show the location of areas that had been swept by the crowns of trees during processing (Class 11) and also the location of timber piles or uplifted piles following forwarder uplift (Class 12).

Figure 13 Ground Disturbance Following Harvester and Forwarder Travel



DEFINITION OF GROUND DAMAGE CLASSIFICATION IN FIGURE 13	
1 Undamaged and untrafficked	7 Minimum deflection of brash mat
2 Obviously trafficked but to no discernible depth	8 Well used evidence of mud and broken brash mat
3 Rutted to a depth of 0–5 cm	9 Brash mat completely sunk or buried
4 Rutted to a depth of 5–15 cm	10 As 9 but topped up with more brash
5 Rutted to a depth of >15 cm	11 Swept by crown during processing
6 Brash mat unused	12 Timber pile at rackside or uplifted timber pile

DISCUSSION

All three operators involved with this study were highly skilled and familiar with working in similar uniform shelterwood stands with dense natural regeneration. The results from this study should be regarded as a fair reflection of expected outputs in similar stands with experienced operators.

Harvester outputs were high at 30.15 m^3/shr with a cost of £2.30/m^3. Motor manual felling and partial processing to assist the harvester produced an output of 8.50 m^3/shr with a cost of £ 3.07 per m^3 (an addition of £0.35 per m^3 OB proportionally across the area studied). Forwarding outputs were also high at 18.63 m^3 per 100m to roadside at a cost of £ 2.88 per m^3/100m.

In the motor manual work studied, a third of the time was spent on snedding. This indicates a considerable benefit that the motor manual operator gave in handling coarsely branched edge trees that would have proven too coarse to be processed by the harvester head. The operator also spent a considerable time (15%) debuttressing the first log length of felled trees, either before or after felling to improve the proportion of green log recovery. This was beneficial given the potential marketing difficulties with large diameter logs and potential revenue forgone.

Incorporating motor manual felling to assist the harvester with large trees requires skilled operators qualified to fell large trees (felling trees greater than twice guide bar length requires additional training, see AFAG Guide 307).

The ground disturbance assessment indicated that only 3% of the harvested area showed signs of the crowns being swept through the regeneration. This proportion was lower than the 9% observed prior to this study at Bron Bannog. This may have been due to the larger size of the regeneration in this crop being more resistant to disturbance.

OPERATIONAL GUIDANCE UPDATE

The operational guidance booklets shown in Table 13 are relevant to this subject. Table 15 also indicates where updates to the current Forestry Commission OGB series are required.

Table 13 Operational Guidance

OGB	Version	Relevance	Update required
7 Managing Continuous Cover Forests	Recently updated	Guidance for managing forests under continuous cover silviculture	OGB is up to date with current operational best practice. This IPIN should be referenced in future revisions of OGB 7 to raise awareness of operational guidance.

CONCLUSIONS

Experience from this operation shows that final overstorey removal in uniform shelterwood is operationally straightforward, provided the work is well organised and carried out by skilled, experienced operators. The presence of natural regeneration caused the most significant obstacle to harvesting, but with careful harvesting techniques and motor manual assistance this was achieved efficiently in a similar way to clearfelling with green tree retention.

The technique of locating the harvester head above the height of the regeneration, then running it down the stem to locate the base of the tree was effective where visibility was restricted among dense natural regeneration. This technique is recommended however, with large trees or those with buttressing, care must be taken to maintain a secure grip on the base of the tree and motor manual take down may be a preferable alternative.

Combining motor manual felling with mechanised harvesting gives operational benefits and is recommended where trees exceed the maximum felling diameter of mechanised harvesters. Due to the additional expense of motor manual working compared to mechanised harvesting, this technique should only be used for components of harvesting that exceed the capability of the harvester.

The motor manual operator aided mechanised harvesting when trees were beyond the capability of the harvester where:

- trees typically exceeded *c.* 1.6 m^3, *c.* 55 – 70 cm dbh in size.
- trees had coarse branching (typically edge trees).
- buttressing was pronounced.
- dense natural regeneration restricted visibility and access.

Comparison between the final overstorey removal studied in this operation and a clearfell in a comparable crop showed similar outputs and costs. The benefits of assisted motor manual felling were achieved therefore without affecting the overall economics of the operation. Safe working procedures were maintained by removing the harvester to an adjacent coupe whilst the motor manual operator was working on site.

Harvester and forwarder outputs were high. Despite the difficult harvesting conditions resulting from the dense advanced natural regeneration, this was a productive operation demonstrating the ability of skilled operators to work in final overstorey removal with conventional forest machinery. The motor manual operator in this operation was experienced and highly skilled at felling large trees. Motor manual chainsaw operators are not abundant in British forestry and this method of working in CCF stands with large trees may be restricted by limited skills availability.

Natural regeneration up to 5 m high and *c*. 50 000 stems per hectare restricted visibility for machine operators and contributed to 3.7% of the harvester study spent on inspecting the crop. During forwarding this was exacerbated by products with similar appearance (length and diameter); product identification could have been improved by colour marking or offset rackside stacking of different products.

This study highlighted the balance between forwarder loading efficiency and preserving natural regeneration. The forwarder operator frequently uplifted individual products one at a time rather than two or more, and in doing so prevented trapping and uprooting rackside natural regeneration at the same time. Managers and operators should be aware of working methods such as this that can be used to reduce harvesting damage to regeneration, provided impacts on outputs are acceptable.

Access provided by the existing rack network was inadequate over a small part of the site and due to the density and size of natural regeneration, harvester movement off the racks was very limited. Consequently some overstorey trees were left as remnants by default, which may not be optimal. Impact on the racks was minimal, with moderate brash reinforcing, showing the benefits of summer working where soils are dry and less susceptible to trafficking.

Introducing a motor manual operator to assist the harvester improved safety and also brought potential health benefits e.g. reduced vibration exposure within the harvester. It is important however, to also safeguard motor manual operator health. Felling large trees is likely to result in prolonged vibration exposure for the motor manual operator for example. Appropriate safeguards should be taken[5] to prevent overlooking motor manual operator heath as well as that of mechanised operators.

RECOMMENDATIONS

Motor manual assisted takedown is recommended for stands in the latter stages of CCF transformation where tree sizes are large and exceed the operational limits of mechanised harvesting. Where motor manual and mechanised harvesting are combined in this way, care must be taken to organise working in a safe way. For further information on safe systems of working with combined motor manual and mechanised harvesting see Forestry Commission TD Internal Project Information Note 10/08 *CCF harvesting method development: harvester head visibility.*

Further research is recommended to measure operator vibration exposure with large tree takedown for harvester and motor manual operators, in order to determine likelihood of effects on operator health and required safe systems of work.

<u>Safety Considerations</u>

Combining motor manual felling with mechanised harvesting in crops with restricted visibility requires stringent safety management, especially in crops where visibility is reduced due to natural regeneration. There is a serious risk of the motor manual operator being struck by the machine and to both operators from being hit by falling trees.

The safest way to allow combined motor manual and mechanised harvesting on the same operation is to separate them into distinct working areas to prevent encroachment into respective risk zones. During this study the operation was planned so that neither operator was working in the same area at the same time. The harvester moved to an adjacent stand while the motor manual operator was working and a system of communication was agreed between them to maintain contact in the interests of safety.

Where motor manual and mechanised harvesting are combined, the following safety precautions are recommended:

- A thorough risk assessment should be produced to assess risk and implement appropriate controls.

- A system of communication between motor manual and mechanised operators should be established as part of the risk assessment process. A ‘buddy’ system should be established with regular communication in the interests of safety. The buddy system should be ‘fail safe’ so that if an accident occurs it will not go unnoticed. Operators should not work alone.

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[5] For further information see AFAG Guide 307, *Chainsaw felling of large trees*.

- Operations should be organised to prevent risk zone infringement; this may require careful organisation where visibility is restricted.

- The motor manual operator must take care to identify an escape route and clear this by cutting natural regeneration if necessary prior to felling each overstorey tree.

- High visibility clothing should be worn by operators on site to maximise visibility.

All safety standards identified by AFAG should be observed.

REFERENCES

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ACKNOWLEDGEMENTS

The author wishes to acknowledge the help of FC Wales staff including Hefin Roberts, Arwyn Williams, Dave Williams and Ian Trow for their co-operation and comments on the operation during this study and Ian Murgatroyd for assistance during the data collection.

Appendix 1

Forwarder Extraction Costs Calculation – Averaged by products cut

Average Load Size	14.08	
(No. of Pieces in load)	60	
Average Piece Size,	0.23	
Average No. Grabs to Load		
Average No.of Piles		
Average No. of Grabs to Unload		
No. of Loads	22	
Terminal Time per Load	**B M**	**Mean Distance**
Manoeuvre in Wood (K)	0.61	
Loading per Load (L)	13.19	
Move to Load (J)	4.56	
Adjust Load (A8)	0.42	
Manoeuvre on Road (A3)	0.08	
Unloading per Load (U)	4.74	
Adjust/Butt Up Stack (A5)	0.28	
Stow/Unstow Grapple/Turn Seat/Adjust Headboard (A6)	1.08	
Move to Unload (A2)	0.04	
Sort/Organise Produce	1.44	
Prep. Route	0.75	
Total Terminal Time per Load	**27.19**	
Terminal Time per m^3	**1.93**	
Travelling Times per Load		
Move in Road (A)	1.11	56.8
Move in Ride (B)		
Move in Rack (C)	3.37	87.6
Move in Wood (D)		
Move out Ride (E)		
Move out Rack (F)	1.28	44.9
Move out Wood (G)		
Move out Road (H)	0.94	57.5
Total Travelling Time per Load	**6.7**	
Extraction Distance		**102.4**
Travelling Time per Load per 100 m Extracted	6.54	
	NA	
Travelling Time per m^3 per 100 m Extracted	0.46	
Total Basic Time per m^3 per 100 m Extracted	**2.39**	
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	2.60	
Travelling Time per m^3 per 100 m Extracted	0.62	
Total Time per m^3 per 100 m Extracted	**3.22**	
Output per Hour (m^3 per 100 m Extracted)	**18.63**	
		Site Output 18.52

Appendix 2

Machine specifications for the harvester, forwarder and chainsaw are shown in Tables 16, 17 and 18.

Harvester Specification

Base machine	John Deere 1270D
Number of wheels	6
Tyres – Front 4	Nokian Forest King F 710/45/26.5
Tyres – Rear 2	Nokian TRS L2 700/55/34
Bandtracks	Clark F10, tracks fitted to bogie
Crane	210 H (9.0 m reach)
Head	H480
Hours on clock	1414 (at time of study)
Nominal weight	c. 19.5 tonnes (including bandtracks)
Machine length	7.70 m
Machine width	2.86m (excluding bandtracks)
Engine	John Deere 6081 HTJ, 6 cylinder, 8.1 litre turbo
Power output (kw)	160 kW @ 1400 – 2000 rpm
Transmission	Hydro-mechanical
Speed (km/h)	0 – 25

Forwarder Specification

Base machine	John Deere 1110D
Number of wheels	8
Tyres Front 4	Nokian Forest King F 710/45/26.5
Tyres Rear 4	Nokian Forest King F 710/45/26.5
Bandtracks	Clark Terralite tracks fitted to bunk bogie
Crane	CF585 (8.5 m reach)
Grab	0.36 m^2
Hours on clock	1760 (at time of study)
Nominal weight	c. 18 tonnes (including bandtracks)
Machine length	9.70 m
Machine width	2.88 m (excluding bandtracks)
Engine	John Deere 6068 HT J75 6 cylinder, 4.5 litre turbo
Power output (kw)	121 kW @ 2000 rpm
Transmission	Hydro-mechanical
Speed (km/h)	0 – 22

Chainsaw Specification

Model	Husqvarna 372
Engine specification	70.7 cm^3
Power output	3.9 kW / 5.3 hp
Fuel tank volume	0.77 litre
Oil tank volume	0.4 litre
Guide bar length	20”
Chain pitch	3/8”
Chain speed at max power	21.4 m/s
Weight (excl. cutting equipment)	6.1 kg

<u>Additional cost of motor manual felling per cubic metre</u>:

Total volume harvested on 101 Stones = 197 trees per ha.
Over 1.22 ha site. At 1.78 m^3 mean tree. = 427.8 m^3.

Cost of motor manual felling component on edge trees and those over capacity of the harvester = (30 trees at mean tree 1.61 m^3 x cost/m^3 £ 2.88) = £ 142.49.

Additional total cost for motor manual element per cubic metre = (£142.49 / 427.8) = £ 0.33 per m^3.

Total cost of harvesting and extraction to roadside using mechanised harvester and forwarder incorporating motor manual felling was £ 5.70 per m^3 OB (£ 2.30, harvesting + £3.07 forwarder extraction + 0.33 motor manual).

Crop and machine specifications for comparison of CCF case studies with clearfelling outputs

Location:	Trallwm: Clearfell	Clocaenog: Bron Bannog: Uniform shelterwood final thinning	Clocaenog: 101 Stones: Uniform shelterwood final overstorey removal
Species	Sitka spruce	Sitka spruce	Sitka spruce
Age at time of felling	37	58	57
Mean tree size m^3	1.06	1.78	1.78
Trees per hectare (pre-fell)	497	283	197
Top Height (pre-fell)	29.3	32.6	30.35
Harvester:	Silvatec 82665 'Sleipner'	John Deere 1270D	John Deere 1270D
Forwarder	Timberjack 810B	John Deere 1110D	John Deere 1110D

Costings of harvester, motor manual felling and forwarder extraction

		John Deere 1270D Harvester	Motor manual felling	John Deere 1110D Forwarder
COST ELEMENT	**UNIT**			
Capital Cost	£	240,000	600	150,000
Residual Value	£	48,000	120	30,000
Life in Years	Years	5	5	5
Hours/Year	Hours	2,000	1000	2000
Interest Rate	% (r=R/100)	0.05	0.05	0.05
Discount Factor	D	0.7835	0.7835	0.7835
Equivalent Annual Cost	AN	0.2310	0.2310	0.2310
Capital Cost / Hour	£/hour	**23.37**	**0.12**	**14.61**
Repair & maintenance	£/hour	16.00	0.50	10.00
		(14 l per hour @ £0/50 per litre)	(1.5 l per hour @ £1.00 per litre)	(12 l per hour @ £0/50 per litre)
Fuel	£/hour	7.00	1.50	6.00
Insurance	£/hour	3.00	3.00	3.00
Operator (inc. on-costs)	£/hour	20.00	21.00	20.00
Total Operating Cost	£/hour	**46.00**	**26.00**	**39.00**
Total Hourly Charge	£/hour	**69.37**	**26.12**	**53.61**
Output		30.15	8.50	18.63
Output units		m^3/Shr	m^3/Shr*	m^3/Shr/100m**
Cost	£/m^3OB	2.30	3.07	2.88

* The motor manual operator only felled and processed the first log – subsequent processing was carried out by the harvester this output excludes complete processing of shortwood products from the remaining stem

** See Appendix 1 for calculations