



# Forest Research

An agency of the Forestry Commission

***TECHNICAL DEVELOPMENT***

## Operational Experience of Continuous Cover Forestry: UK Case Studies

INTERNAL PROJECT INFORMATION NOTE 13/06



Ref. No:

1200S/36/05 & FR06047

Author:

Duncan Ireland (with support from Gary Kerr and Bill Mason)

Date:

September 2006

## Operational Experience of Continuous Cover Forestry: UK Case Studies

### EXECUTIVE SUMMARY

#### Project objective

The objective of the project was to:

Visit each of the Forestry Commission CCF trial sites and describe operational methods and highlight any problems or solutions that could be of wider practical value. In addition, the information sources used in the management of the sites were assessed and any deficiencies highlighted.

#### Operational experience

1. At each of the trial forests the change from conventional thinning of even-aged stands to transformation thinning has been achieved with only minor modifications to practice, largely using the same harvesting methods and systems as conventional silviculture.
2. Areas where FCIN40, 45 and other methods have been used to collect base information have shown that the investment has been worthwhile, notably at Wykeham. In contrast where some base information is unavailable, such as limited soil information in Cowal and Trossachs FD, there have been difficulties in implementing the stratification process in FCIN40.
3. In general, there is a lack of experience of managing stands in which advanced regeneration is present and consequently confidence is low. There are operational, silvicultural, productivity, protection and safety aspects of managing these stands that require further investigation (see 12).
4. Managers have been adaptive and innovative in solving specific problems at each site but frustration was expressed by some managers that there are no formal mechanisms for information sharing between the trial sites. Recent developments since the site visits took place including the re-instatement of the GB Alternatives to Clearfell (ATC) Group have attempted to improve this situation.
5. Problems with continuity of management have been minimised through good record keeping. Wykeham is a good example; management plan and monitoring information has been produced, stored and is easily accessible. In some areas difficulties have arisen with ease of access to management records where paper based systems have been used historically, so while thorough information exists it is not conveniently searchable and accessible, such as in Scottish borders FD.
6. Managers do not regard natural regeneration as the only option for restocking in transformation and in Glentress, Cowal and Trossachs FD and Morangie forest, planting has been used as a method of regeneration. There is a desire for more guidance on planting trees in non-clearfell situations.
7. Many monitoring systems are currently in use, some locations are using the procedure outlined in FCIN45 (Wykeham and in Northwest England) whilst other Districts were using a variety of local systems, which were integrated into the management process in varying degrees.
8. The move to CCF will mean that larger tree sizes will become more common as trees are felled beyond the age of maximum MAI. There is uncertainty about how to manage operations in these crops, particularly where there is a dense understory of natural regeneration, although experience is increasing as is the case in Fernworthy forest and in many of the trial forests in Wales.
9. Brash management was not the problem that many people had thought at the outset of transformation. Where low load bearing ground conditions had been limiting to machine movement, innovative methods to support machine movement have been developed, Cym Berwyn is a good example.

10. A consistent problem cited by managers is a lack of skilled operators to carry out felling and management operations, particularly in adverse site conditions such as steep ground extraction. Lack of skilled operators was expressed as a problem at nine of the trial sites.
11. Local markets vary and have considerable influence on the economics of transformation thinning, both in absorbing volume of small dimension produce from first thinning and also allowing large dimension timber to be marketed from later thinning. The development of a large-scale woodfuel market near to Wykeham has created a market for small dimension first thinning material, improving the economics of early transformation felling. At many of the trial sites (Fernworthy, Clocaenog, Cowal and Trossachs) large tree sizes are becoming increasingly common under CCF and while markets exist for this material the volume that they can absorb is likely to be limited.
12. Working in stands with advanced regeneration has raised concern about difficulties with deer control, due to reduced visibility due to presence of natural regeneration and at Wykeham from 'snaking' racks through the stand rather than creating straight 'tunnels' which are less attractive from a visitor perspective. At Wykeham deer lawns have been created in an attempt to alleviate the problem of reduced visibility for deer control. Concerns were also expressed over reduced operator visibility within the crop due to dense natural regeneration and the subsequent potential risk to recreation users of the forest, approaching machines unknown to the operator (views expressed at Wykeham and in Northwest England Forest District).
13. There were some general misconceptions about the different thinning prescriptions required to achieve simple and complex structures, i.e. frame tree and seed tree were used as synonymous terms.
14. Different approaches to marking were observed; in some forests site and crop conditions prevented feller-select requiring marking of trees for removal, typically the case at Fernworthy and Morangie Forest. Elsewhere feller-select had been used to good effect in transformation thinning (as was the case at Clocaenog, Cym Berwyn, Inshriach and Craigvinean and Glentress); often at the trial sites a sample was marked to provide a reference for thinning the stand.
15. There were significant information gaps regarding the respacing of natural regeneration. Guidance on appropriate management of regeneration is urgently needed. Fernworthy and Clocaenog planned to respace natural regeneration in the interests of future tree quality.
16. Feedback from several of the trial sites was that removal of larger tree sizes during transformation thinning had increased the proportion of timber products in the larger product categories which improved the economics of thinning, as reported in the trials at Wykeham and Cym Berwyn.
17. Concern was expressed in Cowal and Trossachs FD over the wide species and size class mixture that was developing under transformation causing complications with yield modelling.
18. Vertical integration of the workforce was a common theme at all the trial forests, with managers and operators showing a strong interest in the silvicultural techniques in use. Managers and operators have developed a shared enthusiasm and efficiency for working in transformation stands.
19. There was general confirmation that the adoption of CCF is management objective driven, rather than because it was a 'good thing to be doing'. Specifically managing stand structure at Morgangie and Inshriach forests to provide habitat for Capercaillie and at Clocaenog for Red squirrels. Objectives sought to maintain forest cover for recreation at Glentress as well as preserving landscape character at Fernworthy and Craigvinean. Management experience across the trial sites suggests that transformation forests are well suited to provide for a wide range of management objectives.
20. Success of transformation to CCF silviculture was greatest where there had been a significant long-term commitment, sustained over a period of time e.g. at Glentress, with the other trials showing excellent potential for successful transformation.

## **Recommendations**

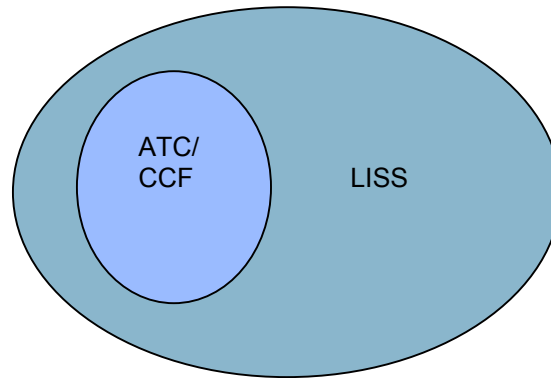
This report has identified a wide range of issues surrounding the management of CCF, many of these are fundamental difficulties facing the whole forest industry linked to markets and availability of skilled operators. However, the project has also highlighted a number of areas where there are information gaps or problems that could be solved by better communication or improved procedures. The following recommendations are offered based on the findings of the project.

- a) Guidance on the management of established natural regeneration is a priority. Silvicultural guidance is required on if, when and how to intervene as well as operational aspects of carrying out the job, particularly when there is a managed overstorey.
- b) The FC trial areas have each developed methods of management planning, monitoring and operations; in many cases the approach to the latter has been innovative. However, there is no forum for information exchange between the trial sites and it was clear that many managers would welcome the opportunity for better communication with colleagues facing the same issues.
- c) Experience from the trial sites has shown planting to be a useful and effective means of regeneration during transformation. Most written guidance available to managers refers to restocking and there is confusion about best practice for underplanting. Further underplanting guidance is required for managers and this should be incorporated into future research outputs.
- d) Many of the techniques developed by the staff in the trial forests have identified useful modifications in working practice to achieve transformation under difficult operating conditions. Many of these methods should now be formally evaluated to determine their efficacy and cost implications to inform operational best practice.
- e) There is a lack of clarity about different types of thinning regimes to produce simple and complex structures and better guidance on crown thinning would be welcomed by many managers in the trial sites and probably elsewhere.
- f) More work is required on the impacts of larger trees and different assortments of products from transformation thinning on wood supply and the forestry industry.
- g) Some managers expressed concern about the lack of suitable yield models for transformation and CCF scenarios. This has been identified as a priority for Forest Research.
- h) There was considerable variation between trial sites concerning the methods of monitoring that were being used, some used FCIN45 and others used other procedures. At a time when everyone is on a steep learning curve it would be advisable to standardise an approach to monitoring.

## INTRODUCTION

CCF is an approach to management that suits current requirements to increase species and structural diversity in forests to provide for multi-purpose objectives. For example, the United Kingdom Woodland Assurance Scheme (UKWAS) requires forest managers to 'increasingly favour' lower impact silvicultural systems (LISS) in windfirm conifer plantations (UKWAS, 2000: section 3.4.4.). The appropriate silvicultural systems for meeting this requirement are defined as 'group selection, shelterwood or under-planting, small coupe felling systems, minimum intervention and single tree selection systems'. For the purposes of this report, CCF is considered to be synonymous with 'alternatives to clearfelling' (ATC), a term widely used in the Forestry Commission (FC).

The interrelationship between CCF, ATC and LISS is shown in the diagram below.



Continuous cover forestry is not well established in the UK and experience is therefore limited. CCF is more common in continental Europe, however, differences in resources, species, climate and past management of UK forests mean that European management practices cannot be directly transposed to the UK; management techniques require modification and development to suit UK conditions.

The majority of forests in the UK are composed of non-native conifers in even-aged plantations. In order to move the stand structure towards CCF there is usually a 'transformation' period, during which management aims to increase structural diversity. Many forests in the UK where CCF management is being attempted are currently undergoing this transformation phase.

To help improve understanding of CCF management in the UK the Forestry Commission has established 11 trial forests to demonstrate CCF transformation and management throughout the UK on a large scale (c. 500 ha). The selection of trial sites has attempted to represent the major species grown in the UK, over a variety of site types. The trial sites allow a demonstration of the management, economic, social and environmental benefits of CCF.

This report focuses on operational experience in the Forestry Commission CCF trial sites. Information is included on operational methods and systems, problems and solutions as well as information on a range of related issues concerned with making the change to wider usage of CCF. This study has also gathered feedback from managers on the information sources currently available for CCF transformation and outlines where information gaps currently exist.

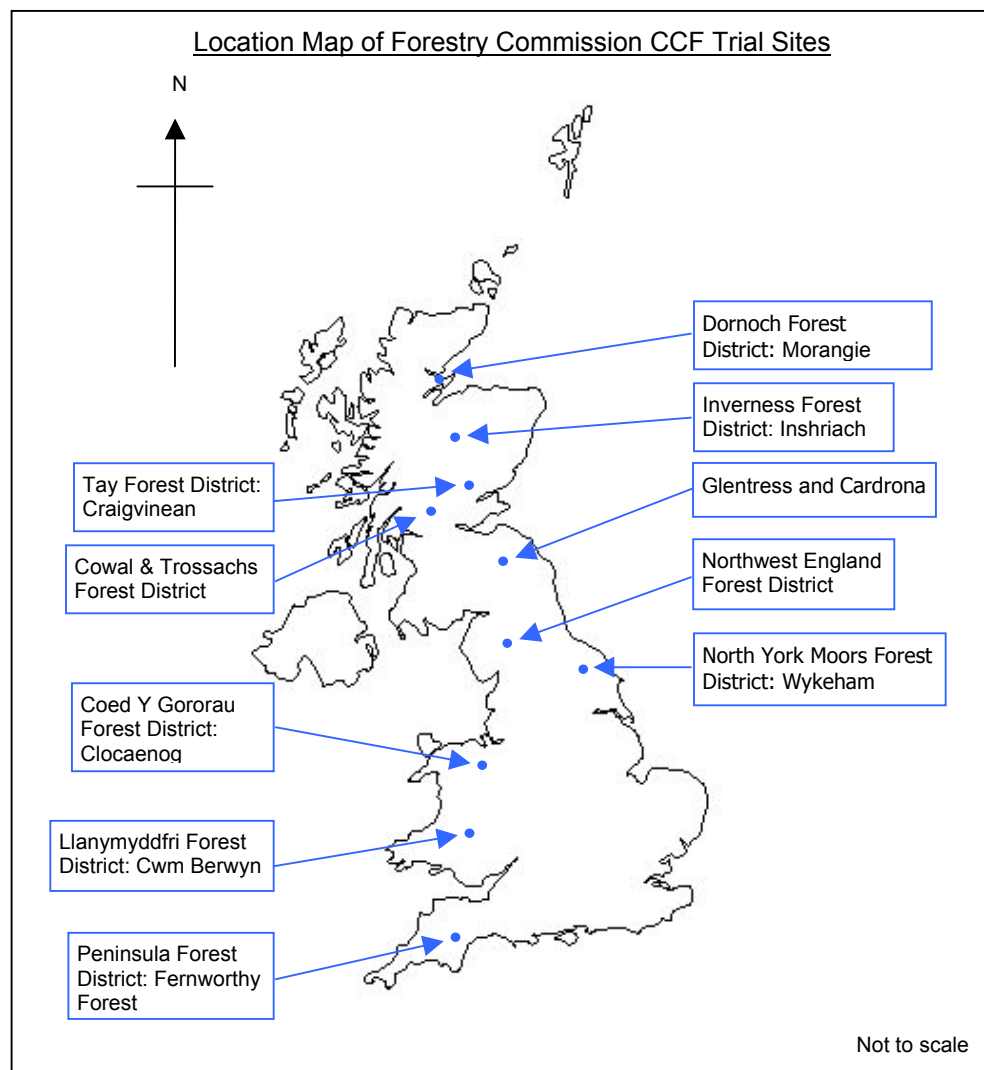
Many of the techniques described in this information note have not undergone detailed field evaluation and this will be required to investigate their full efficiency and cost implications.

## SITE VISIT REPORTS

The FC CCF trial sites were visited between October 2005 and January 2006 and information gathered on operational experience to date, the information collected has been distilled into the case studies in this report.

### Case Study Site Visits

• North York Moors Forest District: Wykeham	Page 06
• Northwest England Forest District	Page 11
• Peninsula Forest District: Fernworthy Forest	Page 15
• Coed Y Gororau Forest District: Clocaenog	Page 19
• Llanymyddfri Forest District: Cwm Berwyn	Page 23
• Scottish Borders Forest District: Glentress/Cardrona	Page 29
• Cowal & Trossachs Forest District	Page 33
• Inverness Forest District: Inshriach	Page 36
• Tay Forest District: Craigvinean	Page 40
• Dornoch Forest District: Morangie	Page 45





## NORTH YORK MOORS FOREST DISTRICT: WYKEHAM

Wykeham is located in North Yorkshire, England, managed under North York Moors Forest District. Site and Stand details for Wykeham are shown in Table 1.

Table 1. Wykeham Site and Stand Condition Summary

Area	Total area of forest at Wykeham is 1113 ha. The site has been assessed for suitability for transformation and this showed that 375 ha (34%) has good potential for transformation to CCF; 315 ha (28%) as moderate and 178 ha (16%) as low (this was done using the method in FCIN 40)
Terrain	Terrain is split between plateau and sloping valley sides, access on the plateau is good, the steeper valleys are in places only likely to be accessible by winch extraction
Soil Type	Predominantly iron pan soils, banded to the north with brown earths and gley soils
Windthrow risk	In the Wykeham ATC area WHC is predominantly 2 with some areas in classes 1 and 3
Limiting site factors for CCF	Terrain limits working method on steeper valleys. Currently browsing has not been a limiting factor for the establishment of natural regeneration, however some fraying damage can be seen on natural regeneration. Wildlife rangers have expressed the need to plan for deer management within CCF to prevent establishing a forest structure that hinders deer control to the extent that damage levels threaten successful regeneration.
Species mix	Generally Larch, pine and broadleaf species on iron pan soils with fir and spruce on brown earths and gleys
Age range	P year ranges from 1940's and 50's, through the 1970's, younger crops p 80's and 90's have been omitted from the original assessment
Tree size	Variable and interspersed with strong advanced natural regeneration in some stands
Yield Class	YC ranges with site conditions and species (typical range: YC 4 to 20)
Limiting stand factors for CCF	Limiting factors have been avoided through thorough stratification of site suitability to CCF, following FC IN 40. Efforts are targeted on sites assessed as having high to moderate potential for transformation under FCIN 40.
Selection criteria for CCF	The forest was selected for transformation following input from the ATC Steering Group, highlighting its potential for CCF. Local managers consider CCF as the best option to achieve the management objectives. A management plan has been written to cover the transformation to CCF, dividing the trial site into five zones that will be worked, one per year on a five year rolling rotation.

### CCF Management

Primary management objectives at Wykeham are timber production, conservation and recreation. Wykeham has been stratified for suitability to CCF following Forestry Commission Information Note 40 and subsequently mapped to show areas with good, moderate and low potential to transformation to CCF. Following this assessment and an inspection on the ground the 'good', 'moderate' and 'low' stands have been selected for transformation. First thinning involves establishing racks at c. 15 – 18 m spacing, thinning the matrix at the same time. Later thinning is to a prescribed basal area guided by the FC thinning control system. Where a simple structure is aimed at tree selection is for c. 100 seed trees per ha. Where a complex stand structure is aimed at the number of frame trees will be 40 – 50 per ha. The thinning control system has been used to control basal area in first thinning.

In one stand 'herringbone' thinning has been trialled, as shown in Figures 5 and 7. Felling to waste has been used in some areas of the forest to encourage broadleaf regeneration as part of PAWS restoration, this has been achieved with the assistance of grant funding from English Nature. In the long term the forest will be managed under uniform and irregular shelterwood silvicultural systems. To date transformation thinning has involved frame tree and crown thinning.

### Operational Experience

To date all CCF transformation felling has been done with harvester and forwarder combination, with some skidding on steeper areas. In the operation shown in Figure 1 felling was done by a Ponsse HS16 harvester with a Valmet 830 forwarder. Elsewhere the machine combination was a Timberjack 1270 harvester and Timberjack 810 forwarder. There are few practical operational differences with conventional thinning, the major difference is the additional resource input in gathering monitoring information pre and post felling.

No specific harvesting difficulties or problems have arisen in transforming to CCF on the plateau. This is mainly due to appropriate stratification, however, there may be more problems when felling is attempted on the steeper slopes and valleys.



Figure 1 Formerly windblown stand with abundant natural regeneration



Figure 2 Rack through stand where regeneration has been cut to allow harvester access



Figure 3 Advanced regeneration of larch



Figure 4 Deer fraying damage to regeneration in stand thinned on herringbone pattern (see Figure 7)

Areas are typically sold as standing sales with one area felled using direct production. Harvesting on contract has been carried out to a high standard. Local staff have taken time to discuss the prescriptions applied and the reason behind the management and local staff report a good response from contractors. Difficulties have arisen obtaining specialised labour for steep ground working, either skidder or cable way teams. A site plan is drawn up and given to the operators showing felling area, constraints including archaeological features, roadside stacking space, access and working direction. Other information given to contractors includes risk assessment and a written description of the felling specification as well as rack spacing and intensity. Large tree sizes are not currently causing problems with marketability of timber.

Costs of felling and extraction are not significantly greater than thinning and clear felling, however there is an additional input required to collect pre-felling information (mainly the size and distribution of regeneration).

Access has not been a problem and soils are sufficiently load bearing to allow machine movement; on the valley sides soils change to gleys and can be wet and may cause problems with future management. The lower slopes run into a watercourse that is a tributary of the river Derwent; operations need to be cautious of runoff to make sure that siltation does not occur (consult with FC Water Guidelines for further information).

While travelling on the racks regeneration has been cut by the harvester to allow harvester access, this has been achieved by gripping the regeneration with the felling head and pulling the stems out of the ground. The resulting 'ripped' stems can be seen in the racks in Figures 1 and 2. The regeneration in the racks was too small and whip-like to be felled conventionally and this has proved to be an effective method.





Figure 5 Marker post showing the layout of formal herringbone thinning through a stand of larch and Scots pine



Figure 6 Rack cut through Douglas fir on steep ground showing some stems that may have been felled to waste in the past

Racks imposed on a permanent layout are at a similar spacing (c. 18 m) and specification as conventional clearfell and restock silviculture. Racks in transformation thinning are 'snaked' through the crop to prevent racks forming long, visually unattractive tunnels through the forest.

In one stand thinning was laid out using a herringbone pattern to impose a framework for thinning on the stand. Main extraction racks were established at 170m spacing with herringbone racks plotted from the main rack network at a spacing of 15m (Figure 7). The thinning was done with motor manual felling and skidder extraction. Operational experience revealed drawbacks to this system. Firstly, skidding whole tree lengths could lead to debarking of the remaining crop trees as the lengths were skidded around the tight angles on the herringbone pattern. Secondly, laying out the herringbone pattern was labour intensive and took a long time to plot and mark with stakes prior to thinning as shown in Figure 5. Subsequent thinning in this stand will revert back to standard racking at 18 m spacing.

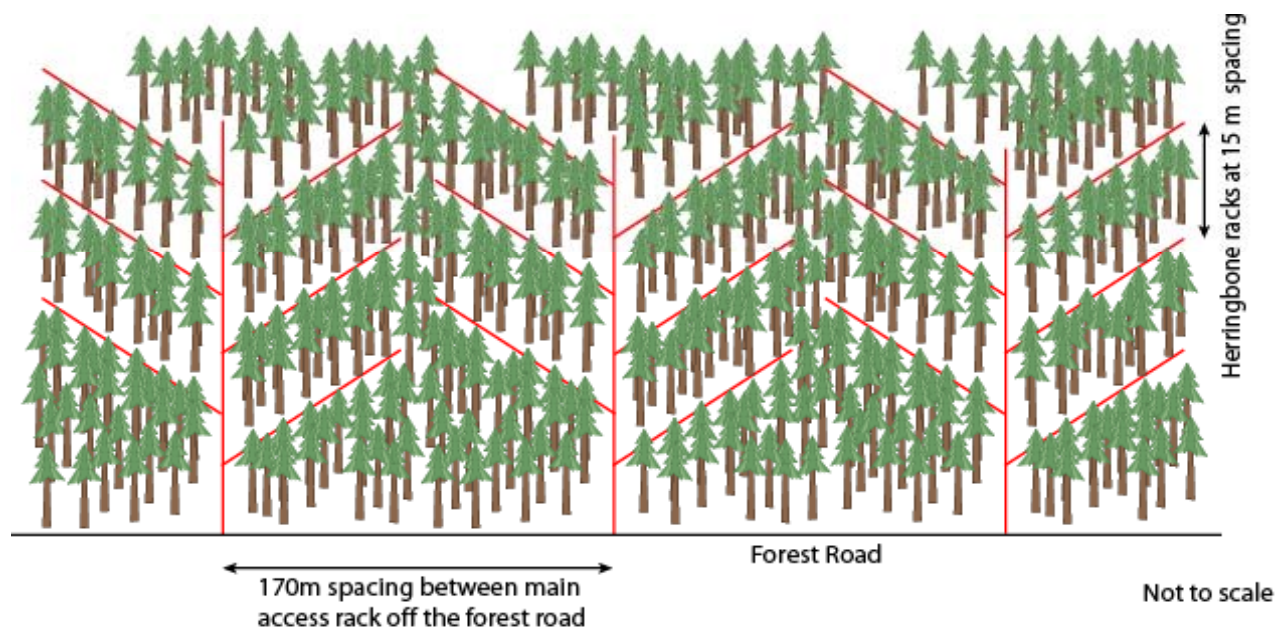


Figure 7 Herringbone racking as a systematic thinning method

In a recent first thinning access was modified by constructing a brash 'relief road' or key route (shown in Figure 8). This was constructed to run roughly adjacent to the forest road and allowed machines to travel within the stand, preventing degradation to the road surface. The key route allowed the turning angle from the rack to the road to be reduced, the lower turning effort of the forwarder resulting in less degrade of the road surface through the action of the forwarder and harvester wheels, see Figure 10. Preserving the condition of access through the forest is very important for CCF, where access will be required into perpetuity.



No additional cost was incurred from the construction of the key route there was additional income received from the felling involved and potential road reinstatement cost were avoided through preventing the aggressive turning movement of harvesting machinery at rack: road junctions.



Figure 8 Brash 'key route' constructed at an acute angle to main forest road



Figure 9 Surface of brash 'key route' with racks connecting from the main part of the stand on the left

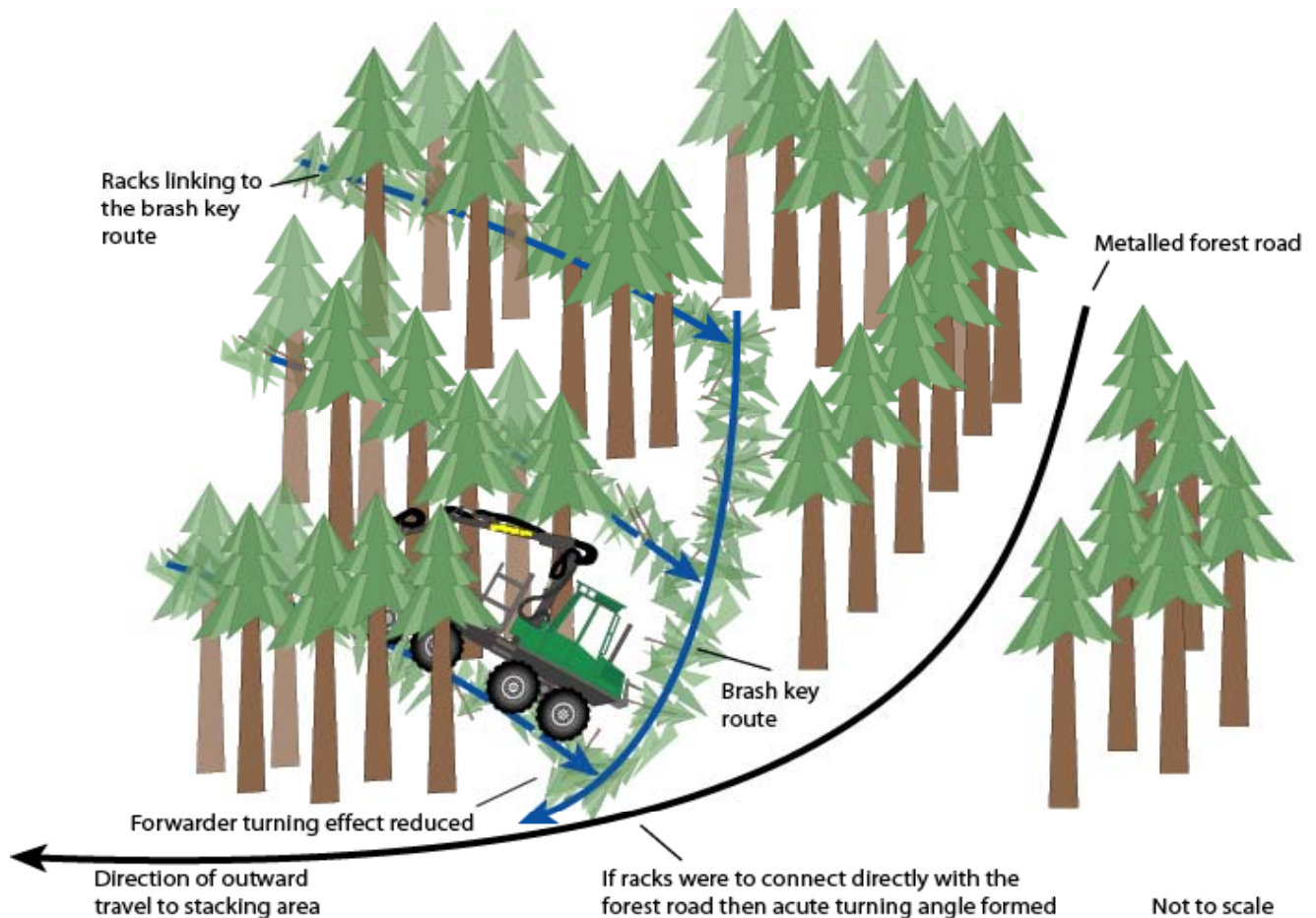


Figure 10 Construction of brash 'key route' linking racks to the main forest road.

## Brash Management

To date quantities of brash have been adequate for rack construction and future brash supply is not anticipated to be a significant problem.

## **Problems, Causes and Solutions**

On some sites there are felling restrictions due to schedule one bird species, this precludes work between March and August.

Marketing of products has not been a problem; product specifications are consistent with standard thinning. Markets in the area are good, particularly so for first thinnings. The Sempcorp plant near Middlesbrough will take large quantities of chip-wood for wood fuel combustion, significantly improving the economics of thinning.

In order to maintain communications between other foresters involved with the pilot sites annual meetings are held which involve the other Districts in England managing trial sites as well as representatives from Forest Research.

During mechanised access in a recent first thinning, where the forwarder has travelled along racks where ploughing has been carried out in the past as a means of ground preparation the ground has an undulating profile. Where the forwarder has travelled along this undulating ground profile the machine is pitched over to one side with the result that the forwarder bolsters have unavoidably skinned (debarked) some rackside trees. This problem could be alleviated if some flexibility in tree selection can be incorporated into thinning to allow damaged trees to be removed.

Wildlife rangers have expressed concerns that deer control in CCF is likely to be hampered by poor visibility through the stand due to natural regeneration. There is fraying damage to regeneration as shown in Figure 4, however this is not anticipated to be a significant problem with deer glades created to provide an opportunity for culling.

## **Feedback on Guidance and Information Gaps**

Local staff report positive feedback of FC publications. OGB 7 has been a good reference with a very structured approach. Feedback on OGB 7 is that it is a useful means of formalising planning, helping to clarify the objectives and give structure to the management process. The stand stratification for suitability to CCF outlined in IN 40 has also been carefully followed at Wykeham with positive results. The transformation process at Wykeham is undergoing continual monitoring using FC forest craftsmen, the monitoring process in IN 45 being used for stand monitoring. There is good transfer of data collected between Forest Research and the Forest District with information being passed between the two for the benefit of each.

No information gaps reported to date.

## NORTHWEST ENGLAND FOREST DISTRICT

Northwest England Forest District manages a number of forest areas under CCF principles including Whinlatter, Wythop, Dodd, Lowther Park and Ennerdale forests.

Table 2. Northwest England Forest District Site and Stand Condition Summary

Area	1226 ha at Whinlatter, Wythop Wood: 275 ha, Dodd Wood: 300 ha, Lowther Park: totalling 339 ha with 50 ha designated as CCF (15%) and Ennerdale totalling 851 ha with 548 designated under CCF (64%).
Terrain	In many areas there is an adequate access network for forwarder and harvester travel, but steep slopes in many areas are a limiting factor. Steep sites represent the most significant access difficulty for harvesting due to the lack of operators and resources for steep ground working.
Soil Type	Variable across the District, brown earths are typical in many CCF transformation areas
Windthrow risk	CCF is deliberately concentrated on low wind hazard class areas, generally WHC 1 and 2 with a maximum of 3
Limiting site factors for CCF	Steep slopes in places requiring cable way extraction or skidder working
Species mix	Species mix typically includes Douglas fir, Sitka spruce and larch with a component of mixed broadleaves (there is a desire to promote the proportion of broadleaves where CCF transformation is being attempted).
Age range	Ranges throughout the Forest District
Tree size	Ranges throughout the Forest District
Yield Class	Typically Douglas fir achieves YC 10 – 18 and Sitka spruce YC 6 – 24
Limiting stand factors for CCF	Stand factors generally not limiting – FCIN 40 use to guide selection of appropriate stands for transformation
Selection criteria for CCF	CCF has been attempted where best suited to meet management objectives, controlled and implemented through the management planning process.

### CCF Management

CCF transformation is being carried out at a number of forests throughout Northwest England Forest District. Establishing a stable crop through regular thinning is recognised as a priority allowing flexibility when selecting future silvicultural systems. There is a desire in the District to ensure that areas under CCF management are sufficiently large to make them economically thinnable rather than small fragmented blocks.

Transformation to CCF is guided by management objectives which aim to produce a balance of landscape, public access, watercourse habitat functions and timber production. In CCF transformation timber production is usually a lower priority objective. FC IN 40 has been used to stratify stands for suitability to CCF, those where transformation is being attempted are classed as good to moderate.

### Operational Experience

The transformation process involves first and second thinning prescriptions consistent with regular silviculture (as would be the case with clearfelling); later thinnings aim to increase stand structural diversity, appropriate for CCF. Management of CCF is not solely reliant on natural regeneration; Douglas fir at Wythop has been successfully regenerated through group felling and planting.

When marking later thinning interventions frame tree thinning has been used to encourage within stand irregularity. Frame trees are selected on the basis of tree stability and quality based on crown development. The frame tree thinning approach gives good structure to marking, removing some of the deliberation of conventional thinning. Knowing that frame trees will be established at an approximate set distance (c. 10 m apart throughout the stand) helps to speed up tree selection, therefore time difference for marking compared to a standard thin is negligible.

During recent thinning frame trees have been marked with green bands and competing trees for removal marked with contrasting orange paint. Frame tree thinning aims to promote the frame tree crown development and reduce stand basal area to encourage natural regeneration. FC Information Note 63 (*Managing Light to Enable Natural Regeneration in British Conifer Forests*) has been used to inform thinning intensity. Harvesting is carried out on contract using Harvester and Forwarder combinations where slope is not limiting to mechanised access. On steeper sites motor manual felling with tractor skidding is necessary, pairing the skidder with 2-3 fellers. Typical skidder winch line reach is 50 – 60 m. Currently (2006) chainsaw felling with skidder extraction in first to third thinnings using contract labour under direct production costs from c. £ 1000 to £1500 per hectare.





Figure 11 Well constructed culvert, instated prior to harvesting through consultation with FC Civil Engineering



Figure 12 Cut-off drain viewed from down-slope

In mature crops (Douglas fir and Sitka spruce, mean tree size 0.75 to 5 m<sup>3</sup>) where regeneration has become established careful skidding and directional felling are required to avoid damaging groups of regeneration and the remaining crop trees. Tractor skidding typically requires wheel chains to provide adequate traction on the steeper slopes. In some areas where extraction has been by skidder produce at roadside can be widely dispersed along the length of the road, the solution to this is to bring in a forwarder to accumulate products at roadside, this product accumulation increases the efficiency of loading for timber lorries.

Operators report that in later thinnings the mature overstory trees for removal are often widely distributed throughout the forest, consequently the winch line has to be run out a greater number of times to accumulate loads. This impacts negatively on the economics of harvesting. When removing large tree sizes e.g. in mature Douglas fir stands this is less of a problem as the volume per piece improves bulk handling and the weight and momentum of larger stems is an aid to directional takedown, with fewer resulting hung up trees.

To date it has not been necessary to respace natural regeneration although cleaning of regeneration often forms part of first thinning. Larch crops at Uldale are producing good levels of natural regeneration which will be allowed to self thin. On these sites planting in gaps may be carried out if there is an absence of sufficient natural regeneration or to introduce Douglas fir which is seen as easier to manage in CCF and has a greater final value. Ongoing monitoring of the success of transformation is being carried out with excellent effect within the District generating spatial data of regeneration success, with good feedback on the FC IN 45 monitoring system. A range of GPS linked GIS monitoring tools have been used in the District, see Figure 13 and 14. GIS has been used to input survey information from permanent monitoring plots and from coning assessments to predict seed production as well as mapping potential skyline coverage prior to felling.



Figure 13 Assessment plot for monitoring the transformation process to CCF



Figure 14 Integrating monitoring plots with GPS location and GIS mapping

### Access Requirements for CCF

The specification of access is evaluated on a case-by-case basis; as part of the planning process roads are inspected prior to felling and are upgraded where necessary, their ongoing condition is monitored during harvesting. Access tracks and racks are currently constructed to the same specification and intensity as regular clearfell and restock silviculture and are on a permanent layout. The sites where CCF transformation is underway are commonly limited by slope and consequently access tracks tend to be located opportunistically as slope allows.

There is close integration between the Forest District and FC Civil Engineering who upgrade access roads as required prior to thinning. The Ops 1 process notifies FC Civil Engineering of felling allowing their formal co-ordination in access planning. Good use of culverts and cut-off drains has been made to control water movement, preventing access tracks from being eroded (see Figures 11 and 12). Provision and maintenance of lower specification tracks and racks is the responsibility of the Forest District.

### Brash Management

Efforts are made to organise felling to maximise brash availability. Where skidder extraction has been used careful directional felling has enabled accumulation of brash on extraction racks.

### Problems, Causes and Solutions

District staff identified the greatest problem being the completion of first and second thinnings especially on steep sites due to lack of skidder and cable way operators and costs involved and thus budgetary constraints. The directly employed Forest Commission cable way team was disbanded around 1996 leaving little resource for thinning on steep ground. It is possible to bring in contractors from Scotland to do cable way work, but only if the work is economically attractive, their skill is in great demand and it is not in their interest to travel long distances to fell low value early thinnings when there is easier work available to them. However, over the last few years the District has increased its programme of first thinnings targeting priority recreation and landscape areas and where the transformation to CCF is most likely to succeed.

Pockets of windblow can be problematic to deal with during harvesting as they need to be cleared in one go leaving an open group and additional trees may need to be felled to allow access for extraction. Where this is the case however the resulting change in stand structure can be a benefit. If restocking can be achieved through natural regeneration there is a potential restocking saving in excess of £1000/ha, however it is currently difficult within the budgetary system to offset this potential saving against additional thinning expenditure.



Figure 15 It is economically preferable to manage CCF in larger scale blocks in the landscape as shown here, rather than smaller fragmented blocks



Figure 16 Information board explaining the nature and purpose of felling under CCF management

With the high recreation use in the District it has been very difficult to exclude people from active sites during operations. In many cases recreation users of the forest will ignore signs and enter active sites; in CCF the presence of natural regeneration can restrict the operators view through the stand and it can be difficult to see people that could be at risk during felling and extraction. Attempts are being made to provide detailed explanation panels to inform people of the work that is going on and to encourage greater respect for exclusions (Figure 16).

### Feedback on Guidance and Information Gaps

FC guidance on CCF including FCIN 40, FCIN 45 and OGB 7 as well as ESC have been well received and very well implemented during the management of transformation to CCF.



## PENINSULA FOREST DISTRICT: FERNWORTHY FOREST

Fernworthy forest is located in Peninsula Forest District in Southwest England. Fernworthy has been actively managed as a CCF forest since 2004, where intermediate thinning has been replaced by crown thinning with frame tree selection in order to begin transformation to an irregular stand structure.

Table 3 Fernworthy Site and Stand Condition Summary

Area	Approximately 25% of the total area: 575 ha of Fernworthy Forest is to be managed under CCF
Terrain	Generally not limiting to operations, although in some areas large pieces of granite need to be negotiated by machinery. Slope is a limiting factor, requiring skidder extraction on c. 20% of the area, the remainder can be accessed with a conventional harvester and forwarder combination
Soil Type	Soils are mostly podzolised with a peat layer (mostly thin with pockets of deep peat)
Windthrow risk	WHC 3 to 5. Transformation thinning is being implemented in the WHC 3 areas with conventional intermediate thinning elsewhere
Limiting site factors for CCF	Potential windblow; the fragmented granite parent material results in good soil structure. However due to the good anchoring support provided by the soil high winds can result in windsnap
Species mix	Predominantly Sitka spruce
Age range	Range from first thinning to mature overstorey beyond age of max MAI, in stands considered for transformation P year ranges from 1920 to 1984
Tree size	Normal range with some trees in excess of 3m <sup>3</sup> in mature Sitka spruce overstorey
Yield Class	In Sitka spruce crops YC is commonly 14 – 24. Average YC 16
Limiting stand factors for CCF	Large tree sizes, requiring modification to harvesting system using combined motor manual felling and harvester processing
Selection criteria for CCF	Mainly based on landscape impact, with the desired stand structure (simple or complex) being determined by landscape considerations. Complex systems will be attempted in the lower valleys near to Fernworthy reservoir with simple systems elsewhere to preserve the rolling landscape character of the Dartmoor landscape

### CCF Management



Figure 16 Frame tree thinning at Fernworthy showing previously brashed Sitka spruce stems which aided visibility through the stand during marking and harvesting

Managed for landscape value and timber production. Fernworthy is highly visible in the Dartmoor landscape and preserving the even, rolling landscape appearance is a landscape design priority. Managing the forest for public access is also an important objective.

The transformation process involves the following stages: First thinning; cut racks at approximately 15m centre to centre spacing with a normal intermediate thinning in the matrix. Crown thinning then usually begins at the second thinning stage, where the stand begins to be progressively opened up to encourage natural regeneration and structural diversity. This culminates in the removal of the overstorey either partially or completely once regeneration has become established.

Currently stands are undergoing transformation with some areas already being managed towards

either a simple or complex system. The trial area has been split into age class bands due to the uniformity of the crops to aid management and monitoring throughout the trial site rather than the process in FCIN 40. Permanent monitoring sites will be set up, within age class bands, to record and compare stand development between areas being managed towards simple and complex systems as well as the normal clearfell method. In other areas due to landscape considerations, a strip system is proposed, aiming for a uniform strip shelterwood. In one area a uniform shelterwood already exists, due to unplanned circumstances where Sitka spruce has regenerated under a mature crop. This particular site is already beginning to give valuable experience in the harvesting of large dimension trees (over 2m<sup>3</sup>) while trying to minimise damage to the understorey.



## Operational Experience

Historically first thinning has been done motor manually, simultaneously brushing the crop establishing a rack layout and removing some of the matrix. Currently mechanised thinning is done on contract using a purpose built Logsett Titan harvester and a Cat 318 tracked harvester both with Logset heads with extraction by a Logset 5F forwarder. Crown thinning has been carried out in areas where transformation is being attempted.

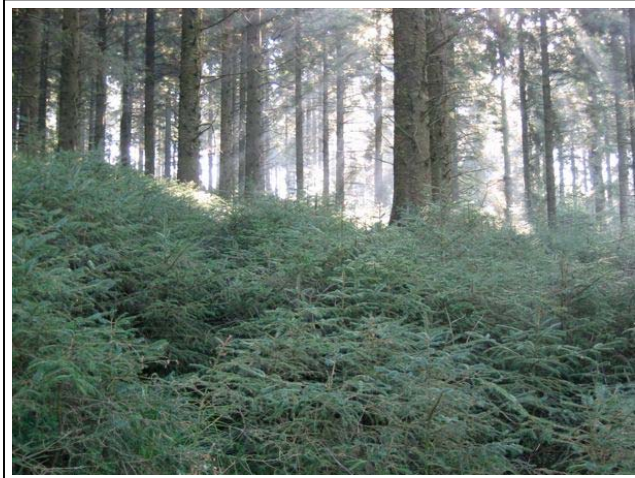


Figure 17 Dense Sitka spruce natural regeneration below mature overstory at Fernworthy; low light levels are currently holding the development of this regeneration back



Figure 18 Location of an extraction rack (wheel marks still visible), planned to be used in future felling, overgrown with natural regeneration (A5 notepad in left-hand wheel run shows scale)

The Logsett Titan harvester has been used in thinnings of stands undergoing transformation; it is anticipated that this will be suitable for trees up to a mean volume of  $0.7\text{m}^3$ . Thereafter, once mean tree sizes exceed this limit (individual trees could reach  $3 - 4\text{m}^3$  under extended rotations) a system of motor manual felling, assisted by subsequent mechanised processing with the Cat 318 (due to its superior lifting and slewing capabilities) will be used. Where past thinning has been done motor manually this has been an advantage for subsequent thinning as the standing trees were brushed during these early thinnings and now allow excellent visibility to assist with seed/frame tree selection with the move to CCF (Figure 16).

Where crown tree thinning has been adopted there is a small time penalty of approximately 1 man hour per hectare for marking of seed/frame trees, compared to intermediate thinning; apart from this no significant problems are apparent during the marking of transformation thinnings. The machinery combination functions as well during transformation as in conventional thinning. The additional volume produced as a result of crown thinning has been welcomed by contractors as well as the FC, as there is an accompanying increase (10-12%) in the proportion of log material at the transformation stage due to selection of a higher proportion of co-dominants and sub-dominants than in a conventional thinning.

Transformation felling carried out to date has not required any changes in harvesting and extraction techniques or machine combinations, compared to standard thinning operations and it is anticipated there will be little if any change in harvesting costs until regeneration becomes well established. A 5-year long-term contract is in place, and all harvesting is done on contract. The standard of contract labour is high and, the quality of thinning is consistently good, with low disturbance to the site and standing crop.

There are problems with sourcing skilled operators for some work activities; chainsaw operators are becoming particularly scarce. This may cause difficulties sourcing labour for the felling systems proposed later in the development of the CCF sites, combining motor manual felling of large trees with mechanised processing. The prison service (as part of their resettlement scheme) has been used to good effect to provide labour for site preparation operations at Fernworthy. Prisoners are trained and certificated in forest management work and are employed alongside the FC craftsmen.

In some of the mature compartments dense natural regeneration has developed; motor manual respacing is proposed, using brush cutters. Natural regeneration on racks will be treated as sacrificial and the current rack layout will be maintained in perpetuity. When felling is carried out to remove overstory trees, the aim will be to limit damage to natural regeneration. Respacing natural regeneration is necessary to reduce competition and improve the remaining stock, to clear racks for efficient machine access and to allow the harvesting head manoeuvrability among the crop.

The current proposal is to carry out respacing when the regeneration reaches c. 6ft tall, this will be less expensive than respacing at a later age and local staff consider that this will result in more stable trees than would result if the trees were allowed to self thin or were respaced at a later stage. Subsequent developments in wood fuel may influence this thinking. Currently it remains essential from a safety point of view as well as allowing visibility for operators to select felling direction when working motor manually in tall regeneration.

### **Access Requirements for CCF**

No access problems have arisen during harvesting besides time constraints imposed on felling due to timber haulage restrictions in the summer due to heavy tourist numbers in the local area (see below). Access for CCF does not differ from that required under clearfell and restock silviculture, it is anticipated that permanent racks will be created to allow access through the CCF stands, reinforced with brash and cleared of regeneration manually with chainsaws. Tracks are imposed throughout the forest with permanent racks providing access for motor manual and mechanised felling. Tracks are inspected prior to felling interventions and necessary maintenance decided upon following this assessment.

### **Brash Management**

Figures 19 and 20 show brash rack formations at Fernworthy, created during second thinning of Sitka spruce as part of Frame tree selection transformation thinning. Quantities of brash have so far proven adequate for brash rack construction. This may become an issue in later thinnings. Future felling has been planned to concentrate available brash on extraction racks during motor-manual takedown of trees in the latter stages of transformation.



Figure 19 Extraction Rack through Frame tree thinning of Sitka spruce showing abundant brash for rack construction



Figure 20 Brash mat formation below Sitka spruce showing wheel impressions; on close inspection no soil disturbance was seen

### **Problems, Causes and Solutions**

There are considerable constraints on access for operations in the forest. The primary constraint is to avoid timber movements during the peak tourism season through the restricted access in the village of Chagford north of Fernworthy Wood that and through which the only route for timber lorry haulage passes.

Feller select is not an easy option in the transformation thinning using the crown thinning prescription, as visibility from the machine cab is not good enough to evaluate the crowns of the standing trees. Only a low thinning would have been possible with the limited view from the machine cab, based on an assessment of the stem. The time of year that felling can be carried out in Fernworthy is restricted to the period October – March (out-with the tourist season) and during this period the harvesting operator can spend significant time in darkness at the beginning and end of the working day, reducing visibility further.

Large tree sizes will need to be felled and snedded motor manually with subsequent processing by Cat 318 excavator based harvester, this will require careful co-ordination to guarantee safety and efficiency. The proposed felling system for harvesting large tree sizes under CCF involves combined motor manual felling and snedding, removing the first log or two manually with the remainder of the tree being processed by the harvester and subsequent forwarder extraction. It is not anticipated that individual product sizes will exceed forwarder crane capacities. Large, heavily branched crowns are developing in the mature overstory, the branches are likely to prevent mechanised delimbing through a harvester head and require motor manual delimbing.

It would be detrimental to operate a harvesting system using motor manual felling and skidder extraction in the areas of dense natural regeneration. If this were the case then during skidding the effect of pulling felled stems through the understory would result in damage to the natural regeneration. Incorporating the harvester into the felling system allows the produce to be processed in a straight pull or lifted with produce accumulated at rackside, minimising damage to the natural regeneration.

Marketing large timber is anticipated to be an issue in the future. Markets for large dimension timber do exist, but they require long transport distances and can only absorb relatively small volumes.

### **Feedback on Guidance and Information Gaps**

Overall managers are well informed of CCF systems and transformation using published material as a reference point. Direct discussion and advice has been received from Forest Research, as well as CCF training through Forestry Training Services (FTS) and emphasis was placed on the value of direct contact from FR in information exchange.

## COED Y GORORAU FOREST DISTRICT: CLOCAENOG

Clocaenog forest lies to the west of Ruthin in north Wales, within Coed Y Gororau Forest District. Conversion to CCF began in 2001 following its designation as a trial site under the Woodlands for Wales Strategy.

Table 4 Clocaenog Site and Stand Condition Summary

Area	Clocaenog forest extends over an area of 4183 ha on the Hiraethog Moor, west of Ruthin. Transformation to CCF is being attempted over approximately 50% of the forest; over 2000 ha
Terrain	Clocaenog occupies an undulating plateau at >300 m elevation. Terrain is generally not limiting to operations
Soil Type	Soil types considered appropriate for conversion are brown earth, iron pan and podzols; other soil types may be used if they have a DAMS score less than 17
Windthrow risk	Windthrow Hazard Class (WHC) varies considerably over the forest, with around 25% in WHC 5 and 6. These areas are automatically rejected for conversion to CCF at the planning stage
Limiting site factors for CCF	Areas with WHC of 5 or 6 are considered inappropriate for CCF, those with WHC 4 and below undergo a site evaluation to determine their suitability (see 'selection criteria for CCF below')
Species mix	The predominant species is Sitka spruce, followed by Norway spruce and small areas of pine, larch and broadleaf species
Age range	A large proportion of the CCF trial area is P 1950s
Tree size	Range of tree sizes, tree size is not currently generally limiting for CCF
Yield Class	Sitka spruce has a YC typically in the late teens, in places over YC 20
Limiting stand factors for CCF	Limiting stand conditions have largely been avoided due to careful site selection for CCF
Selection criteria for CCF	Suitability for transformation to CCF is based upon soil type and windthrow risk using the DAMS score (Detailed Aspect Method of Scoring, based on tatter flag data). Soil types considered appropriate for conversion are brown earth, iron pan and podzols; other soil types may be used if they have a DAMS score less than 17. The Windthrow Hazard Class (WHC) varies considerably over the forest, with around 25% in WHC 5 and 6. These areas are automatically rejected for conversion to CCF at the planning stage. Crops with a WHC of 4 or below undergo a site evaluation to determine their suitability, dependant on soil type and DAMS score

### CCF Management

The main management priorities for Clocaenog are to promote the forest as a habitat for red squirrel and black grouse; the continuous canopy provided by CCF is ideally suited for red squirrels; economics are regarded as equal importance as the environmental objectives; social provision although an important consideration has a lower priority due to the low recreation demand in the area.

Management of CCF transformation is administered through the FC Management Plan process. The transformation process involves first thinning; cutting racks at spacing dictated by machine reach (c. 20 m) see Figure 23. Frame trees marked at time of second thinning. Frame trees are maintained during subsequent thinnings, removing those trees in competition. Where a simple structure is aimed for the overstory will be removed once advanced regeneration has successfully established. In the majority of the forest a uniform shelterwood silvicultural system has been adopted to achieve the objectives of CCF.

### Operational Experience

Harvesting is based on a shortwood system, using a harvester and forwarder machine combination with a Timberjack 1110 Forwarder and 1270D Harvester (head with 65 cm diameter capacity).

Natural regeneration is prolific in places. Where dense natural regeneration has been left unmanaged to grow into a mature crop problems have resulted from high stocking density causing difficulties with harvesting at first thinning as the harvester head struggles to function efficiently in very highly stocked natural regeneration (see Figures 21 and 22). An accumulator felling head has now been purchased, one of the uses for which will be to trial respacing in such crop types. There is a strong desire for effective respacing to prevent similar difficulties in the future.

Operators have used the Timberjack 1270D harvester to good effect in CCF thinnings; the felling head of the machine has a lower saw base and longer bar than many alternatives, meaning that it is very well suited to tackling the buttressed crop trees at Clocaenog. Operators also report great advantages in having a chainsaw feller to accompany the harvester to fell trees with a dbh in excess of the harvester head as well as heavily buttressed trees.



Natural regeneration has caused difficulties when harvesting, preventing the operator from seeing the base of the stem. This increases the time taken to accurately locate the head for the felling cut, particularly in crops with large tree sizes (greater than the 65 cm capacity of the felling head) that require the head to be repositioned on the stem and a second cut made to fell the tree. There is also a potential effect on volume forgone through not making the felling cut as low as possible on the main stem.



Figure 21 Dense natural regeneration, not previously respaced, now causing difficulties at age of first thinning



Figure 22 Densely stocked natural regeneration

Large trees can prove difficult to handle with the harvester crane at full reach.



Figure 23 Timberjack 1270D harvester operating in first thinning crop



Figure 24 Soil disturbance can occur between the stone-surfaced secondary road (foreground) and brash-surfaced rack (background). The proposed solution to preserve the entrance to the rack is to stone the rack bell-mouth safeguarding the condition of the rack into perpetuity

## Access Requirements for CCF

Access routes under CCF are created as a permanent network, unlike clearfell and restock silviculture. Some wetter areas have caused access problems for machine movement, and in order to prevent compromising future access it is proposed that selected sections of the rack network will be reinforced with stone and stone bell mouths created at rack/secondary road junctions to ensure a permanent access network is maintained.



The FC staff decide on the required length and layout of access and co-ordinate with Forest Civil Engineering, who decide on the precise track or road specification and carry out the construction. The machine combination in use allows racks to be spaced at 20m centre to centre spacing, as dictated by machine crane reach. Well specified forest roads are connected by stoned secondary roads which subsequently connect to the rack network. Soil and slope factors are generally not limiting to operations and therefore have little influence on access. Sections of track crossing localised areas of more vulnerable soils have been strengthened with a layer of stone. Track condition is assessed after harvesting whereupon necessary maintenance is decided upon. Maintenance is then carried out by Forest Civil Engineering (this will be the case for the work shown in Figure 24).



Figure 25 Product accumulation and sorting at rackside increasing forwarder efficiency, especially important among dense regeneration



Figure 26 Dense natural regeneration that may require respacing in the future

## Brash Management

In some areas limited availability of brash has caused problems for access, particularly where racks meet the secondary road network. For example the 11 t forwarder, carrying a further 11-12 t of timber is a considerable weight to be borne on the racks and in thinnings. If this continues to be a problem then work may have to be restricted to summer time working to prevent damage in wet conditions. Bandtracks are fitted to the machines in use primarily to aid stability. Machine movement has, in places been restricted to alternate racks to concentrate brash and improve efficiency of travel, loading from either side of the racks used.

## Problems, Causes and Solutions

The timing of harvesting is site specific and determined by factors such as exclusion periods for Schedule 1 species, and ground conditions.

Currently local staff are considering options for removing the mature overstory where natural regeneration has been successful.

Buttressing in mature crops has caused difficulties with mechanised felling, and this is likely to continue to be a problem in the future if tree sizes increase.

Direct labour is used for felling through Wales Harvesting and Marketing (WHAM) consequently there are fewer problems with sourcing good operators than in some areas of the UK. Harvesting and extraction are carried out to a very high standard. A site plan to guide operations is issued to operators prior to work commencing. Operators report difficulties with visibility of tree crowns from the machine cab during thinning. When working a single shift the operator starts work at 7.00 am and usually does not finish until after 4.00 pm. Work during the winter months therefore starts and ends in darkness, worsening visibility still further. Where the felling program allows this problem has been avoided by clearfelling during the darker winter months and thinning during the rest of the year.

Natural regeneration in the racks has not presented a problem for harvesting. Travelling the racks with harvesting machinery on a five yearly basis is anticipated to keep access open.

The area is affected by *Dendroctonus* which could represent a problem to CCF management if significant numbers of seed bearing trees become infected. This may be accentuated under CCF transformation if trees are maintained beyond maximum MAI.

Natural regeneration will require respacing to prevent operational difficulties at age of first thinning; methods and prescriptions for regeneration management are not well developed.

It has been difficult to predict costs of operations in advance, this will be more closely monitored in the future.

It is difficult to maintain continuity of management due to staff turnover, to ensure continuity of information and records over time to enable management continuity under different managers.

### **Feedback on Guidance and Information Gaps**

Forestry Commission Information Note 40 has been used to guide the selection process for suitability of transformation. A significant number of the stands where CCF is currently being successfully implemented at Clocaenog are in a higher windthrow hazard class than FCIN 40 recommends. Currently however, transformation is being managed effectively with little windblow impact, this indicates that the effect of windblow may have been overly pessimistic, although this will only be confirmed following further experience of operations at the trial sites.

There is a need for information on thinning dense natural regeneration where respacing has been neglected in the past, resulting in densely spaced, drawn up crops.

## LLANYMYDDFRI FOREST DISTRICT: CWM BERWYN

Cwm Berwyn is located in mid Wales, part of Llanymyddfri Forest District. The forest has been managed as a CCF trial site since 2001. The District began experimenting with CCF silviculture in 1995, using a strip system in parts of the forest.

Table 5 Cwm Berwyn Site and Stand Condition Summary

Area	The forest covers 1800 ha; under the original CCF stratification 60% of the forest was designated for transformation, this has subsequently been scaled back to 25%, in the light of operational experience
Terrain	Terrain is generally not limiting to machine access, elevation varies locally within the forest, but averages 425 m above sea level
Soil Type	Soils are poorly drained and include a mixture of peaty gleys, flushed peat bogs and unflushed peat bogs in approximately equal proportions over c. 90% of the forest area. Iron pan and surface water gley soils occupy the remaining area
Windthrow risk	Approximately 60% of the total forest area is categorised as WHC 4 and approximately 40% as WHC 5
Limiting site factors for CCF	Windthrow risk is one of the most limiting factors for implementing CCF at Cwm Berwyn. Wet soil conditions are also severely limiting to operations, however these have largely been overcome through the use of corduroy roads (see text)
Species mix	Predominantly Sitka spruce in the CCF areas
Age range	The majority of the CCF stands range in P year from 1960 – 75
Tree size	Ranges over the forest
Yield Class	In Sitka spruce crops YC ranges from 10 – 18 with some stands in excess of YC20
Limiting stand factors for CCF	Dense natural regeneration in felled corridors from the 1990's strip felling has limited access for further harvesting – care is being taken to avoid this in the future
Selection criteria for CCF	Cwm Berwyn is not a site that would be conventionally considered appropriate to CCF transformation under the selection criteria outlined in FC IN 40. WHC is high and soils generally wet and low load-bearing. One of the drivers for CCF in Cwm Berwyn is to achieve restocking through natural regeneration, saving planting costs of £1400 - £1500 per hectare. Prior to adopting CCF calculations were made to determine the revenue forgone through not clear felling and the results used to decide what proportion of the forest could reasonably be transformed to CCF economically

### CCF Management

CCF silviculture was first attempted at Cwm Berwyn c. 1995 when a strip system was imposed over part of the forest. Access problems now exist due to the previous felled strips forming wet swathes of dense regeneration, which restrict machine movement (Figure 27). Lack of thinning over much of the remaining stand together with a high windthrow hazard class has resulted in a crop that is vulnerable to windblow, restricting the area appropriate for transformation.

Originally when the forest was designated as a trial site approximately 60% of the forest was designated under Low Impact Silvicultural Systems (LISS). At present (2006) this has been scaled back to approximately 25% of the forest area. LISS management has now been restricted to the more stable areas that have previously been thinned.

The main objective is timber production, the benefit of CCF management is to enable regeneration of the overstory at minimal cost through natural regeneration, with a potential cost saving of £1400 - £1500 per hectare.

The transformation process begins with racking the stand during the first thinning, with the intention of creating a permanent rack network, the matrix is also lightly thinned at this stage. The stands are monitored and the response to the thinning used to dictate the timing of the next intervention on a five to eight year cycle.

Across the forest a simple structure is aimed for, achieving regeneration by natural means, and progressively removing the overstory. The strips originally felled in 1995 are now being expanded using a strip felling system, felling 30 m strips. Felling the strips allows a good accumulation of brash to support machine movement, Figure 28. Care is taken to prevent machine movement degrading access racks for future thinning interventions.



## Operational Experience

In the latter interventions using crown thinning managers report greater quantities of log and bar material extracted compared with intermediate thinning due to removal of larger mean tree sizes. This greatly improves the economics of harvesting. Further harvesting studies would be necessary to quantify these volume benefits.



Figure 27 Dense natural regeneration in wet felled strips that now form a barrier to machine movement



Figure 28 Felling adjacent to original felled strips to expand regenerated area in a strip shelterwood system, note: large brash accumulation from felled strip

Harvesting has been carried out with Ponsse Ergo harvester and Ponsse Caribou Forwarder. This machine combination is well suited to the tree size at Cwm Berwyn which was specified to offer maximum versatility, to function efficiently in a range of crops from first thinning, CCF and clear fell harvesting.

Due to the high WHC (typically over 4) in many parts of the forest timely thinning is viewed as essential to ensure the stability of the crop throughout the transformation period. It is also anticipated that respacing will be necessary to ensure appropriate stocking density, with the risk of the crop being drawn up and increasing windblow susceptibility.

Operators have constructed corduroy racks (Figure 30) from chip wood produce to allow large scale mechanised harvesting access over the very wet ground conditions. The corduroy racks are constructed from chip wood lengths incorporated with brash to form a reinforced timber construction to support the weight of harvesting machinery. Chip wood was incurring a cost of £8 per tonne to market due to the remote location of Cwm Berwyn resulting in high transport costs coupled with a poor chip wood price. It was beneficial to use the chip wood for corduroy rack construction, safeguarding the racks for future use, rather than compromising access at the time of the next intervention and incurring a cost from marking the product. Further guidance on the use of corduroy racks is given in Technical Development Report 35/91: *Soft Ground Harvesting*.



Figure 29 Travelled rack without corduroy rack construction showing rutting



Figure 30 Corduroy rack formation, constructed from brush and chip wood specification produce

The transformation felling that required corduroy racks for extraction differs from conventional clearfelling silviculture in that many of these areas would have been considered too wet and too high a windthrow risk to thin, managed under a non-thin prescription with clear felling at the end of the rotation.

Harvesting of shortwood using a harvester and forwarder combination is carried out by FC direct operators. A skyline cable way contract team is currently employed within the District on a five-year long-term contract, this LTC is continually renewed on a rolling basis and is now in year 11. Felling and extraction have been achieved at a very high standard, with the construction of corduroy racks in the interests of preserving the access through the forest for future interventions. The skyline team has the resource to fell and extract c. 20 000 t/yr. Operators are given a plan as part of the pre-commencement process.

It is less difficult to source skilled operators than some areas of the UK, although the remoteness of the site and the difficulty of the conditions has made timber harvesting difficult. The main operational change in harvesting methods under CCF management has been the need to develop soft ground working methods to allow thinning in stands that would probably been unthinned under conventional clearfelling. Operators have adapted very well to the specific operating conditions thanks to close integration and co-ordination with management.

### Access Requirements for CCF

Soils are very wet and in places contain deep peat in the upper horizons, support for large-scale harvesting machinery is therefore low. Previous felling of strips through the forest has also resulted in wet corridors that cross the forest, containing abundant natural regeneration, these now form a barrier to machine movement for future management operations.

Corduroy racks have been constructed; the only way to enable machine access without compromising future mechanised access through the forest. These could only be economically justified due to the cost in marketing chip wood material. Access through the forest is inspected prior to felling commencing, and track maintenance and specification decided in advance of the operation. Operators inspect the stands prior to felling.





Figure 31 Brush access track constructed adjacent to metalled forest road preventing damage to the metalled road



Figure 32 Forest road edge travelled by harvesting machinery to the left-hand side of the road. several years after extraction

The rack matrix will be established as a permanent network. The soils are low load-bearing and therefore require careful rack construction and use to prevent damage if they are to be used as permanent routes. Where corduroy racks were not constructed, during the early thinning operations new racks may have to be created due to rutting impeding future machine movement over the site. This is an example of the experience gathered directly improving the sustainability of management in transformation. Maintenance is decided upon following inspection of the roads and tracks in advance of felling as part of the five year felling programme.

### Brash Management

Brash mats were formed by the harvester, supplemented with small roundwood to construct corduroy racks (Figure 30). Managers and operators have identified that insufficient brash will jeopardise future mechanised access through the stand and consequently the corduroy rack formation has been used to excellent effect at Cwm Berwyn. If the price of chip wood should rise this may make the construction of corduroy racks uneconomical in the future; this would necessitate a new approach to harvesting at Cwm Berwyn.

### Problems, Causes and Solutions

There are no constraints on timing of operations, with the exception of soils being very wet i.e. following prolonged rainfall. In some areas where early thinning took place in the absence of sufficient brash to support machine movement rutting developed, this rutting may be an obstacle to future harvesting operations (Figure 29). Products are the same as conventional felling although volumes of log and bar under crown thinning are reported to be greater than under intermediate thinning. Costs of corduroy rack construction were no more than for normal harvesting as they were formed as part of the standard harvesting operation. There was a comparative cost saving of £8 per tonne from not marketing the chip wood (achieved through not incurring the transportation costs to deliver the chip to Kronospan).

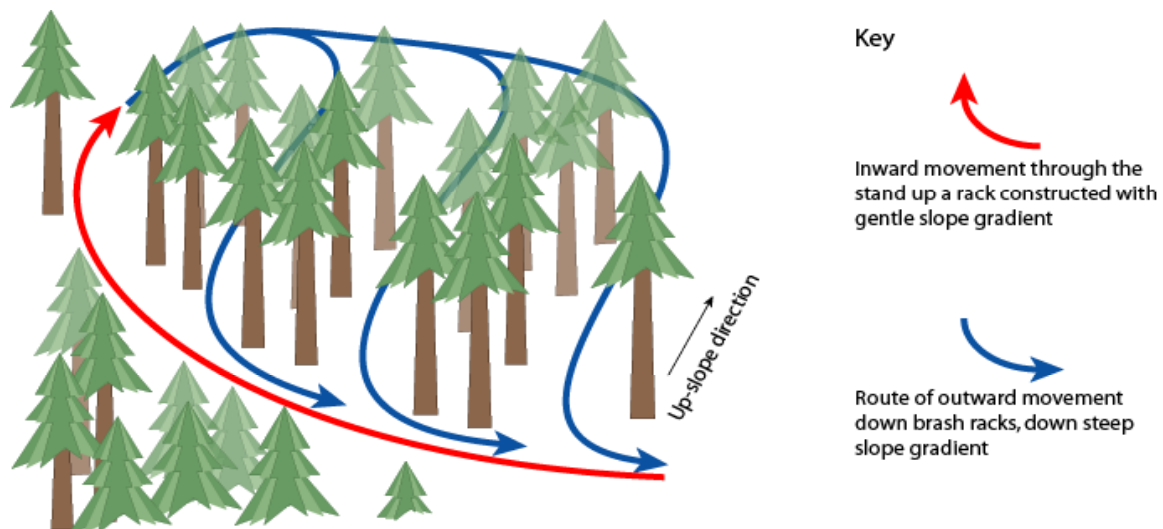


Figure 33 Site organisation for steep ground harvesting



On steep slopes harvesting has been organised to work the slopes in a downslope direction only, as shown in Figure 33. Using this method the steep gradient is then travelled only in a downslope direction which is operationally easier for machines, especially given the weight of the heavier forwarder, this benefits safety, ergonomics and efficiency. The harvester and forwarder travel into the stand on a rack with gentle gradient, levelled using upturned stumps and brash, constructed by the harvester as shown in Figures 34 and 35. This requires a harvester with sufficient power to uproot stumps. Further evaluation of this method of levelling machine access should be undertaken with advice from Forest Civil Engineering to define the specification before this is recommended as best practice.



Figure 34 Inverted stump and brash formation to allow machine movement over steep cross slope

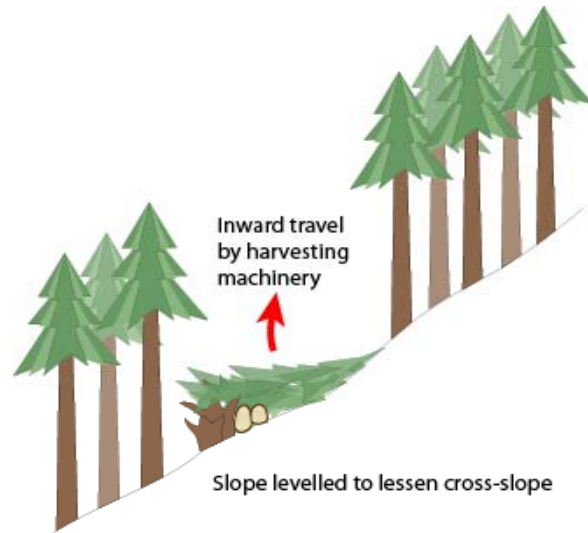


Figure 35 Using upturned stumps and brash to level cross slope to allow machine travel

In some windblow holes in the forest regrowth of side branches on blown stems can give the false appearance of dense natural regeneration (Figure 36). Without close inspection the lateral branch growth can appear to look like advanced natural regeneration. Due to careful site monitoring by local staff this was identified and the branch regrowth could be controlled to prevent competition to natural regeneration in the windblow opening. The lateral branch growth of windblown trees was controlled through brush cutting, motor manually.



Figure 36 Lateral branch development on windblown trees giving the false impression of dense natural regeneration

Respacing of natural regeneration may be necessary in the future. From local past experience care must be taken when re-spacing to ensure that stems are cut below the height of the lowest live whorl to ensure that remaining side branches do not re-grow increasing the density of regeneration rather than reducing the problem, see Figure 37.

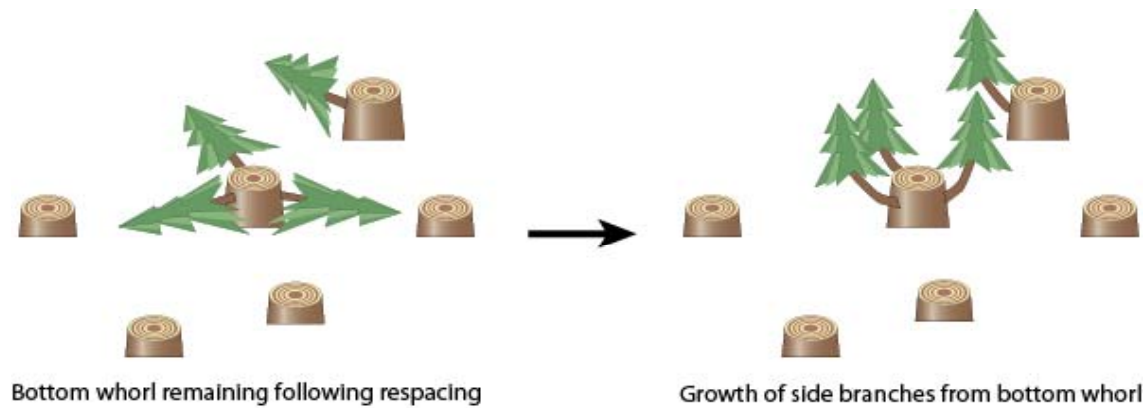


Figure 37 Regrowth from first live whorl of cut stems of natural regeneration.

### Feedback on Guidance and Information Gaps

Both IN 40 and IN 45 have been consulted. The FC OGB 7 was the main reference for information on CCF used by the District staff to inform the management of Cwm Berwyn.

Techniques used at Cwm Berwyn have required considerable adaptation of traditional harvesting methods to deal with the wide range of environmental constraints. This has involved some experimentation and the experience gained will be of great value on similar sites elsewhere.

## SCOTTISH BORDERS FOREST DISTRICT: GLENTRESS/CARDRONA

Glentress and Cardrona forests are part of the Scottish Borders Forest District. The initiation of CCF group felling at Glentress began in the late 1950's. Cardrona forest was designated as a CCF trial site in April 2002.

Table 6 Glentress and Cardrona Site and Stand Condition Summary

Area	The CCF area at Glentress covers 452 ha (the area occupied by the 'Anderson plots' is 120 ha, of which 100 ha is net tree cover) the area managed under transformation to CCF at Cardrona is approximately 180 ha
Terrain	Terrain is generally appropriate for mechanised access, although slopes are limiting in places, through steep valleys Glentress ranges in altitude from 240 – 650m.
Soil Type	Soils are generally well drained brown earths, grading into thin iron pan soils on the upper slopes and heavy till with surface water gleys in the valley bottoms
Windthrow risk	The forest receives a predominantly south-westerly wind with the WHC ranging from 2 to 5; wind exposure is accentuated by the funnelling effect of local valleys
Limiting site factors for CCF	Slopes in some areas of Glentress are limiting, requiring cable way extraction. Windthrow Hazard Class is also high in some areas. Deer browsing has been a limiting factor in establishment, particularly of broadleaves in the planted groups
Species mix	Mixed species at Glentress and predominantly Scots pine in the CCF areas in Cardrona
Age range	Planting at Glentress was established c. 1926 on the lower slopes, rising to c. 1940 on the upper slopes. At Cardrona the majority of the trial area includes mature pine a spruce planted in the 1930's and 40's as well as later conifer planting in the 60's and 70's.
Tree size	Range with age of crop, and large variation with altitude from the lower slopes to the higher more exposed slopes
Yield Class	Ranges with altitude and differing levels of exposure.
Limiting stand factors for CCF	Limited success of natural regeneration, however research into ground preparation at Cardrona is being carried out and where regeneration has not been forthcoming at Glentress planting has delivered acceptable restocking
Selection criteria for CCF	Selection criteria at Glentress based on historical management under CCF silviculture under past management objectives. Elsewhere within the District CCF has been implemented where best placed to meet management objectives, FCIN 40 has been consulted during the selection process.

### CCF Management

Glentress has been managed under CCF silviculture since the 1950s, the management of the forest is guided by a management plan written with input from the FC and Edinburgh University. Under CCF management it was originally proposed (in the 1950s) that the transformation period would take 60 years, felling two hectares per year consisting of small 1/40 ha plots, laid out on a geometric 20 m square grid over the forest. In light of operational experience the felled groups have been increased in size to 0.3 ha on the lower slopes and 0.17 ha groups on the upper slopes (30 m and 16 m diameter respectively).

Objectives include timber production, and heavy recreation usage (primarily mountain biking) in Glentress. It is also a primary objective at Glentress to establish an uneven aged, mixed species stand structure, with a research objective to assess the implementation of CCF silviculture in Scotland. Cardrona also has recreation provision as a primary objective.

Transformation thinning is being attempted in some areas together with group felling systems using various sizes of groups. At Glentress the system of group felling has been modified to account for differences in site productivity over the forest. The lower slopes have approximately twice the growth rate of the upper slopes and the thinning cycle has subsequently been adapted to account for this. Thinning is done on a five-year cycle on the lower slopes and on a ten-year cycle on the upper slopes. This demonstrates that the CCF system has the flexibility to be adaptable and is not a rigid prescription that cannot be modified once in operation.

### Operational Experience

Timber extraction at Glentress was originally by horse when transformation began in the 1950s and is now by forwarder (Timberjack 810 medium sized forwarder). In Cardrona harvesting has been carried out with a Ponsse HS15 harvester and Ponsse Caribou Forwarder.



Tracked machines were used at first but this has proved unnecessary; bare tyres and wheel chains provide adequate traction. Limiting factors include the need to create extraction racks at 20m intervals as defined by the systematic layout of the group felling plots and the need to avoid damaging younger crops. Some skidder extraction has been used on steeper slopes.

Lodgepole pine crops with poor form have been harvested and chipped in the forest using a mobile chipper and transported in lorries for production of board products. This market has allowed timber to be used beyond the standard top cut off of 7 cm diameter. Harvesting material beyond 7 cm has potential implications for soil management in that the 'tops' (<7 cm) are no longer available for brash rack construction or to providing nutrient release as they decay on site, although no difficulties have arisen to date.

Felling is carried out on a feller select basis, with an example area marked to indicate the desired thinning intensity, subsequent site inspections allow the thinning intensity to be checked. The felled groups act as discrete management units and so far there have not been any difficulties with locating produce among the regenerating crop. Generally the methods, machinery and techniques of harvesting used in the CCF stands are the same as in conventional thinning.

In some areas steep conditions mean that timber extraction is only possible by cable way. High cost and the lack of cable way operators has resulted in difficulties thinning these stands and in the future felling to waste may be done as a management intervention for the benefit of the stand without incurring the high costs of cable way extraction. There is also a lack of operators for motor manual felling.

A local felling contractor is operating a harvester modified for steep ground working, through the addition of adapted traction aids with customised grouzers for increased traction. This modification, along with careful site planning has allowed the machine to access steeper sites than would be conventionally achievable with mechanised felling.

A mixture of direct labour and contractors are used for harvesting. Long-term contracts (LTCs) are used with Scottish Woodlands for felling over 5 – 10 year periods. The secure commitment offered by the LTCs has led to a conscientious approach from contractors and ensures continuity of felling. A site plan is issue to operators, with felling area marked on the ground as a reference to the operator, shown in Figure 39.

Commonly at Glentress natural regeneration is not sufficient to provide adequate restocking, this may in part be linked to deer browsing, as a result planting has been necessary. This does not directly affect harvesting methodology.



Figure 38 Open area turned over to recreation usage at Glentress following die off from increased exposure after adjacent felling



Figure 39 White spray reference mark (on dead stem - front right) to guide location of felling intervention

## Access Requirements for CCF

Access racks and roads in CCF have been constructed to the same specification as for conventional silviculture and has not been limiting to operations. The specification of access racks and roads is determined by the anticipated level of use and machine combination. Specification varies from lightly used unsurfaced tracks to heavily used roads constructed by an excavator using stone quarried at Glentress. The use of local stone helps to reduce construction costs. Vehicle access on and off forest roads is aided by stone ramps where necessary and care is taken with rack planning to limit the turning angle of harvesting machinery when moving from racks to tracks or the forest road, see Figure 40.

Terrain has an influence on access location, but this is more closely influenced by the management system and layout at Glentress. The road and track network provides for a wide variety of users, including forwarder, harvester and skidder travel for timber harvesting and forest management work as well as All Terrain Cycles (ATCs), walkers, mountain bikers and horse riders.

At Glentress the formal group felling system is interspersed with a complex track network which allows excellent access for felling and management interventions. The aim is that every tree should be within 50 m of a track. The soil copes well with machine movement off the rack network. Tracks are inspected prior to operations commencing and upgraded as required.

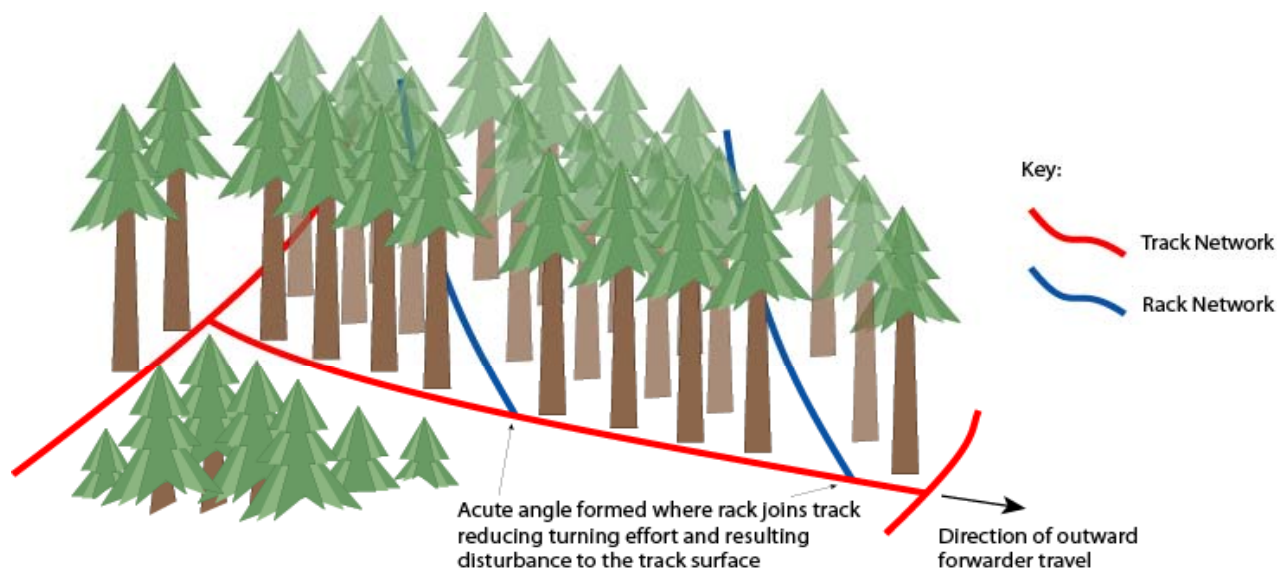


Figure 40 Racks planned to meet forest tracks at an acute angle, limiting the damaging turning effect of machine wheels.

## Brash Management

Sufficient quantities of brash are generally available to meet the required specification for rack construction.



Figure 41 Recently travelled convergence of access tracks showing minimal impact resulting from machine movement

The group felling can occasionally lead to a shortage of brash in places with an abundance in the felled groups, this is resolved by redistributing brash along the length of the route.

### Problems, Causes and Solutions

Operations are restricted in some areas between March and July due to bird nesting. The main restriction on the timing of operations is the high recreational demand; attempts are made to organise any major felling outside peak visitor periods. The preferred approach is to maintain a low level of felling throughout the year, resulting in limited disturbance to recreational users.

Windblow has been a problem at Glentress due to opening felled groups, exposing adjacent groups to increased wind. Invasion of bracken in the felled groups can also be a problem, and spraying to control bracken is carried out.

The available pool of experienced contractors to do felling, particularly motor manual, is diminishing, this could severely restrict the quality and quantity of future work. Local contractors are familiar with the systems being imposed improving harvesting efficiency.

Managers expressed concern about the possibility that damage to the standing crop may result following felling, this may subsequently affect the quality and health of trees retained for CCF. The extent and severity of this potential problem are as yet unknown.

### **Feedback on Guidance and Information Gaps**

Local staff report good feedback from using FR publications (information notes IN 40 and IN 45). Edinburgh University provides silvicultural guidance and Forestry Commission staff have received training courses on transforming even aged crops from Mark Yorke (specialist in CCF transformation).

Records of previous management at Glentress do exist, elsewhere however, local staff report problems obtaining past management records. A mixture of paper and electronic records and no well-established methods of information archiving have resulted in complications in finding out past management history in CCF stands in some areas, newer electronic methods of record keeping will improve this situation, and the accessibility of information to managers.



## COWAL & TROSSACHS FOREST DISTRICT

Cowal and Aberfoyle Forest Districts were merged in 2001 to form Cowal and Trossachs Forest District, with Lochard, Strathyre and Loch Eck designated as CCF trial site in the same year.

Table 7 Lochard, Strathyre and Loch Eck Site and Stand Condition Summary

Area	Throughout the District CCF comprises 4000 ha out of a total of 36,000 ha
Terrain	Terrain varies greatly, generally 80% accessible to conventional harvester and forwarder combinations, with the remainder requiring skidder or cable way extraction
Soil Type	Soil information is lacking throughout the District
Windthrow risk	WHC ranges throughout the District, typically between 2 and 4 in the trial areas
Limiting site factors for CCF	Windthrow risk is the greatest limiting site characteristic for CCF within the District. There is some evidence of deer browsing but this is currently at manageable levels, and is actively managed through appropriate protection
Species mix	Mixed conifer; the diversity of species is great. Originally when the forest areas were planted species choice was led by soil type. Current species comprise Sitka spruce and larch as well as Noble and Douglas fir, recent planting has also included small trial areas of Silver fir
Age range	Wide age range, a large proportion of the original planting was carried out in c. 1930
Tree size	Sitka spruce typically reaches 1 m <sup>3</sup> by c. 40 – 45 years
Yield Class	Recently thinned Sitka spruce has a YC of 22
Limiting stand factors for CCF	Large tree sizes are anticipated to be an increasing problem for harvesting operations if stands are maintained beyond their age of maximum MAI
Selection criteria for CCF	Stand selection for CCF transformation is driven by management objectives, taking into account the landscape, conservation and recreation value. Stands are then evaluated for transformation to CCF based upon DAMS score, condition of road network and past thinning history

### CCF Management

Management objectives in CCF include conservation (primarily Red squirrel habitat conservation), recreation and landscape, aiming to increase structural diversity. Timber production is of secondary importance within the CCF forests.

During transformation first thinning is the same for conventional management, cutting racks and additionally removing a few rackside trees. Racks are imposed at a spacing of approximately 15m, removing 1 in 6-7 rows. Second thinning removes some trees in the matrix, using feller select with a sample marked as a reference for the harvester operator. Group felling, seed tree thinning and variable intensity thinning have been carried out throughout the transformation forests. Currently a number of silvicultural systems are being implemented: seed tree thinning; seed tree thinning with group felling; variable intensity thinning; target diameter thinning; individual tree stability thinning; traditional shelterwood systems and conventional yield model thinning.

### Operational Experience

Harvester and forwarder combinations carry out the majority of harvesting but larger tree sizes require motor-manual felling. On steep areas harvesting of larch has been motor manual with cable way extraction, the high quality of the larch timber justified the expense of this method; the standard of work was very high and resulted in very little damage to the remaining crop trees. To date there has been no need to change harvesting machines or methods specifically for CCF thinning but large tree sizes are beginning to cause difficulties for harvesting with conventional machinery.

Local staff report benefits of increased efficiency through group felling when using cable way extraction, due to consolidation of timber products. Felling is done using contractors with the main thinning contract managed on a five year long term contract (LTC). Although the work is managed under a LTC different operators will work under this contract and the quality of harvesting can vary. The FC Contract Mapper package is used to compile a map of the harvesting operation, this is passed on to the contractor to inform felling and extraction.

Where natural regeneration has developed under appropriate light conditions the effect on operations is minimal. Respacing of natural regeneration may be necessary in the future and this will be assessed as natural regeneration develops.

The presence of an understory of a different species to the overstory is common where regeneration has developed (Figure 42). This has caused some problems with planning due to the difficulty in mapping and recording this stand structure and composition within the current design planning and subcompartment database tools. The habitat value of a two storied, mixed species conifer stand is greater than that of a single species crop, but the constraints on information recording preventing this from being represented accurately.



Figure 42 Mature larch overstory with Sitka spruce natural regeneration beneath



Figure 43 Trial planting of Silver fir fenced – chestnut paling use to increase fence line visibility to prevent risk of bird strikes

### Access Requirements for CCF

The local District staff decide on the required specification and location of roads and this is communicated to Forest Civil Engineering who construct the roads as requested.

Road access is good, metalled roads are constructed using local stone with imported top dressing bought in. The local stone is Schist that breaks up easily under compaction, therefore the road formation benefits from a firm top dressing.

Site organisation aims to keep harvesting machinery off forest roads to preserve their condition for haulage and management vehicles. Racks are created on a permanent layout. There is a road defect reporting system in place on active sites; operators provide details of any necessary road maintenance and this information is then passed to Civil Engineering to carry out the necessary repairs.

Some of the timber (30-40%) to the west of the Forest District is transported by barge from Dunoon, additionally some material is transported by rail to markets in Wales. Making use of alternate transport methods has helped relieve the volume of timber traffic by road.

### Brash Management

Later thinnings are anticipated to involve small volume removal and therefore not generate large quantities of brash, this may be limiting to machine movement.

### Problems, Causes and Solutions

Felling operations in some areas are restricted from February to August due to bird nesting (principally Osprey and additionally the Red squirrel breeding season).

This is a large area for staff to cover with a great deal of travel time involved to cover the area managed under District control. There is a great deal of variation in the crops undergoing transformation, and concern was expressed about the accuracy of yield predictions.

In the absence of natural regeneration in some areas it has been necessary to plant. In order to protect planted trees deer fencing has been erected, however due to the risk of bird strikes from fencing this is removed as soon as the planted stock ceases to be vulnerable to deer damage (Figure 44). There is a fine balance between these two conflicting objectives and in some limited cases the result of fence removal has been fraying damage by deer, as shown in Figure 45.

During the time that the groups were fenced frequent inspections had to be made to check fence condition; windblown trees had the potential to flatten sections of fence and allow deer entry.



Figure 44 Fence materials awaiting removal from site after take down



Figure 45 Deer fraying damage following fence removal

To increase the structural diversity of the stands small clear fell openings have been created to allow scope for views through the forest. However it is becoming more difficult to manage small fellings due to the high management input required for a comparatively small area, given limited resources. It is also very difficult to find the resources to allow thorough monitoring throughout the CCF transformation. The local District staff are trying to develop systems that will allow monitoring of the stand response to CCF transformation interventions.

Local experience of monitoring systems is that they are commonly stand-alone and do not closely integrate. It would be far less resource demanding to integrate monitoring systems for forest management under GIS, requiring one point of data entry to populate all the forest monitoring systems.

Windblow has occurred in some areas following thinning. To date the strategy with windblow has been to clear the affected areas exploiting the opportunity to create within-stand structural diversity. The resulting open areas have been restocked, but in the early years of establishment they form clearings to appreciate views within and outside the forest and form a valuable additional habitat type.

Rhododendron is a problem in Lochard. The stand structure under CCF increases the potential habitat for Rhododendron as it is a very shade tolerant shrub and could present a significant problem for CCF in the District if not carefully controlled. Levels of rhododendron are currently monitored and managed to control the spread using chainsaw clearance and spraying the regrowth with herbicide.

### Feedback on Guidance and Information Gaps

Guidance produced by the FC has been well received by local staff, however there are difficulties implementing guidance such as IN 40. One of the prerequisites for determining suitability to CCF transformation in accordance with IN 40 is a knowledge of soil type, the District as a whole has poor soil information and a very limited budget to collect soil data therefore the IN 40 stratification cannot be completed accurately. Lack of soil information also makes accurate prediction of WHC difficult.

A scarcity of good, up to date aerial photography has also been a constraining factor for planning processes. Aerial photographs are a great visual reference for planning allowing stock maps and road locations to be checked as well as monitoring felling.

Within the District knowledge of harvesting and extraction methods is good but further information of low impact methods for harvesting in CCF would be useful.



## INVERNESS FOREST DISTRICT: INSHRIACH

Inshriach forest is located in North Scotland, part of Inverness Forest District. The 1998 design plan first prescribed management under CCF at Inshriach.

Table 8 Inshriach Site and Stand Condition Summary

Area	436 ha of Scots pine comprises the CCF trial area at Inshriach
Terrain	Generally terrain is not limiting to machine movement and does not cause difficulties, a few small, isolated steep areas do present a barrier for harvester and forwarder access
Soil Type	Moraine and glacial till soils that are load bearing for machine movement, there are large areas of peaty podzols (the peat layer is generally very thin)
Windthrow risk	Windblow has been minimal, typically WHC 3 across the forest
Limiting site factors for CCF	Some isolated slopes are too steep for harvester and forwarder access.
Species mix	Scots pine (95%, remainder is made up of non-native conifer: NS, EL and LP with some naturalised birch) Basal Area is currently 28 – 34
Age range	35 – 40 years old (P c. between 1960 - 1970)
Tree size	Tree sizes are small due to the generally low site fertility, high elevation and exposure, the mean dbh is 17 and mean tree volume 0.133
Yield Class	6 – 8 Scots pine
Limiting stand factors for CCF	Crop factors are not limiting to CCF
Selection criteria for CCF	The forest objectives fit with the stand characteristics created by adopting CCF and the stand at Inshriach is suitably wind firm under the selection criteria identified in FC Information Note 40

### CCF Management

Management objectives include Capercaillie habitat preservation, timber production and landscape preservation as well as recreation.

The majority of the Scots pine crop has been thinned twice previously. Thinning is carried out on a 10-year cycle. The prescription has been to thin to FC management table thinning intensity; variations to this volume are made to leave some areas more heavily stocked to control light creating an environment suited for *Vaccinium* growth for Capercaillie. Some localised areas of the site are too steep for machine movement and therefore it fits with operational limitations to leave these unthinned in the interests of providing Capercaillie habitat.

Currently a number of research plots have been established in the Pine overstory, thinning to variable intensities and also felling groups with deer exclusion plots to assess the likelihood of establishment through natural regeneration. At the next thinning there will be a shift away from conventional management table thinning to move the stand toward an irregular structure. The precise silvicultural prescription has yet to be defined and will be decided upon following monitoring of the response of the stand to the ongoing thinning, and the results from research plots in the forest assessing variable thinning intensity, group felling and the Glenmore SP conversion experiments.



Figure 46 Thinned Scots pine, typical of the CCF crop at Inshriach



Figure 47 Sloping area of the site, purposely unthinned to preserve Capercaillie habitat in agreement with objectives

Conventional intermediate management table thinnings have been carried out to date with some areas allowed to remain at higher stocking density in the interests of habitat creation.

As timber production is a comparatively low priority the existing pine overstory will be gradually removed over the next c. 100 years preserving trees beyond the age of maximum MAI. The forest is currently undergoing transformation to CCF, some areas will use group felling to achieve regeneration.

### Operational Experience

Timber harvesting is carried out by harvester and forwarder combination most recently using a Valmet 911 harvester and Timberjack 810 forwarder, some extraction was done with a Valmet 840 forwarder.

Natural regeneration is not abundant within the stand. Regeneration is developing on disturbed ground where the mineral soil has been exposed, for example along road edges (Figure 50).



Figure 48 Thin peat horizon overlying podzolic soil with deep, load bearing mineral layer



Figure 49 Sporadic natural regeneration currently developing within the stand under Scots pine overstory

The current contractor base is limited and is using medium-scale machinery. Local management report that the Valmet 840 forwarder is as small as many contractors are prepared to invest in. Smaller scale forwarders are viewed as inappropriate, as they may limit versatility in the crops they can operate in under conventional silviculture. While CCF management is a niche in the UK it is difficult for contractors to justify investment in specialised scale of machinery.

Harvesting has been carried out with conventional harvesting and forwarding techniques with no need to deviate from established methods of working to achieve a high standard of thinning. Felling is done using feller select with harvesters on direct production, managed under a three year LTC. The person who manages the harvesting team is a trained forester and therefore has a good understanding of the methods in use and the standard of tree selection using feller select has been high. A site map is prepared to inform felling showing the operational area, constraints and target basal area (BA) for removal, this is given to the contractor to guide the harvesting operation.

Operational costs are currently no different to conventional harvesting, in the long term if natural regeneration is successful then the costs of restocking will be saved. Restocking costs can be considerable: £2000 to £2500 per ha (by year five) due to high levels of beating up.

### Access Requirements for CCF

Current access consists of roads, tracks and racks that are adequate to allow mechanised harvesting and extraction of all the thinned areas, these different levels of machine access are shown in Figures 50 to 53. Landrover access for management operations is possible on the roads and tracks. Track and rack layout is designed to allow full coverage over the whole felling site for harvesting machinery.





Figure 50 Forest road constructed from locally won stone, note natural regeneration on disturbed bank adjacent to road



Figure 51 Access track through the forest



Figure 52 Point of convergence between track and rack



Figure 53 Rack surface over which harvester and forwarder travelled during thinning, the pine provides very little brash cover for rack construction

Compartment boundaries within the forest are left unplanted to allow for mechanised access and as a variation in stand structure for habitat variation. Access is imposed as permanent infrastructure, and due to the excellent ground bearing properties of the mineral soil it forms a solid foundation to machine movement, roads can be constructed only six months prior to harvesting and this is adequate consolidation time before use.

### Brash Management

Quantities of brash from thinning pine are very low and provide only a minimal brash rack formation as shown in Figure 53. The mineral soil at Inshriach supports forwarder and harvester movement very well, no significant rutting impact was observed over any of the CCF area during this case study visit despite the minimal quantities of brash.

### Problems, Causes and Solutions

Operations do not take place during February – June to avoid the Capercaillie breeding season.

Felling to date has been implemented as an intermediate thin, no different to conventional thinning under clearfell and restock silviculture likewise timber products are the same. A strategy for regeneration of crops in transformation is being developed. Research plots evaluating the effect of varying thinning intensity and group thinning have been established and are being assessed to inform future management prescriptions.



Marketing the products from the intermediate thinning is not a problem; products include chip and bar as well as round fencing material for which there is a local market, the fencing material is what makes the thinning economically possible attracting a price of c. £25 per tonne (specification is 1.7m length 8 – 10 cm top diameter).

Difficulties have arisen with the transport of timber products from the forest. The forest is remote from the A9 (the main arterial road through central and northern Scotland). The county road connecting the forest to the A9 is of a poor standard and includes a weak bridge over which timber lorries must not pass. Timber transport therefore has to be diverted 12 miles south to access the A9 after which it is taken north. Transport costs are one of the major components of harvesting costs therefore any increase has negative effects on the overall economics of forest management.

Problems have largely been avoided through appropriate site selection for CCF in accordance with the selection criteria in FC IN 40. Operating conditions are generally not limiting to conventional harvesting and forwarding equipment.

Large tree sizes may be a potential problem in the future due to uncertainty on the marketability of large tree sizes.

Harvesting under direct production has been to an exceptionally high standard with very low site impact and no modifications to working methods have so far been required.

The Capercaillie population means fencing is undesirable due to the potential for bird strikes. Due to the desire to achieve natural regeneration of mixed aged stands without fencing a large investment has recently been made to control deer, the deer population will continue to be managed to levels that allow pine regeneration.

### **Feedback on Guidance and Information Gaps**

Local staff reported FR guidance to be useful. FC IN 40 guidance has recently been used to review the areas proposed under long-term retention and CCF. The area managed under CCF has been expanded since the original design plan was drawn up, as experience of CCF increases and staff are more confident that areas can be operated under CCF.

Forest Research are undertaking research at Inshriach to assess the success of transformation and variable intensity thinning and group felling are being carried out to establish the effects of these management techniques on increasing stand irregularity. This will continue and given the current regular stand structure it is considered unnecessary to begin additional formal monitoring as per FC IN 45, this will be revisited in the future.

Case study information would be welcome to increase knowledge of operational experience elsewhere and to highlight avenues of possible information exchange with those in similar situations.

If natural regeneration is not forthcoming then it may be necessary to carry out mechanised ground preparation, at what stage to go down this route is as yet undefined and little information exists to provide guidance.

The likelihood of large product sizes emerging in the future under CCF and potential difficulties in harvesting and marketing these are as yet unknown.

## TAY FOREST DISTRICT: CRAIGVINEAN

Craigvinean is located in Tay Forest District in Northern Scotland; CCF has been operated at Craigvinean since c. 1996. Currently 50% of Craigvinean forest is designated under CCF, other areas less than 10 years old may be brought under CCF management with successive management plan revisions.

Craigvinean is one of the earliest established commercial forests, with planting dating back to the 1700's. The Dukes of Atholl planted larch, Norway spruce and later Douglas fir was established, some of these original stands are now in their fourth rotation.

Table 9 Craigvinean Site and Stand Condition Summary

Area	Total forest area 1943 ha with CCF being operated over approximately 50%
Terrain	Terrain is steep in some areas of the forest requiring cable way extraction
Soil Type	Soils are predominantly brown earths
Windthrow risk	Typically WHC 3
Limiting site factors for CCF	Windblow can be limiting when opening up exposed stands, slope can also be limiting to transformation. Deer are being managed to control damage to acceptable levels; experience suggests that in the forests where there is high recreation use deer are less common as the people act as a deterrent
Species mix	Sitka spruce (27%); Norway spruce (14%); Lodgepole pine (11%) with the remainder composed of larch, Scots pine, Douglas fir, as well as 'other' conifer and broadleaf species
Age range	A large proportion of the forest was established in the 1940s with subsequent largescale planting in the 1970s a wide age range currently exists across the site due to felling and restocking in recent decades
Tree size	Wide range across the site
Yield Class	Yield Class in spruce is typically in the high teens, with pine commonly around YC 10 – 12.
Limiting stand factors for CCF	Pine does not grow particularly well in Craigvinean, an indurated layer in the soil may act as a barrier to drainage, preventing successful pine regeneration, regeneration of other species is considered acceptable to provide for restocking.
Selection criteria for CCF	The selection criteria for CCF are a combination of timber production, recreation, landscape and conservation requirements, identified as part of the design planning process where CCF is best served to meet these objectives then CCF is implemented. The southern side of the forest is highly visible from the A9 trunk road and as such landscape impact of any interventions are critical. The northern side of the forest is less visible in the landscape and consequently better suited to conventional clear felling

### CCF Management

Management planning for Craigvinean is administered through the FC management planning process. The long-term management objectives at Craigvinean are a balance between landscape (highly visible along the A9 corridor), recreation and timber harvesting, wildlife conservation is also a priority due to Capercaillie and Red squirrel populations. Unlike some of the trial sites the Capercaillie population is generally out with the CCF trial sites, and this is therefore less of a constraint for CCF management.

First thinning involves cutting racks into the stand with a harvester and forwarder combination, or in some steeper areas skidder extraction by tractor using motor manual felling. Racks are imposed at a spacing of 18 – 21 m centres. Second thinning involves crown thinning with a view to developing final crop trees (frame trees). Third thinning onwards looks to identify trees for removal to promote final crop trees. Felling is carried out using feller select, sample plots are marked, targeting 20 – 25% of the overstory for removal (1 in 4 trees marked, concentrating on the stand subdominants), any areas of windblow are opened up to encourage natural regeneration. To date natural regeneration has developed very well in small windblow areas.

### Operational Experience

Machinery used for shortwood harvesting has included a Valmet 840 forwarder fitted with full bandtracks (Figure 54) and a Valmet 941 harvester. No access problems have arisen specifically due to implementing CCF, although it has been difficult to construct adequate racks in places due to limited brush availability.

Difficulties have been overcome with proactive management through appropriate machine and method selection. On steep slopes a Timberjack Hillclimber (tilting base machine) and Silvatec 8 wheeled hillclimbing harvester has been used to increase terrainability, elsewhere skidding with tractor winch extraction has allowed thinning to go ahead on steeper slopes.

Density of natural regeneration in places is becoming an issue that may need increasing attention in the future. Regeneration has been respaced using an excavator 'combing' the trees.



Figure 54 Forwarder timber extraction at Craigvinean (Valmet 840 fitted with full bandtracks, front and rear)



Figure 55 Heavily thinned block at Craigvinean, assessing potential natural regeneration success

In some CCF areas in the District felling has been carried out motor manually with forwarder extraction to roadside. This system has resulted in exceptionally low impact on racks as shown in Figure 59.

Felling is done on contract with the timber sold either as a standing sale or from direct production (the latter having the advantage that it allows managers far greater control over the felling). There is a good contractor base locally but there is still a struggle among the contractors to source good quality operators. The District does struggle to get cable way extraction work completed due to a general lack of cable way expertise.

For a standing sale contractors are given a location map and sales plan, details of constraints and access as well as the U18 data outlining the crop breakdown. The contractor then produces their own site plan and carries out the risk assessment. Under direct production the site plan, risk assessment and felling specification are all given to the contractor by the District.

In some circumstances in CCF thinning where there is high wind exposure edge trees are left unthinned to create a windfirm edge, as shown in Figure 56.

Operators have adapted to thinning in CCF very well and take an active interest in the management of the CCF stands.

There have been no reported problems with natural regeneration blocking the operator's view from the machine cab during harvesting. Where natural regeneration is dense motor manual fellers have been used to carry out felling this reduces the risk of damage to regeneration during felling. Motor manual fellers are able to see the base of the tree easier, rather than struggling to locate the felling head at the base of the tree from the rack. The costs for CCF operations are no different to standard thinning, but where there is a preference to use motor manual fellers in CCF felling can be more expensive than if mechanised felling were used.



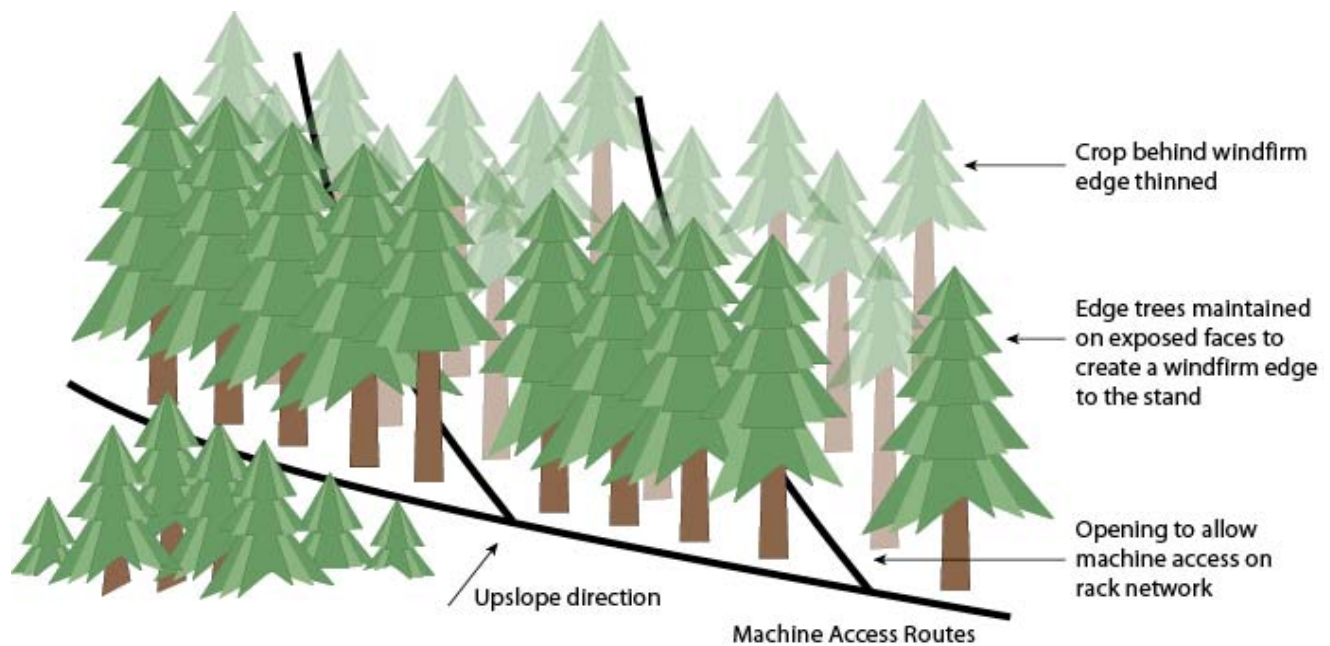


Figure 56 Maintaining a windfirm edge on exposed sites to prevent windblow.

Larch (c. 10 years old) has been respaced motor manually at Five Mile Wood close to Craigvinean using brush cutters. The cost for respacing was £300 per ha (based on two operators costing £90 each per day: 3 ha took 5 days to work – 10 man-days in total) respacing to 1.5m –1.8m stems (Figure 58). Elsewhere at Craigvinean there are areas of Sitka spruce natural regeneration that need respacing (Figure 57), there is little guidance on how to effectively respace these crops.



Figure 57 Dense Sitka spruce natural regeneration with overstory removed in previous felling



Figure 58 Larch natural regeneration, respaced motor manually with brushcutter

Large tree sizes are causing problems with marketing products; any produce with a butt diameter greater than 50 cm effectively attracts a red log price due to the fact that these have to be transported further to an alternative mill that can deal with large produce.

### Access Requirements for CCF

There is no difference in specification of access under CCF although due to the need to preserve access into perpetuity forwarder movement along racks is carefully managed to make sure that racks and tracks are not damaged. Should significant disturbance to tracks result from extraction then contractors are required to reinstate tracks to their pre-harvesting condition as a contract condition. Roads are constructed to category 1 A standard. The District decides on appropriate provision of access racks, tracks and roads. Rack spacing is determined by machine reach, established at the time of first thinning.

Craigvinean is very well racked and rack lengths are typically short distance due to the high density of forest roads so that machines have relatively short distances to travel on racks before reaching the road network, this reduces trafficking on racks to a minimum. Access maintenance is decided upon prior to harvesting as part of the management planning process. Harvesting equipment and timber lorries as well as general management vehicles use the access network.



Figure 59 Route travelled by forwarder showing minimal impact: felling carried out motor manually



Figure 60 Harvester and Forwarder movement adjacent to the road, preserving the road surface condition for timber lorry travel

Racks are imposed on a fixed layout. Many of the roads take the route of old estate roads that follow routes created when the forest was established, these have remained and as they are the correct gradient for timber lorry access.

Craigvinean forest falls within a National Scenic Area (NSA) and as a result of this classification all tracks, ramps and other such access infrastructure created in the forest requires planning permission and an environmental impact assessment before they can go ahead.

### Brash Management

Brash racks are constructed by harvesting machinery, in some cases quantities of brash have reportedly been lower than desirable for adequate rack construction.

In some stands the harvesting method has been adapted to involve felling motor manually with subsequent forwarder extraction, this has led to a reduction in the trafficking received under machine movement, Figure 59 shows the resulting low impact of machine movement on the racks. Standing sales contracts state that any disturbance to racks must be reinstated to their former condition following use.

### Problems, Causes and Solutions

In part of the CCF trial site felling is restricted between March and June due to Capercaillie breeding.

The economics of harvesting are a particular problem with first thinnings. On the higher slopes where the economics of first thinning are particularly poor there is a proposal to restock felled areas with a mixture of Corsican pine and Sitka spruce. This will act as a self-thinning mixture as the spruce out performs the pine, this should benefit the form of the spruce, without incurring the cost of thinning.

Where restocking is successfully achieved through natural regeneration the quality of the stems for future timber is unknown.

To improve information exchange within the District the shared 'T drive' at the Forest District office is used to record design plan prescriptions in an attempt to secure continuity of management records and prescriptions. There is a plan to produce a thinning database for the forest that will hold details of thinning prescriptions, timings and volumes removed.

One major difficulty in planning is that the use of GIS has limitations to overcome; thinning coupes differ from felling coupes, which differ from compartment boundaries. The CCF prescriptions are applied on a compartment basis, complicating management in reconciling differences with the thinning coupes.

Marketing of low value broadleaf timber in Craigvinean has been overcome by felling poor quality broadleaf species and stacking them in the wood in 1m lengths, then 'scavenging' permits are issued at £35 per time for people to come in and collect this material for firewood. If the recent rejuvenation of UK domestic woodfuel markets continue to develop then this may be an increasingly popular means of achieving small-scale stand management.

### **Feedback on Guidance and Information Gaps**

Local staff have read FR guidance notes and these are regarded as useful reference documents.

Comments were received from district staff that there is a lot of good information relating to CCF in research papers, old publications and journals. The available information is very scattered and difficult to access. It would be advantageous if this information were collected together with references to where useful sources of information exist in an easy to access format to inform management.



## DORNOCH FOREST DISTRICT: MORANGIE

Morangie forest is located in the North of Scotland; ATC management was initiated on the site in the interests of Capercaillie habitat preservation in the 1999 design plan. Prior to the adoption of ATC the stand was managed with regular thinnings and areas of value to Capercaillie were designated as minimal intervention and long term retention.

Table 10 Morangie Site and Stand Condition Summary

Area	The total forested area at Morangie forest is 4902 ha. 1665 ha is designated as ATC
Terrain	The area is characterised by gently rolling hills, ranging from sea level to 396 m
Soil Type	Soils are described as 'moderately fertile' over much of the forest where peaty podzols are common; in the North and West poorer peaty soils dominate
Windthrow risk	Windblow risk in CCF sites is low-moderate, typically < WHC 3
Limiting site factors for CCF	Exposure is a factor in the higher parts of the forest but is not a major influence
Species mix	Scots pine dominates with some areas of Lodgepole pine on the poorer slopes planted in the 1970's and 80's, in places in mixture with Sitka spruce
Age range	0.5% of the forest is below 5 years in age with 14.5% at the establishment stage (5 – 15 years), 40% of the forest is thicket stage (15 – 30 years) with 39% classed as mature (30 – 60 years), 6% over 60 years old
Tree size	Ranges over the crop
Yield Class	Yield class is described as 'moderate' within the management plan and is generally YC 8 within the pine stands
Limiting stand factors for CCF	Browsing pressure (partially attributed to Capercaillie) and vegetation competition has resulted in limited development of Scots pine transplants in the felled groups
Selection criteria for CCF	The desire to preserve a suitable habitat for Capercaillie has been the main driver for the selection of stands for CCF. Within the design plan 'younger areas with the potential to be developed as ATC have been identified'. Where Capercaillie use is low, clear felling will be operated, elsewhere the stands are managed through a mixture of ATC, retentions and non-intervention

### CCF Management

Habitat preservation for Capercaillie is the main influencing factor on forest management objectives, the objectives of recreation, timber production and landscape are all managed with Capercaillie protection in mind. One of the main aims of managing the forest under CCF is to maintain tree cover that creates a light environment to suit the growth of *Vaccinium*; a valuable food source for Capercaillie. Currently the dappled light reaching the forest floor through the pine canopy is suited to the growth of *Vaccinium*, if too much light reaches the forest floor then heather will out compete the *Vaccinium*, reducing the available food source for the Capercaillie. The main constraining factors for obtaining Scots pine natural regeneration are light environment, vegetation competition and browsing pressure.

CCF transformation is being established in a Scots pine crop that has been previously thinned. Groups have been felled within the crop c. 28 m in diameter (0.06 ha). The next thinning intervention will be an intermediate thin with a progressive enlargement of the groups (Figures 61 and 62). The desire to maintain the *Vaccinium* growth below the canopy and prevent windblow means that conservative volumes will be removed in the thinning.



Figure 61 Felled group at Morangie forest, with route of access rack running along the eastern edge



Figure 62 Group showing central monitoring post for regeneration/ restocking assessments

Cultivation has been carried out within the felled groups, using an excavator bucket to disturb the herb layer exposing the top soil to encourage natural regeneration. In response to low levels of natural regeneration underplanting has been carried out using Scots pine transplants.

### Operational Experience

Harvesting has been carried out using shortwood harvester and forwarder extraction. The whole forest has terrain that is suitable for harvester and forwarder access.

The limited response of natural regeneration of pine within the felled groups has been a problem, necessitating planting to ensure adequate restocking. The main difficulty has been managing the light environment to allow sufficient light for regeneration, but not too much to allow the development of a dense vegetation layer which can impede natural regeneration.

All felling is done as standing sales with contract felling. The Forest District does not have much influence on the specific contractors that are brought in to do the felling, but the contracts are written to specify that machine combinations must be suitable for the operation. Site damage resulting from felling has not been a problem. Operators have reacted well to the changes in working, welcoming the variety in felling. A site plan is prepared to guide felling showing the location of the groups to be felled. Trees to be removed are marked, feller select is not used. GPS co-ordinates of the felled groups are taken to allow accurate mapping and as part of the monitoring process stocking density counts are made on a sample of the felled groups.

There have been no difficulties with visibility from machine cabs as the pine crop allows good visibility compared with denser crops such as Sitka spruce. The tree sizes of the pine in the ATC areas are not limiting to harvesting and this is not anticipated to be a problem during the transformation period.

### Access Requirements for CCF

Forest roads and tracks have sustained machine movement well. Despite the lack of brash from felling the pine overstory the impact of felling machinery has not compromised future access. Terrain is moderate and generally not limiting to machine movement, the only obstacle to machinery on the site is the presence of melt water channels that cross the site (Figure 64), these have so far not caused significant problems for access.

Other machine types using the access infrastructure at Morangie forest include a tracked excavator that was brought in to carry out ground preparation and small scale ATVs, used to transport transplants for restocking. Access provision in CCF does not differ in specification from conventional thinning. Access requirements are assessed as part of the design planning process and areas where new road access will be needed or upgraded are identified, based on site inspection. Permanent racks have been established through the stands to allow access to the felled groups, rack spacing allows all the trees in the group to be felled without the need for machine movement off the racks.

### Brash Management



Figure 63 Access rack showing wheel marks through the dense vegetation sward, but very little rutting of the soil



Figure 64 Old melt water channel crossing the forest, c. 1m depth



Brash from the pine overstory is minimal, however soils are generally sufficiently load bearing to allow machinery movement without damaging the ground and compromising future access (Figure 63).

### Problems, Causes and Solutions

Timing of operation is restricted to October – March due to the need to avoid the Capercaillie breeding season.

The site conditions at Morangie forest are not limiting to conventional harvesting and forwarder machinery and the indication is that implementing CCF will not be limited by operational factors. The main difficulties arise from the very fine balance of controlling the light environment in the interests of encouraging regeneration in harmony with *Vaccinium* growth.

The growth of the pine transplants and natural regeneration has shown good lateral extension, but the trees are 'whippy' and drawn up, they are observed by local staff to be putting on height growth at the expense of girth (Figure 66). This is likely due to the small group sizes with minimal light reaching the forest floor. The consequence for management and successful regeneration of this drawn up tree form is unknown.

Capercaillie have been responsible for browsing damage to the planted pine, deer also have browsed the regeneration and due to the risk to Capercaillie of fence collisions fencing is not an option to exclude deer.



Figure 65 Dense vegetation layer on the forest floor comprising moss, grasses, heather and *Vaccinium*



Figure 66 Young Scots pine transplant in felled group (pen in foreground for scale)

### Feedback on Guidance and Information Gaps

Forestry Commission OGB 7 has been consulted to inform the transformation to CCF, feedback is that this document is a very useful tool for management.

More detailed information would be useful on the required light levels for *Vaccinium* growth and the interrelation with light requirements for natural regeneration of pine and growth of heather. This would allow the correct balance to be maintained to safeguard the quantities of *Vaccinium* for Capercaillie, and achieve successful pine regeneration. Further information on tree protection methods for pine transplants against predation from Capercaillie is also needed in forests where there is a significant Capercaillie population.



## CONCLUSIONS

In the first five years since their establishment the FC CCF trial forests have generated a wealth of operational experience. The selection of trial sites has been appropriate to provide a wide range of operational conditions and constraints for gaining management experience of CCF transformation. Management in the trials has typically been adaptive and flexible, allowing difficulties to be overcome.

The trial sites are being managed under 'real-world' operating conditions and constraints helping to identify and overcome problems with practical solutions that are appropriate for large scale application over a wide range of forest conditions throughout the UK. In the majority of cases only minor changes to operational methods and systems have been required to successfully transform stands toward irregular silviculture.

The transformation process is leading to many new management challenges and opportunities as new irregular stand structures are emerging. CCF silviculture is well served to meet current management objectives.

Management issues still to be resolved include:

- Limited resources for specialist harvesting and extraction e.g. on steep sites requiring cable way extraction;
- Future marketability of large dimension produce in CCF;
- Crop protection issues;
- Methods for managing natural regeneration;
- Information sharing and networking.

It is encouraging to observe the commitment to CCF among local FC staff and the vertical integration of the workforce (from higher managers to operators) is also encouraging and is one of the principle factors why CCF is being successfully implemented at the trial forests.

The operational techniques for achieving transformation described in this report still require formal field evaluation, however any future revision to the Forestry Commission Operational Guidance Book series should take the findings of this report into consideration.

Experience from the trial sites shows tremendous success in overcoming the obstacles of transformation so far encountered. Caution should be applied however, to adopting these new techniques and methods, before they are fully evaluated. New operational methods will require a period of formal evaluation to investigate their long-term sustainability, and to make sure that they enable transformation without compromising the varied functions of CCF forests.

## APPENDIX 1

### STANDARDS OF ACCESS

During observations at the trial forests four grades of access were commonly observed. These were forest roads, secondary roads, tracks and racks. This terminology has been used consistently throughout this report. The figures below show examples of the standard of these access routes through the forest with descriptions of their specification.

#### Forest Roads



Forest Road – stone surfaced road, capable of supporting a range of machinery travel including timber lorries. Forest Roads are constructed to the Forestry Commission Civil Engineering standard 'category 1 A'.

#### Secondary Forest Road



Secondary Forest Road – stone surfaced road to allow machinery for timber harvesting and management access to the forest. These are lower specification than a 'category 1 A' roads and are not intended to support prolonged timber lorry travel.

#### Track



Track – access route through the forest that links the road and rack networks. Tracks are constructed to a lower specification than forest roads usually without stone reinforcing; the construction of forest tracks will involve some earth works, e.g. removing or compacting topsoil, creating a durable surface for machine travel.

#### Rack



Rack- these are the lowest specified access routes through the forest and are simply unsurfaced corridors through the standing crop to allow access for timber harvesting and forest management operations, racks are often reinforced with brash to increase their longevity.

## ACKNOWLEDGEMENTS

I would like to thank the following for their assistance and support during the information gathering and production of this report:

Jon Bates and Graham Jackson (North York Moors Forest District), Kevin May and Gareth Browning (Northwest England Forest District), Peter Verney (Peninsula Forest District), Richard Carrick and Dave Williams (Coed Y Gororau Forest District), Neil Stoddart, Dave Ellerby and Huw Thomas (Llanymddyfri Forest District), Steve Morgan and John Ogilvie (Scottish Borders FD), John Hair and Rowan Stuart (Cowal & Trossachs Forest District), Neil Proctor (Inverness Forest District), Graham Stirling, Peter Fullarton and Charlie Taylor (Tay Forest District), Roddy Macleod (Dornoch Forest District)

Additionally thanks to Gary Kerr and Bill Mason (Forest Research) for their support in producing this report and to John Blyth for his input at Glentress forest.

## REFERENCES

Anon (2003) *Managing Continuous Cover Forests*. Forestry Commission Operational Guidance Booklet 7 Forestry Commission, Edinburgh.

Hale, S. (2004) *Managing Light to Enable Natural Regeneration in British Conifer Forests* Forestry Commission Information Note 63 Forestry Commission, Edinburgh.

Kerr, G., Mason, B., Boswell, R. and Pommerening, A. (2002) *Monitoring the Transformation of Even-aged Stands to Continuous Cover Management*. Forestry Commission Information Note 45 Forestry Commission, Edinburgh.

Mason, B., Kerr, G. and Simpson, J. (1999). *What is Continuous Cover Forestry?* Forestry Commission Information Note 29 Forestry Commission, Edinburgh.

Mason, B. and Kerr, G. (2004) *Transforming Even-aged Conifer Stands to Continuous Cover Management*. Forestry Commission Information Note 40 (revised) Forestry Commission, Edinburgh.

Spencer, J.B. (1991) *Soft ground harvesting review of methods to minimise site damage*. Technical Development Report 35/91. Forestry Commission, Ae, Dumfriesshire.