www.robin-wood.it

**The Robinwood WEM report:**

# Identifing Joinery Grade Timber in Softwood logs

Comisiwn Coedwigaeth Cymru
Forestry Commission Wales

PROJECT PART-FINANCED BY THE EUROPEAN UNION
North East SOUTH West
INTERREG IIIC

## Robinwood project: 'Sustainable Forest Management and Industry Development'

## Identifying Joinery grade timber in Softwood Logs

### Project aim

To investigate the relationship between site type and silvicultural system on the yield of joinery grade timber in sitka spruce crops.

### Introduction

In 2004 an evaluation of sawn timber in the BSW sawmill at Senghenydd showed that there was a significant proportion of potentially higher value joinery grade material in the output from smaller diameter logs (215mm or 155/165mm). (Nicolas Blanchard, BSW Report 2004)

Unfortunately, it was not possible to track the graded material to its source so no conclusions could be drawn about the effect of site type and harvesting pattern on the yield of joinery grade timber. However it demonstrated that half the timber in the samples surveyed was eventually being sold into sub optimal markets.

The purpose of this latest study is to establish whether different growing sites and different management systems influence the yield of joinery material and whether logs containing this material can be identified in the forest.

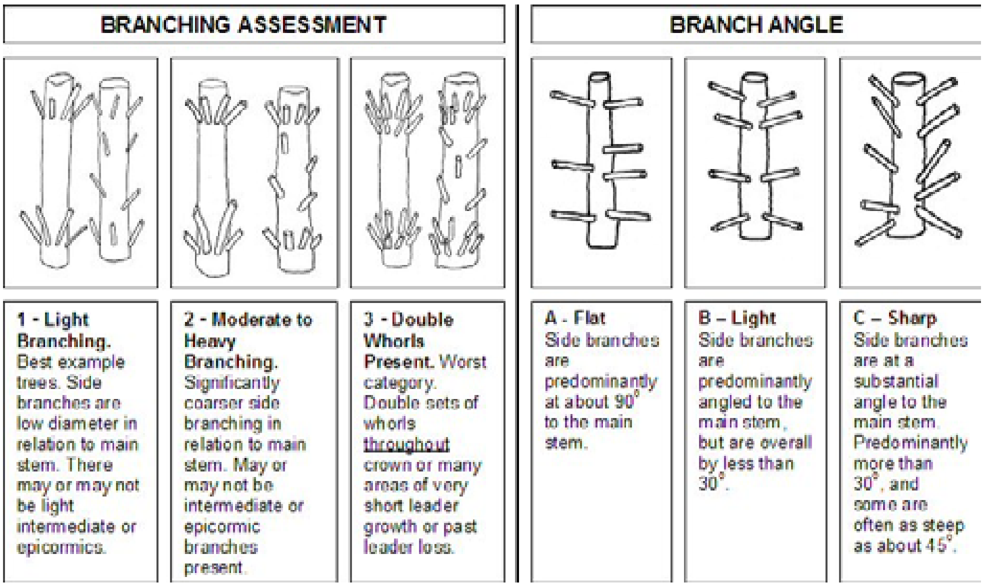
### Methodology

Eight areas were surveyed with differing yield classes and elevations. These included unthinned sites, conventional low-thin and continuous cover sites. (This work was carried out by Andrew Price, Forest Research - the research agency of the Forestry Commission. For details of crops and standing volumes see Appendix 1.)

The quality of standing timber was assessed using an agreed scoring system to measure branch density and angle.


**This report has been produced as a result of the Robinwood Project, a 45 month European Interreg 111c Regional Framework Operation project – a first for Wales and delivered by Forestry Commission Wales on behalf of the Welsh Assembly Government. It looked at how we should manage our trees and forests to provide solutions to hydrological issues, increase the amount of wood used in heat and energy and the key role they play in helping to regenerate rural communities across Europe.**

**The Italian project leaders named the project after Robin Hood – a deliberate play on the UK folk hero best known for taking from the rich and giving to the poor. Research carried out by the project now provides valuable new information on how forests can provide all kinds of opportunities for the future.**




**For testing the methodology when used by different operators see Appendix 2.**

A sample of thirty trees was felled from the Coety site and two sample logs 18cm and 12 cm top diameters respectively removed to the Heartwood Sawmill at Caersws for sawing and grading. The logs were individually numbered and boards numbered off the saw to retain their identity. Comparisons of yield of different grades of timber from the sample logs is presented below. The grades used are from the EU standard as used in the Blanchard study and are summarised below:

| | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Sound knots | 20mm | 30mm | 45mm | 60mm | >60 |
| Dead knots | 10mm | 20mm | 30mm | 60mm | >60mm |
| Number | 2 | 4 | 6 | >6 | >6 |
| Occluded | 0 | 10mm | 25mm | 50mm | >50 |
| Loose | 0 | 0 | 0 | 0 | ∞ |

## **Thermal treatment**:

A sample of spruce was compared with other homegrown softwoods in a heat treatment trial. High temperature treatment of timber (>180°C) results in greater stability and durability of the timber. We had previously observed that machining properties of certain softwoods were also improved so the following range of locally sourced softwoods were tested:

Pine, Scots and Corsican
Western Red Cedar
Sitka spruce
Douglas fir
Larch, probably hybrid
Noble Fir

Small (0.2m$^3$) samples of 15-25cm logs were collected by FC and Coed Cymru staff and processed to 110x30mm sawn stock at Heartwood Sawmill, Caersws.

Boards were individually marked and put “in stick” to air dry. When dry the samples were heat treated using the standard programme of 190$^{0}$c for 3.5hours and rehydrated using steam. The timber was then transferred to BSW Newbridge for planing with their moulder (conventional 6 blade heads).

## Utility of the timber:

To demonstrate the utility of the higher grade joinery timber a range of products are illustrated below.

# Results

## Observations on survey and results

- ### No-thin sites, available bar volume

Although we found some for the survey, there is an overall lack of suitable no-thin sites for comparing against equivalent CCF or LT sites, especially when looking at older crops. NT areas tend to be on poorer or inaccessible ground, and perhaps with a significantly lower yield class than identical crops planted on better ground – so not ideal for ‘paired’ comparisons.

However, un-thinned crops contain a far higher proportion of lower dbh stands than the more ‘managed’ areas and as such will contain a significantly greater proportion of bar material. Even in relatively older crops - for example the 46 year old un-thinned Sitka at Cwm Berwyn – there is still a relatively high proportion of bar material.

- Un-thinned age 35 at Cefn Llwyd contains high bar volume (55%)
- Un-thinned age 46 at Cefn Llwyd contains significant bar volume (19%)

As the proportion (albeit from all site types) is believed to contain up to 50% suitable for higher quality end uses, then perhaps looking to identify un-thinned crops from sub-compartment data records and even aerial photographs may prove effective in identifying potential sites with a likely high bar content. This is certainly cheaper than field surveys for form by branching.

Age of crops is evidently a critical factor in determining likely volumes of bar material from thinning or clear-felling.
From the Radnor study, it is evident that there are still significant standing volumes in the bar categories within both the (relatively younger) No-Thin and the Low-Thin stands. This is in crops aged 26, 29 and mostly 30 years old. Comparison with other more mature stands that have been thinned shows a significant decrease in the available volume of bar material.

- **Light thinned sites, available bar volume**

By age 30, light-thinned stands at Radnor still contain relatively high bar volume on all site classes (26 to 55%).

Bar volume decrease significantly with age in thinned stands beyond age, for example at Cefn Llwyd where it is only 4% at age 48.

- **CCF sites, available bar volume**

The stands assessed in this study will be typical of many in Wales that will become designated for continuous cover. They have a good thinning history, are easily accessed and windthrow hazard is not prohibitively high.

From the data available, management under CCF systems appears in all cases to heavily reduce available bar volume (to almost negligible levels in some cases). This is due to lower stocking density and accordingly higher growth rates in remaining stems.

However it is important to note that CCF is in its infancy in Wales and all stands surveyed should be regarded as 'transitional' towards CCF rather than well established. Future studies will have the opportunity to assess more diversely structured stands as the under-storey crops become established. These are likely to have a greater available volume of bar material from the middle storey.

It is apparent from the size of the remaining trees in more mature CCF stands that they will have a very high proportion of sawlog material and a corresponding low out-turn of bars. This needs to be considered in the short term at least, as very few stands have an under-storey that will be thinnable for some years to come. Will the future availability of bar material be significantly delayed at some stage, given the move to designate 50% of the forest estate (both public and private) in Wales under CCF systems?

There is a relatively lower stem count in these CCF areas, greater local exposure and therefore higher potential for broken tops (which was particularly evident in the mature CCF at Cefn Llwyd). In older stands, the quality of the bar content (which will be predominantly from upper main stems) may be decreased by breakage in the crown area and localised decay.

Windblow is evident in all higher elevation stands. However in each stand assessed it is likely that before the time when this becomes 'catastrophic' (if ever) there will be well established under-stories of crop trees.

- **No-thin sites, effect on branching**

There may be a trend towards decreasing branching scores as trees become larger and / or more dominant. Again, could there be value in identifying the younger to mid-rotation and close-grown crops from records as opposed to extensive surveys?

There may be a trend towards better branching scores ('1') in the more suppressed, lower diameter trees (although no trees of less than 7 cm d.b.h. were assessed). For future development of the method it may be useful to consider excluding a wider range of smaller stems (say everything < 12 cm d.b.h.) to get a more meaningful mean branching score for the valuable stems.

There are inherent access difficulties with assessment of un-thinned crops and this makes them considerably more expensive to survey.

- **Light thinned sites, effects on branching**

Previous thinning design varies widely between (and sometimes within) sites. LT stands have usually been thinned very systematically, e.g. one row in three or six now a rack, with six trees in 10 removed from either side. It was particularly evident in the older LT study at Cefn Llwyd that form was excellent in terms of diameter and main stem straightness and that this was probably been the main criteria for selecting thinnings adjacent the rack. Most trees looked excellent in these terms, but there were noticeably many present with poorer branching scores.

Its become increasing evident throughout this study as to how individual each CCF and LT stand is in terms of branching score, reflecting the different thinning histories and management objectives of each site.

Rack thinning appears to lead to poorer branching scores in the adjacent rows, given the increased local light levels. Also, its relatively common for a forked tree to have different branching scores, especially where one stem is in more light.

- **CCF sites, effects on branching**

It should be borne in mind that, on the CCF sites (and the advanced CCF site in particular) there is a relatively low count of over-storey trees per hectare – so the data is less extensive than from the NT or LT sites.

A degree of caution should also be taken when considering current CCF sites, given that these have often been designated only relatively recently and that prior to that they would have been considered as more typical 'thinning' sites. These would of course have been thinned more heavily than the LT stands assessed for this study.

From observation only, form by branching at the more 'middle' site class at Clocaenog is considerably better than at the other two areas However, form according to stem straightness and taper are very good at each site (NB not formally assessed). This raises question as to whether site factors are or are not significantly responsible for form, and to what extent branching form has been influenced by previous thinning policy (i.e. remove the more stunted and crooked trees only, without taking account for branching). See also above comment on historical 'thinning design'.

[As above - It has become increasing evident throughout this survey as to how individual each CCF and LT stand is in terms of branching score, reflecting the different thinning histories and management objectives of each site].

It should be noted that trees of the height and girth common under older CCF systems are now considered sub-optimal for marketing due to difficulties associated with extraction and processing. Clocaenog Area 3 in particular has clearly had many of the largest stems removed at the last intervention, probably to reduce the overall diameter profile of the remaining crop.

Form assessment is complicated in more the mature CCF (and some LT) stands due to a higher level of self-pruning in the lower main stems and this disguises the likely knot size and frequency below bark. Assessment of branching from the crown only is unreliable, as many upper branches become disproportionately larger once a tree becomes dominant.

Also, in the more mature stands branching may be coarser in the crown than lower down the tree. Bar material is likely to be located in the crown, but form becomes more difficult to assess at these heights.

## Branch angle – all sites/systems

There does not appear to be any correlation between branch angle and any of the management regimes or site types assessed in the survey. What is apparent is that only a very minor proportion of trees fall into the poorest category 'c', and only a minor proportion fall into the best category 'a'.

Assessing branch angle increases assessment time (and therefore survey costs) due to need to step away from the tree to get a good perspective. Will need to consider how useful this scoring is, given very high incidence of mid score ('b') / medium branch angle in all areas so far visited.

Also, there is a high degree of variance between assessors in determining branch angle.

On the basis of the data collected it would not appear that there is great value in adopting the branch angle aspect in the assessment method, should it be promoted for small growers in the future.

If desired, future study could look at whether there is a correlation between sharper branch angle and suppression in trees in a younger, dense plantation. These trees would be more likely to be removed at thinning and therefore not appear in a survey of more mature crops.

## Resin pockets – all sites/systems

It is observational only, but it is very apparent from surveying these more mature spruce that there is a higher external resin presence than in younger crops. This is also supported by observation in the mature LT stands at Cefn Llwyd. Is this a reliable indicator of the extent of resin pockets likely to be present in the sawn timber, and likely to have a negative effect on grading?

## Site effects on form by branching

The highest elevation sites have a higher prevalence of forking, lost leaders and wind-blown tops. This has had an obvious effect on the number of branch score '3'. There may be a trend towards more of the poorest branching scores ('3') in the higher areas due to frequent damage and leader loss, rather than inherent form characteristics of the trees. Effects on volume should also be considered as 'lost' volume from upper stems may not be readily apparent to a surveyor.

## CCF and site effects on stocking

When considering the effects of site quality on recruitment and timing of future volume production from a lower storey, ground conditions may be quite significant. On an apparently less fertile, wetter and unstable site (Clocaenog site 1) the most abundant conifer under-storey was recorded. This was due to the presence of a good mossy layer, and light and moisture levels being apparently quite optimal for natural regeneration of Sitka spruce. This may lead to bar volume being produced earlier on a 'poorer' site type than an apparently 'better' one.

**For details on the crops and standing volumes see Appendix 1**.

## Observations on the sawmill and grading trial.

The samples from the Coety site produced a very high proportion of grade 1 (18%) and grade 2 (69%) joinery material, consistent with Blanchard's observations.

| Grade | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Number of boards | 27 | 101 | 15 | 3 |
| Percentage of total | 18 | 69 | 10 | 2 |

Attempts were made to correlate branching score with grade score, with and without reference to the branching score.

| Branching score | Average grade score | D.O.B | Average grade score |
|---|---|---|---|
| 1 | 1.99 | 18cm t.d.o.b.<br>12cm b.d.o.b. | 1.99<br>1.99 |
| 2 | 1.89 | 18cm<br>12cm | 1.95<br>1.82 |
| 3 | 1.97 | 18cm<br>12cm | 2.1<br>1.83 |

Comparison of grade against branching score showed no apparent difference nor was there an apparent difference between top and bottom logs. We had expected fewer dead and occluded knots in the top logs but on this site all the timber was consistently good. On the basis of this limited survey it would appear that predicting the yield of joinery grade timber within the forest is not possible using these methods.

## Observations on the heat treatment trial of Welsh softwoods

The properties of heat-treated timbers are widely known but there is limited information available on the performance of heat-treated home-grown softwoods. All the species responded very well retaining good form without cracking.

**Results of the machining trials were as follows:-**

| Species | Subjective Score | Description |
|---|---|---|
| Sitka Spruce | 1 | Worse than untreated samples |
| Douglas fir | 3 | Better than untreated samples |
| Larch | 3 | Better than untreated samples |
| Noble fir | 3 | Better than untreated samples |
| Western Red Cedar | 4 | Much better than untreated samples |
| Pine | 5 | “Perfect” |

In all cases the clear timber in all species planed very well indeed, whilst the differences were in the behaviour of the knots. Spruce knots cracked and tore very easily and the resulting timber was unacceptable. A subsample of spruce was taken to Kenton Jones Ltd (Welshpool) to try the spiral cutters on their planing machinery but the damage to knots was no better. Much better results were obtained using a coarse thicknessing sander.

The enhanced durability of all species should enable them to be used in hazard class 3 applications like external cladding and joinery. The difficulty of machining spruce can be overcome by producing sawn cladding profiles prior to heat treatment with the option of light sanding to finish. The exceptional results obtained with pine are very encouraging. As well as external joinery and cladding HT pine is suitable for domestic flooring and some furniture. Further work is planned to look at the productivity and utility of pine in greater detail.

## Observations on the use of small diameter spruce

Small sections of spruce can be used in a wide range of carpentry and structural applications. Since it is a non-durable timber it should only be used in low hazard applications, for example internal joinery and carcassing. As an impervious timber it is very difficult to treat by methods that involve impregnation but applications such as external joinery and cladding which require only surface treatment will be acceptable. Heat treatment is a possible solution for some applications but the results suggest that other softwood species respond better to this treatment.

Standard Exterior Cladding

Novel cladding designs

Painted spruce window

Interior wall panelling

Laminate door

Ty Unnos Housing components

## Conclusions

The results of this survey have confirmed that a significant proportion of the sitka spruce crop contains joinery grade material 1 and 2 but no means of selecting this material in the forest was identified. The availability of this material is likely to increase if target dimension felling is adopted widely. This will apply to small dimension logs and in time to larger logs in longer retention. It will be for the sawmills to decide if and when to begin to select this material for higher value markets. Forest owners who are dependant on the supply chain are not likely to see any premiums for their raw materials until that happens.

**EUROPEAN REGIONAL DEVELOPMENT FUND**
**INTERREG III C**
**Community initiative on interregional co-operation across the entire EU territory and neighbouring countries**

## APPENDIX 1

## COMPARISONS WITHIN AND BETWEEN CASE-STUDIES

### 1) CEFN LLWYD – MEDIUM ELEVATION CCF vs. LT (both p.59)

| | CCF | Low Thin |
|---|---|---|
| Estimated Volume / ha | 300 $m^3$ | 530 $m^3$ |
| Current Log Vol./ha (18+ cm) | 285 $m^3$ (95%) | 488 $m^3$ (92%) |
| Current Bar Vol./ha (12-17 cm) | 12 $m^3$ (4%) | 32 $m^3$ (6%) |
| Current Chip Vol./ha (7-11 cm) | 3 $m^3$ (1%) | 10 $m^3$ (2%) |
| Mean Branch Score | 1.7 | 1.9 |
| Branch Angle **a** | 0 % | 0 % |
| Branch Angle **b** | 96 % | 80 % |
| Branch Angle **c** | 4 % | 20 % |

Bar availability is minimal under both systems due to the long thinning history and the high concentration of timber in the sawlog grades.

Both systems have produced high overall scores for form according to branching, with that in the continuous cover stand being slightly better than that in the light-thin stand (although as the sample size is relatively small in the CCF this difference may not be entirely significant).

Branch angle in the CCF stand has a higher concentration of scores in the middle grade 'b' and a lower concentration in the poorest grade 'c' than in the LT stand. Again this is likely due to more of the poorer-looking trees having already been removed through the heavier thinning of the CCF system.

### 2) CEFN LLWYD – MEDIUM ELEVATION - CCF vs. NT (both p.72)

| | CCF | NT |
|---|---|---|
| Estimated Volume / ha | 397 $m^3$ | 364 $m^3$ |
| Current Log Vol./ha (18+ cm) | 357 $m^3$ (90%) | 189 $m^3$ (52%) |
| Current Bar Vol./ha (12-17 cm) | 32 $m^3$ (8%) | 120 $m^3$ (33%) |
| Current Chip Vol./ha (7-11 cm) | 8 $m^3$ (2%) | 55 $m^3$ (15%) |
| Mean Branch Score | 1.7 | 2.0 |
| Branch Angle **a** | 6% | 6% |
| Branch Angle **b** | 82% | 76% |
| Branch Angle **c** | 12% | 18% |

Standing volumes are quite similar between systems, as would be expected.

CCF has led to a strong improvement of form according to branching - this would be expected as the poorest specimens would have been removed at an early stage.

CCF has resulted in a very large reduction in the standing volume of bar material – this is due to substantially increased mean d.b.h. and height growth in the remaining trees and a subsequent concentration of growth in the saw-log grades.

CCF may have had a slightly improving effect on branch angle, apparently giving less of the poorest '**c**' scores. The results may not be significant however, given the relatively low sample sizes – but 'poorer-looking' trees may well have been removed during thinnings. Also, is there a correlation between sharper branch angle and suppression in trees in a younger, dense plantation?

### 3) CWM BERWYN – 'UPPER LIMIT' CCF vs. NO THIN (p. 61)

| | **CCF** | **NT** |
|---|---|---|
| Estimated Volume / ha | 502 $m^3$ | 464 $m^3$ |
| Current Log Vol./ha (18+ cm) | 452 $m^3$ (90%) | 306 $m^3$ (66%) |
| Current Bar Vol./ha (12-17 cm) | 40 $m^3$ (8%) | 107 $m^3$ (23%) |
| Current Chip Vol./ha (7-11 cm) | 10 $m^3$ (2%) | 51 $m^3$ (11%) |
| Mean Branch Score | 1.8 | 1.8 |
| Branch Angle **a** | 23 % | 36 % |
| Branch Angle **b** | 64 % | 58 % |
| Branch Angle **c** | 13 % | 6 % |

Standing volume is not significantly different between the two systems.

Volume production in the bar grades is significantly higher (although not very high) in the no-thin system relative to the continuous cover system. CCF trees are slightly larger in terms of height growth, but substantially larger in terms of mean d.b.h. (greater stem taper would be expected given the exposure at these sites), so have a higher concentration of saw-log grades.

These two sites in this study were not assessed by the author. Both systems have been assessed with a mean branching score of 1.8, which is at the best end of the range recorded across all sites. The stem count in the no-thin system is 1250 per hectare (relatively low) suggesting a high level of self-thinning / mortality within the crop (this is also borne out by the Radnor high-elevation survey). The relatively low stem count in both survey areas at Cwm Berwyn may account for the similarity in form scores. However it ought to be considered that the assessor here was relatively inexperienced in this new scoring method and has probably scored the sites higher than would the Author. There may be more value here in comparing scores just between the Cwm Berwyn NT and CCF sites and not between this and other studies.

Beneficial branching form effects from thinning design may not be so pronounced at this elevation and WHC as at lower or less exposed sites. CCF thinning at Cwm Berwyn has proceeded in a 'what is possible' manner (according to localised site conditions), as compared to the more 'systematic' thinning carried out at all of the other lower elevation / lower WHC sites.

4) **CLOCAENOG – MEDIUM ELEVATION CCF vs. CCF vs. CCF**
**Same Uniform Shelterwood System – Different Site Quality (x3)**

| | **CCF**<br>WHC 2<br>390 m<br>Wet | **CCF**<br>WHC 3<br>410 m<br>Dry | **CCF**<br>WHC 3<br>370 m<br>Dry & more fertile |
|---|---|---|---|
| Estimated Volume / ha | 555 $m^3$ | 482 $m^3$ | 479 $m^3$ |
| Current Log Vol./ha (18+ cm) | 538 $m^3$ (97%) | 463 $m^3$ (96%) | 464 $m^3$ (97%) |
| Current Bar Vol./ha (12-17 cm) | 11 $m^3$ (2%) | 14 $m^3$ (3%) | 10 $m^3$ (2%) |
| Current Chip Vol./ha (7-11 cm) | 6 $m^3$ (1%) | 5 $m^3$ (1%) | 5 $m^3$ (1%) |
| Mean Branch Score | 2.1 | 2.1 | 1.8 |
| Branch Angle **a** | 0 % | 0 % | 0 % |
| Branch Angle **b** | 83 % | 71 % | 100 % |
| Branch Angle **c** | 17 % | 29 % | 0 % |

No very significant difference in terms of standing volume between the three sites, although the wetter but more sheltered site is probably more productive in terms of yield class and this may be reflected in the estimate of current standing volume.

Again, bar volumes are minimal in this age of crop under either system – and are probably limited to the upper canopies and subject to heavier branching and any crown damage.

There does appear to be a moderately poor score for form according to branching on both of the former heath and heath / grass mosaic sites, and a substantially better one for the more fertile, lower-lying and better drained site. It should be noted however that this site is somewhat easier to harvest than the other two (although not by a great deal) and previous thinning operations could have been able to be more selective here.

Branch angle is not significantly different in the two higher sites, but there is a noticeable lack of any in the poorest grade 'c' at the lower site. This again may infer that accessibility has led to greater selectivity during previous thinnings - perhaps a more influential factor on current form than site effects.

## 5) TRALLWM – MEDIUM ELEVATION CCF vs. CCF
## (Group Shelterwood CCF vs. 'Frame Tree' CCF)

| | Group | Frame Tree |
|---|---|---|
| Estimated Volume / ha | 394 $m^3$ | 397 $m^3$ |
| Current Log Vol./ha (18+ cm) | 359 $m^3$ (91%) | 365 $m^3$ (92%) |
| Current Bar Vol./ha (12-17 cm) | 27 $m^3$ (7%) | 24 $m^3$ (6%) |
| Current Chip Vol./ha (7-11 cm) | 8 $m^3$ (2%) | 8 $m^3$ (2%) |
| Mean Branch Score | 2.0 | 1.8 |
| Branch Angle **a** | 18 % | 17 % |
| Branch Angle **b** | 73 % | 73 % |
| Branch Angle **c** | 9 % | 10 % |

Both CCF systems have produced nearly identical standing volumes of timber and identical assortments in the bar grades.

The 'Frame Tree' CCF system has been assessed with a significantly higher mean branching score than the 'Group Felling' CCF system. This would be explained by a higher degree of thinning selectivity being employed within the 'Frame Tree' system, as opposed to the more non-selective strategy of opening up larger areas in the 'Group' system. Also, within a 'Group' system there are more edges exposed (around the clear-felled patches), and hence branching in the adjacent trees will become coarser – depressing form scores.

As with all systems assessed, there is an overwhelming concentration of trees in the middle branching category 'b'. Again, these sites were not assessed by the author and there appears to be an unlikely proportion of trees in the 'best' branching category 'a' (virtually flat branching throughout). The inherent subjectivity experienced in using and interpreting this method is discussed below.

## 6) RADNOR FOREST – MEDIUM TO HIGH ELEVATION
## Low Thin vs. No Thin at Three Elevations

**Medium Elevation – 415 m a.s.l. (WHC3)**

| | No Thin | Low Thin |
|---|---|---|
| Estimated Volume / ha | 314 $m^3$ | 366 $m^3$ |
| Current Log Vol./ha (18+ cm) | 129 $m^3$ (41%) | 216 $m^3$ (59%) |
| Current Bar Vol./ha (12-17 cm) | 135 $m^3$ (43%) | 106 $m^3$ (29%) |
| Current Chip Vol./ha (7-11 cm) | 50 $m^3$ (16%) | 44 $m^3$ (12%) |
| Mean Branch Score | 1.8 | 1.8 |
| Branch Angle **a** | 2 % | 8 % |
| Branch Angle **b** | 73 % | 74 % |
| Branch Angle **c** | 25 % | 18 % |

**Medium-Higher Elevation – 505 m a.s.l. (WHC 3)**

| | No Thin | Low Thin |
|---|---|---|
| Estimated Volume / ha | 298 $m^3$ | 323 $m^3$ |
| Current Log Vol./ha (18+ cm) | 128 $m^3$ (43%) | 207 $m^3$ (64%) |
| Current Bar Vol./ha (12-17 cm) | 122 $m^3$ (41%) | 87 $m^3$ (27%) |
| Current Chip Vol./ha (7-11 cm) | 48 $m^3$ (16%) | 29 $m^3$ (9%) |
| Mean Branch Score | 1.9 | 1.9 |
| Branch Angle **a** | 6 % | 4 % |
| Branch Angle **b** | 77 % | 80 % |
| Branch Angle **c** | 17 % | 16 % |

**High Elevation – 590 m a.s.l. (WHC 3)**

| | No Thin | Low Thin |
|---|---|---|
| Estimated Volume / ha | 295 $m^3$ | 281 $m^3$ |
| Current Log Vol./ha (18+ cm) | 159 $m^3$ (54%) | 155 $m^3$ (55%) |
| Current Bar Vol./ha (12-17 cm) | 98 $m^3$ (33%) | 87 $m^3$ (31%) |
| Current Chip Vol./ha (7-11 cm) | 38 $m^3$ (13%) | 39 $m^3$ (14%) |
| Mean Branch Score | 2.2 | 2.1 |
| Branch Angle **a** | 5 % | 2 % |
| Branch Angle **b** | 89 % | 95 % |
| Branch Angle **c** | 6 % | 3 % |

Volume production has not differed greatly between the upper and lower sites. It should be noted however that thinning in the lowest site has had some effect of increasing standing volume, where at the highest site is had significantly decreased standing volume. This effect is important and it should be noted that previous thinning strategy at the higher, more difficult (and economically more marginal) site has probably intended to remove the larger more valuable stems – whereas the thinning strategy lower down has (more conventionally) sought to concentrate growth in the better stems)

Volume production in the bar grades is still relatively high in this age of crop, with a relatively narrow range between the systems and elevations – except in the medium to high elevation LT site where it is reduced to about 50% of that in the NT site. It is likely that the most recent thinning here has removed much of the standing volume assorted to bar grades, and thinning has promoted growth in remaining trees and thereby increased their proportion in the sawlog grades.

Form (by branching) has been assessed as relatively good at the lower and medium to higher elevation sites – with no difference between NT and LT regimes. Although elevation is quite high for both sites, there is a reasonably good degree of shelter present (see comment on WHC below).

Form at the high elevation site is significantly poorer than at both lower sites, with probably no significant difference between NT and LT regimes. Note that there has been a significant amount of natural mortality / self thinning in the high elevation NT site, which has had the effect of reducing stocking to fairly close to that of the LT area.

Although the upper two assessment areas are at quite substantial elevations, Radnor Forest is situated in quite an 'inland' location, and windthrow hazard is estimated by the Foresty Commission at '3'. Local yield classes are also better than may be expected in Welsh woodlands situated further west and north. There should be some caution therefore in comparing with other future survey sites, if based purely on elevation of skyline exposure.

## Appendix 2

**TESTING OF BRANCH SCORING METHOD – DIFFERENT OPERATORS**

### Radnor Forest, Medium Elevation - Light Thin Area

Although the branch scoring method is designed to be relatively simple, there will always be an inherent degree of subjectivity involved when it's used by different operators. In order to test the method and get an impression of likely differences in scoring, the same stand off trees (though at different plot locations) was assessed by a skilled forest craftsmen and secondly by the author.

The stand was Survey Area 1 – medium elevation (415 m a.s.l.)

The craftsman was initially accompanied in the stand, and instructed in the method by the author and issued with the latest score card. He was then left to complete a survey of 10 plots (totalling 0.1 ha) assessing both branching score and branch angle score. The results were as follows:

…………………………………………………………………………………….

| | | | | |
|---|---|---|---|---|
| Mean branch score | Author | 1.8 | | |
| Mean branch score | Craftsman | 2.1 | | |
| | | | | |
| Branch angle | Author | 8% a | 74% b | 18% c |
| Branch angle | Craftsman | 2% a | 83% b | 15% c |

……………………………………………………………………………………..

Although the difference in assessment of branch angle is fairly insignificant, the comparison has led to quite a startling variance in branch score.

The Craftsman has assessed the stand to be far poorer in terms of branching than the Author, in fact has submitted a mean score similar to the Author's assessment of the poorest-formed stand at the highest location (Survey Area 3). Reasons for this are likely to have been unfamiliarity with the method (it was the Craftsman's first attempt), and perhaps a degree of expectation on the part of this operator that the data should conform to a likely distribution.

In any event this discrepancy probably highlights the need for a greater degree of training and consolidation with new operators, rather than brief instruction and issuing with a score card, and should be considered as a potential limitation on the method.