Environment Agency

using science to create a better place

Environmental best practice for continuous cover forestry

Science Report: SC020051/SR

ea/br/e/sci/v1

SCHO0306BKKY-E-P

The Environment Agency is the leading public body protecting and improving the environment in England and Wales.

It's our job to make sure that air, land and water are looked after by everyone in today's society, so that tomorrow's generations inherit a cleaner, healthier world.

Our work includes tackling flooding and pollution incidents, reducing industry's impacts on the environment, cleaning up rivers, coastal waters and contaminated land, and improving wildlife habitats.

This report is the result of research commissioned and funded by the Environment Agency's Science Programme.

Published by:
Environment Agency, Rio House, Waterside Drive, Aztec West, Almondsbury, Bristol, BS32 4UD
Tel: 01454 624400 Fax: 01454 624409
www.environment-agency.gov.uk

ISBN: 1844325474

This report is printed on Cyclus Print, a 100% recycled stock, which is 100% post consumer waste and is totally chlorine free. Water used is treated and in most cases returned to source in better condition than removed.

Further copies of this report are available from:
The Environment Agency's National Customer Contact Centre by emailing enquiries@environment-agency.gov.uk or by telephoning 08708 506506.

Author(s):
Ireland D, Nisbet T R and Broadmeadow S

Dissemination Status:
Publicly available

Keywords:
Forestry, soil, water, quality, continuous, Cover, forestry, clearfell

Research Contractor:
Forest Research
Alice Holt Lodge, Farnham, Surrey, GU10 4LH
Tel: 01420 22255
www.forestresearch.gov.uk

Environment Agency's Project Manager:
Wendy Merrett, Wales

Science Project Number:
SC020051

Product Code:
SCHO0306BKKY-E-P

Science at the Environment Agency

Science underpins the work of the Environment Agency. It provides an up-to-date understanding of the world about us and helps us to develop monitoring tools and techniques to manage our environment as efficiently and effectively as possible.

The work of the Environment Agency's Science Group is a key ingredient in the partnership between research, policy and operations that enables the Environment Agency to protect and restore our environment.

The science programme focuses on five main areas of activity:

- **Setting the agenda,** by identifying where strategic science can inform our evidence-based policies, advisory and regulatory roles;
- **Funding science,** by supporting programmes, projects and people in response to long-term strategic needs, medium-term policy priorities and shorter-term operational requirements;
- **Managing science,** by ensuring that our programmes and projects are fit for purpose and executed according to international scientific standards**;**
- **Carrying out science**, by undertaking research – either by contracting it out to research organisations and consultancies or by doing it ourselves;
- **Delivering information, advice, tools and techniques,** by making appropriate products available to our policy and operations staff.

Steve Killeen

Head of Science

Executive summary

Environmental best practice for conventional forest harvesting based on the clearfell system is well established. However, the guidance does not address the recent trend away from clearfelling to alternative harvesting techniques such as CCF.

This report looks at the applicability of current best practice guidance for protecting soils and water at the planning/design and operational stages of continuous cover forestry (CCF). It also considers practical experience at five CCF demonstration forests and the requirements for long-term monitoring of CCF.

The first section describes the background to the study. CCF is generally expected to have a more benign impact on the environment compared to clearfelling because of the smaller-scale nature of the management operations. Nevertheless, there are a few areas of concern. At the catchment scale there are issues about the effects of maintaining a permanent forest canopy on forest water use and the scavenging of atmospheric pollutants, while at the site level the main threat is thought to be linked to the need for more frequent machine access to sites for thinning operations. A lack of brash to protect routeways could potentially lead to increased soil compaction, rutting and erosion. There are also constraints on drainage work, which may have implications for soil damage and siltation of watercourses. Another concern is the possible greater reliance on the use of herbicides to control weeds.

Section 2 summarises the current best practice guidelines in terms of soil and water protection at both the planning/design and operational stages of CCF. It covers all known issues and identifies information gaps where further research is needed.

Section 3 then assesses the experience gained from a selection of the Forestry Commission's CCF demonstration forests in the UK. Observations are presented from visits to the sites at Cwm Berwyn, Clocaenog and Trallwm in Wales, Whinlatter in England and Glentress in Scotland. These records provide a valuable insight into the practical issues associated with implementing CCF in Britain.

It is concluded from the site visits that the transformation of even-aged stands on freely draining soils on sheltered sites, and their management under a CCF regime, is likely to pose few threats to forest soils and water (at least on an operational basis). Freely draining soils are more resistant to damage and the greater availability of brash means that existing best practice is effective at minimising any impacts. Sites are already subject to a thinning regime and the same types of machinery are used as under conventional clearfelling. The absence of forest drains removes the need for any supplementary or corrective drainage work.

Most problems occurred where CCF was being pushed onto less suitable soils, especially wet soils on more exposed sites. The combination of soft ground and insufficient quantities of brash meant that there was often insufficient support for machine movement. This resulted in an increased risk of soil rutting, erosion and water pollution. The provision of adequate drainage was another key issue. However, the experience gained from the demonstration sites is leading to the development of novel methods to overcome these additional pressures and impacts. The methods are taken forward and further developed in a Technical Information Note, which will be published by the Forestry Commission. Initial assessments indicate that the methods are effective in protecting vulnerable soils and waters, but there remains a need for a formal evaluation of costs and benefits. The site visits re-emphasised the importance of good site planning and the need for a thorough site survey and regular monitoring, especially during the transformation stage to CCF. The results suggest that CCF can probably be extended to a wider range of site types than was originally envisaged.

In the majority of cases the availability of skilled operators to carry out thinning and timber extraction is diminishing. This could prove to be a major limiting factor in extending the conversion of even-aged stands to CCF. It also poses the risk of unskilled operators not implementing best practice correctly or important management operations being omitted. Emphasis must therefore be given to the proper training and supervision of contractors. Another important issue is the current low prices for timber. This has the beneficial effect in some locations of leaving large volumes of low value pulpwood available for use in strengthening permanent access routes. However, it also makes some operations such as remedial drainage work uneconomic, which can increase the risk of site damage.

The final section of the report assesses whether any of the existing long-term hydrological and water quality monitoring studies in the UK are suitable for examining the impacts of CCF. The assessment of 49 catchments found that only one (the Afon Cothi catchment in mid Wales) was suitable for converting a significant area of forest to CCF. This reflects the fact that most of the sites comprise small headwater catchments in exposed upland areas, which are generally unsuitable for CCF. If such sites are typical of upland Britain, then it raises a question about the likely scale of forest conversion to CCF at the catchment level.

Experience suggests that if the change to CCF involves less than 20% of a catchment then the effects are likely to be minor and remain undetectable. This is especially relevant in the context of the more subtle and gradual changes associated with CCF compared to conventional clearfelling. Consequently, there is a need for a wider assessment of forest plans to characterise the planned scale of CCF at the catchment level. A good starting point would be to determine the relative proportions of the catchments of the individual waterbodies that have been designated under the EU Water Framework Directive. As Wales is at the forefront of the change to CCF, there would be merit in focusing attention on a regional or country-wide assessment. This would help to clarify the potential risk to fresh waters and help guide the need for further research.

It would also be sensible to consider the scope for reinforcing the monitoring work at Afon Cothi. This site's long-term stream water chemical record provides a good baseline for assessing the effects of the future large-scale conversion of the forest to CCF. The existing monthly sampling regime is probably sufficient to monitor any chemical changes but the biological survey work would need to be strengthened. However, the main deficiency in the catchment study is the lack of any flow monitoring work. There is a need to scope the suitability of the site and the best method for monitoring catchment stream flow to determine whether the costs of installing measuring instruments can be justified.

Contents

1 Background

Environmental best practice for conventional forest harvesting based on the clearfell system is well established. Detailed guidance on environmental protection is provided by the *Forests and Soil Conservation Guidelines* (Forestry Commission 1998), *Forests & Water Guidelines* (Forestry Commission 2003) and a range of other documents (Nisbet 2001). However, the guidance does not address the recent trend away from clearfelling to alternative harvesting techniques. These are variably referred to as Continuous Cover Forestry (CCF), Alternatives to Clearfell (ATC) or Low Impact Silvicultural Systems (LISS). The main driver for the move to CCF is to increase species and structural diversity in existing even-aged plantation forests to better provide multi-purpose benefits. Forestry Commission Wales is at the forefront of this change, with a target to convert half of the National Assembly's woodlands to CCF over the next 20 years. This represents a marked shift in policy and practice and requires an assessment to ensure that there will be no detrimental effects on forest soils or water.

CCF is generally expected to have a more benign impact on the environment compared to clearfelling because of the smaller-scale nature of the management operations. Nevertheless, there are a few areas of concern, both in terms of planning and site operations. At the catchment scale there are issues about the effects of maintaining a permanent forest canopy on forest water use and the scavenging of atmospheric pollutants, while at the site level the main threat is thought to be linked to the need for more frequent machine access to sites for thinning operations. A lack of brash to protect routeways could potentially lead to increased soil compaction, rutting and erosion. There are also constraints on drainage work, which may have implications for soil damage and siltation of watercourses. Another concern is the possible greater reliance on the use of herbicides to control weeds.

The Forestry Commission has set up a network of pilot sites across the UK to help develop the silvicultural knowledge and skills that are required to transform even-aged stands to CCF. These sites provided an opportunity to examine the applicability of current best practice for addressing the environmental pressures and impacts associated with CCF. The Forestry Commission and the Environment Agency therefore agreed to collaborate in funding a study of environmental best practice for CCF.

The overall aim of the work was to establish the likely environmental impacts of continuous cover forestry techniques, and to identify best practice to address these impacts. There were four objectives:

- To review the applicability of current best practice for protecting soils and water at the forest planning and design stages of CCF.
- To review the applicability of current best practice for protecting soils and water at the operational stages of CCF.
- To produce environmental best practice guidance for protecting soils and water for dissemination to forest managers and operators.
- To carry out a scoping study to determine the requirements of long-term monitoring to establish the impacts of changing techniques on water quality, hydrology and soils.

The findings are presented in three main sections. The first reviews the applicability of existing Forestry Commission best practice guidance on environmental protection in relation to the transformation of forest crops to CCF. It covers forest planning, design and site management operations. The report draws principally on the Forestry Commission's *Forests and Soil Conservation Guidelines* (1998) and *Forests & Water Guidelines* (2003). These are assessed in terms of their coverage of the environmental risks and benefits associated with the transformation and management of forest crops under CCF. Shortfalls in existing guidance are identified and recommendations provided on how these should be remedied or be the subject of further research to establish best practice.

The second section assesses the experience gained from the Forestry Commission's establishment of a number of CCF demonstration forests throughout the UK. Observations are presented from visits to the demonstration sites at Cwm Berwyn, Clocaenog and Trallwm (private sector forest) in Wales, Whinlatter in England and Glentress in Scotland. The location of the trial sites studied is shown in Figure 1.1. These records provide a valuable insight into the practical issues associated with implementing CCF silviculture across Britain.

The final section assesses whether any of the existing set of long-term hydrological and water quality monitoring studies in the UK are suitable for examining the impacts of CCF. This includes a database describing the main characteristics of each site.

A Forestry Commission Technical Information Note that covers the planning, design, construction and maintenance of access routes and brash mats, as well as dealing with drainage issues, has been prepared and will be published in 2006/07.

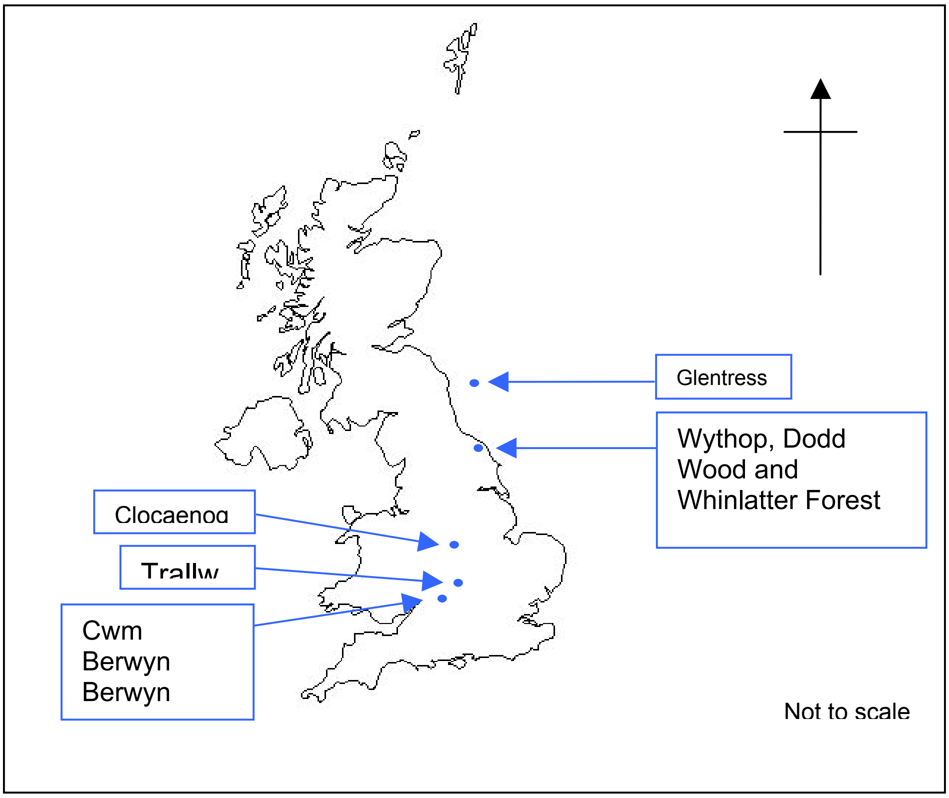


Figure 1.1 Location of CCF demonstration sites visited as part of this study

2 Review of Forestry Commission environmental best practice guidance on transformation to CCF

2.1 Review of current environmental best practice for protecting soils under CCF

2.1.1 Introduction

The Forestry Commission's *Forests and Soil Conservation Guidelines* are the principal source of guidance on best practice for the protection of forest soils. They were introduced in 1998 and advise owners and managers on how to conserve the soil as a fundamental resource upon which trees and the whole forest ecosystem depend. The guidelines are currently being reviewed and a second edition is due to be published in 2006/07.

In general, forestry tends to have broadly beneficial effects upon soils compared to other land uses (Forestry Commission 1998). Forests can help to prevent erosion, accumulate organic matter in the soil and conserve nutrients. Forestry practices, however, have the potential to damage these functions and values, and management should be aimed at preventing any adverse physical, chemical or biological changes. In particular, there is a need to minimise:

- loss of soil fertility
- loss of organic matter
- accelerated soil acidification
- excessive soil disturbance
- soil erosion and compaction
- soil contamination and pollution.

The guidelines have been written in the context of the forest management practices traditionally operated in the UK, with a focus on clearfell and restock silviculture. The effects of alternative, less intensive silvicultural systems receive only a brief mention and this section of the report considers whether the existing guidance is sufficient to safeguard the various functions and values of the soil during the transformation of regular forest stands to CCF. The applicability of the guidance to the forest design and planning stages is addressed first, followed by site management operations.

2.1.2 Applicability of current best practice relating to the planning and design stages of the transformation of forest stands to CCF

The transformation of traditionally managed forests to CCF poses relatively few threats to the soil that need to be addressed at the planning and design stages. The main issues affecting site selection and design are described below in order of importance.

Soil physical degradation

(i) Excessive soil disturbance

Windthrow risk is a major factor in relation to soil disturbance because of the severe consequences of windthrow for timber production and environmental protection. In terms of the soil, the uprooting of trees can cause excessive disturbance and mixing, leading to accelerated erosion, stream bank collapse and even landslips. Windthrow can also have a major impact on site conservation, recreation and landscape.

The majority of upland conifer forests in the UK lie on land of low fertility and poor drainage, often comprising wet soils such as gleys and peats. Until recently, these conditions were considered unsuitable for transformation to CCF because of the shallow rooting of planted crops and the high risk of windblow if trees were left to grow to older age. For example, Mason and Kerr (2001) indicate that CCF will be most successful on dry, sheltered sites. However, developments in policy such as the Woodlands for Wales' strategy aim to manage at least 50% of the Welsh Assembly's woodlands under continuous cover are extending CCF onto a much wider range of site types.

The assessment of windthrow potential is based on the Forestry Commission's windthrow hazard class (WHC) system and the ForestGALES windthrow risk model, which have been developed to guide the selection of sites for thinning treatments and the timing of final harvesting. This system is also applicable to determining the suitability of sites for transformation thinning to CCF. Existing guidance by Mason and Kerr (2001) is comprehensive and includes a consideration of soil type and its influence on WHC. However, attempts to extend CCF onto less suitable soils will need to be closely monitored and the guidance revised as appropriate. There is also some uncertainty about how the establishment of a more broken forest canopy under CCF will affect windthrow risk, and this merits further study.

(ii) Soil erosion and compaction

Soil erosion and compaction is a relatively minor issue in CCF site selection since the threat posed by stand conversion can be largely controlled by operational factors, which are discussed below. However, there may be some soil types where the risk of soil damage is too great or the measures required to protect the soil are too costly to make transformation to CCF a practical option. For example, there may be too little brash to provide support for repeated access over very wet sites during thinning. Knowledge is lacking on this aspect and the need for additional guidance awaits the results of the trial sites and wider practical experience. The use of brash and pulpwood in the construction of permanent access tracks will greatly reduce the volume of residues available for harvesting. This constraint needs to be acknowledged when planning which sites are suitable for extracting residues for biomass fuels.

Soil fertility

(i) Loss of soil fertility

Soil fertility is unlikely to be a significant factor in site selection. This is because nutrient demand is expected to be similar or even lower under CCF due to the reduced uptake associated with older forest stands and the establishment of a greater proportion of less demanding, native broadleaf species. In addition, nutrient losses are likely to decrease as a result of the cessation of clearfelling; the presence of a permanent tree cover and undergrowth will help to retain nutrients released following the smaller-scale thinning operations.

(ii) Accelerated soil acidification

CCF could pose an increased risk of soil acidification because of the potential for a permanent and more broken forest canopy with a greater length of forest edge to increase the capture of acidic pollutants in the atmosphere. The impact of greater nitrogen deposition could be especially marked in parts of the UK approaching nitrogen saturation. The increased proportion of old-aged crops under CCF would add to this problem since crops older than 30 years appear to ‘leak’ more nitrate. Another important consideration is the reduced flexibility to alter forest type and species under CCF without active intervention. Natural regeneration will be controlled to a large extent by the nature of the surface organic matter and will obviously favour the previous crop. This is likely to pose a significant constraint where a change is desirable, for example to reduce base cation removal or pollutant capture. More information is needed on the effect of CCF on pollutant capture and nitrate release in order to determine whether stand conversion should be recommended within acid-sensitive areas.

(iii) Loss of soil organic matter

This is unlikely to be a significant issue since forest conversion to CCF is likely to lead to more stable levels of soil organic matter due to the reduced level and scale of site disturbance. The main risk would be from uncontrolled forest fires, which may be increased under CCF because of the likelihood that fires could spread more readily. This may require improvements in forest design, such as the provision of a more effective system of firebreaks. Information is lacking on how CCF will affect the number and severity of uncontrolled fires and, since fire risk may increase in the future with climate change, this aspect merits further study.

Soil contamination

There are no contamination issues that need to be addressed at the planning and design stages. One minor concern is the potential for the permanent and more broken canopy under CCF to increase the capture of atmospheric pollutants such as heavy metals or PCBs (polychlorinated biphenyls). However, in view of the low levels of these in the general atmosphere and the expectation that any additional scavenging by CCF would be relatively small, this is unlikely to pose a significant problem.

2.1.3 Applicability of current best practice relating to the operational stages of CCF

The management operations employed in transforming forest stands to CCF differ in certain respects from those used in traditional clearfell and restock systems. These differences are considered below in relation to their potential impact on the soil and the applicability of current best practice guidance.

Soil physical degradation

(i) Harvesting/thinning

The *Forests and Soil Conservation Guidelines* note that harvesting operations present the greatest risk to the physical condition of the soil through causing erosion, compaction and displacement. Soils are classified according to the risk of damage and the emphasis is placed on selecting the best machinery for the soil conditions. This guidance is directly applicable to the conversion of forests to CCF since the same types of machinery and harvesting systems (shortwood, pole length, part pole, whole tree) are involved. However, there are a number of important differences that have a bearing on soil protection in relation to product size, access tracks and brash management:

- Product size

Transformation to CCF will require some trees to be retained beyond the age at which they would normally be felled to provide a seed source for natural regeneration. The large size and extended range of products resulting from such trees could lead to larger machines and heavier loads. Larger diameter sawlogs are usually better suited to skidding rather than forwarder extraction but skidding is to be avoided on soft ground because of the tendency to disrupt protective brash layers and cause greater soil disturbance. This would have implications for the use of brash and the design and construction of extraction/access tracks in order to reduce the risk of ground damage (see below). Larger products may also require greater working space at the roadside, which would need to be factored into the design of road handling facilities.

- Access tracks

The design of access tracks differs from traditional thinning and harvesting practice in terms of the need for repeated access along the same routeway. This greatly increases the overall loading exerted on the soil and therefore requires greater care in selecting the best layout and attention to improving track construction. A system of permanent, reinforced tracks may be required on softer soils. Although current guidance emphasises the benefits of using relatively low cost metalled forwarder routes to reduce long-distance off-road haulage on vulnerable sites, such options are very expensive and limited to key sections and main access points. Cheaper options need to be investigated, including the use of mixtures of brash, stumps and low value produce. Little guidance is available on track specifications for different site conditions, and this requires further evaluation and study as a part of the trial sites.

- Brash management

Frequent thinning interventions will reduce the quantity and availability of brash for track construction and renewal, while the ageing of existing material will affect track bearing capacity. This has implications for track design and layout to ensure that sufficient material remains available. More guidance is needed on maximising the efficient use of limited supplies of brash. The demand for brash for track construction is also likely to leave little brash within the stand matrix. Further guidance may be required to address off-track movement of harvest machinery on soft ground in order to prevent soil damage.

(ii) Ground preparation

Minimal ground preparation will be necessary since natural regeneration will form the principal method of re-establishment under CCF. The most likely form of cultivation will be mounding of the forest floor. This is a well-developed method of cultivation and poses little risk of soil degradation. A related issue, however, is the use of rear-mounted tractor flails with limited mulcher height control used for respacing of dense natural regeneration throughout CCF stands. Machine trafficking and the operation of the mulcher has the potential to cause rutting, compaction and significant soil disturbance. This is a relatively new technique and there is a need for operational guidance to minimise the risk of damage, especially where the technique is used on sensitive sites such as within riparian buffer areas.

(iii) Road construction

Stand conversion to CCF may require some extension of the existing forest road network but this will be covered by current best practice concerning the design, construction and maintenance of roads.

(iv) Drainage

Restrictions on machine access because of the permanent tree cover under CCF severely limit the scope to reinstate the original drainage system, carry out new drainage work to meet requirements in terms of gradient and layout (e.g. to create buffer areas) and correct any badly eroding sections. Additional guidance is required on dealing with such problems, including the possible development and availability of appropriate small-scale equipment such as mini-diggers. Another information gap concerns the need for supplementary drainage to protect and control run-off from the system of permanent access tracks.

Soil fertility

(i) Fertilising

Little or no fertiliser should be required under CCF and existing guidance will cover any needs. Areas of dense natural regeneration could induce short-term nutrient deficiency, although this would be addressed by respacing rather than fertiliser application. The repeated addition of brash to the main access tracks may lead to gradual, localised soil enrichment but it is likely that this would be controlled by root uptake from adjacent trees and undergrowth, and evened out via litterfall.

(ii) Forest fire

Conversion to CCF would eliminate the need for burning lop and top, which can damage soil fertility and promote soil erosion.

Soil contamination

(i) Pesticides

Herbicide use could increase during transformation to CCF as a result of the need to control dense natural regeneration. However, this will be limited by the ongoing movement to adopt non-chemical methods of control and improved methods of regulating natural regeneration through manipulating levels of canopy shade. The focus on natural regeneration will eliminate the use of insecticide-treated planting stock and could reduce the need for any top-up spot applications. Cut stumps will still require urea treatment to control fungal infection but the need for this could decline with the reduction in the scale of felling and thinning work. Existing guidance will address any threats posed by pesticide use under CCF.

(ii) Oil spillage

The use of fuel oils and lubricants is unlikely to change under CCF and existing best practice should remain effective at controlling the small risk of leaks and spillage.

(iii) Sewage sludge

Sewage sludge or other waste applications are unlikely to benefit CCF stands and thus will rarely be applied. Existing guidance will address any threat.

2.1.4 Summary of information needs for soil protection under CCF

Table 2.1 Issues requiring further information at the planning and design stages of CCF

Future	Description of information needs
Soil disturbance	Applicability of windthrow hazard class to CCF. Risk of windthrow under CCF on soft ground. Effect of more broken canopy under CCF on windthrow risk
Soil erosion and compaction	Establish whether certain soils (e.g. soft ground) should be excluded from conversion to CCF because of a high risk of soil damage
Soil acidification	Quantify the effect of CCF on pollutant deposition and nitrate release in order to determine whether stand conversion should be restricted within acid-sensitive areas/critical loads exceedance squares
Soil organic matter	Impact of CCF on fire risk

Table 2.2 Issues requiring further information at the operational stage of CCF

Future	Description of information needs
Physical degradation of soils: harvesting and thinning	Guidance on the design and construction of permanent access tracks and road facilities, including track specifications and efficient use of brash for soil protection, especially on soft ground and for handling larger-sized products

Ground preparation	New guidance to minimise the risk of soil damage resulting from the use of mechanised flails to control natural regeneration
Drainage	Guidance on soil drainage work under CCF, especially in relation to correcting deficiencies in existing drainage systems and providing drainage for permanent access tracks

2.2 Review of applicability of current environmental best practice for protecting watercourses under CCF

2.2.1 Introduction

The Forestry Commission's *Forests & Water Guidelines* are the principal source of guidance on best practice for the protection of watercourses in relation to forestry operations. They were first published in 1988 and have since undergone three revisions to ensure that they continue to reflect the most recent research and practical experience. The fourth edition was published at the end of 2003 and considers some of the issues surrounding forest transformation to CCF. The applicability of the guidance to the forest design and planning stages is assessed first, followed by site management operations.

2.2.2 Applicability of current best practice relating to the planning and design stages of the transformation of forest stands to CCF

The fourth edition of the *Forests & Water Guidelines* identifies those issues that are best addressed at a catchment rather than site level. A new section on catchment planning deals with the contribution of forestry to acidification and eutrophication, the effects of forestry on water yield, flows and flooding, and the design of riparian buffer areas. The transformation of forest stands to CCF has the potential to affect all of these, although a lack of knowledge precludes any definitive conclusions. The likely impacts and information gaps are considered below.

Acidification

The guidelines use the freshwater critical loads approach to identify those areas where forest planting presents an increased risk of acidification. For the first time, consideration is extended from new planting to include restocking. Conifer forests above 300 m pose the greatest threat because of their greater scavenging of pollutant cloud deposition. Where a large proportion of the catchment above this altitude is occupied by conifer forest, the guidelines advocate selective deforestation subject to a detailed catchment-based assessment as part of a wider Environmental Impact Assessment. No guidance is provided on the effect of converting such crops to CCF.

Reference is made to the fact that a change to CCF is likely to affect pollutant scavenging and thus the risk of soil and water acidification, but no details are provided. Pollutant deposition can be expected to be enhanced by the maintenance of a permanent tree canopy with a greater length of edge between young and old stands. The impact of this change across different altitudes and under a future climate of reduced pollutant emissions remains to be quantified.

The impact on nitrogen dynamics is likely to be the most important, with the potential for CCF to increase both nitrogen pollutant deposition through greater scavenging and nitrate leaching due to the decline in nitrogen demand with forest ageing. However, this will be partly countered by the expected reduction in nitrate leaching following the cessation of clearfelling operations. Nitrogen-saturated areas will be at greatest risk and merit further assessment.

CCF will also affect site losses of base cations. Their removal in harvested produce may be reduced if there is a focus on sawlogs rather than pulpwood, while losses by leaching should be greatly curtailed by the cessation of clearfelling. The extent to which these factors are able to counter the enhanced scavenging of acid pollutants needs to be quantified.

Eutrophication

The main issue connected with forestry concerns the run-off of phosphate following aerial fertiliser applications. Since nutrient demand and losses are expected to reduce under CCF, little or no fertiliser is likely to be required by transformed stands. The leaching of phosphate associated with large-scale clearfelling on sensitive soils will be greatly reduced by the small-scale working under CCF and nutrient uptake by ground vegetation and adjacent crops. Thus, the threat of eutrophication is likely to be largely eliminated under CCF.

Water yield, flows and flooding

The greater water use of forests, especially coniferous forests, compared to other land uses, can pose a threat to water supplies and the freshwater environment in general (Nisbet 2005). Catchments where the supply is being, or is planned to be, fully exploited are most at risk. Concern centres on the effects of large-scale new planting, with the guidelines requiring early consultation with the water regulatory authority and/or water undertaker to establish whether planting would be acceptable. Existing forests have generally attracted less concern, although this could alter with climate change and the continuing rise in water demand. The ongoing restructuring of the forest estate to create a greater mix of tree ages and species is expected to help by significantly reducing water use at the catchment scale. This results from the lower water use associated with younger-aged forest stands, broadleaves and open space, which form significant components of re-designed forests.

Conversion to CCF has the potential to reverse the benefits of forest restructuring for water resources due to the higher water use associated with a more permanent and broken forest canopy. Work is required to quantify this effect and the extent to which it might be offset by the development of an older age structure under CCF, with its associated lower water use.

The potentially higher water use associated with CCF could also have implications for base river flows. Base flows are believed to be generally unaffected by forestry outside headwater catchments because of the opposing effects of the different stages of the forest cycle that are represented within a larger forest. However, the restrictions on cultivation and drainage due to limitations on machine access under CCF and the absence of clearfelling, both of which are associated with increasing base flows, could contribute to an overall diminution in these flows. In marked contrast, CCF can be expected to have the opposite effect on flood flows, with the reduced level of soil disturbance and higher water use likely to increase rainfall infiltration and reduce direct surface run-off. Data are lacking on these effects and further field scale and modelling studies are required.

Riparian forestry and buffer areas

The *Forests & Water Guidelines* require that a buffer area be left between forest stands and watercourses to protect both riparian and aquatic habitats from disturbance. The vegetation within the buffer area should preferably be native to the location and soils, and comprise an open woodland canopy with an intricate mix of open ground, occasional large trees, trees with open glades, scrub thicket and closed canopy woodland. About half of the length of a watercourse should be left open to sunlight, with the remainder being under dappled shade from trees and shrubs.

Conversion to CCF presents a number of potential management problems for achieving the desired structure and composition of riparian buffer vegetation. Firstly, machine access for respacing and thinning work is likely to be more difficult and needs to be carefully planned, especially since trafficking within the buffer generally is to be avoided. Secondly, the reliance on natural regeneration within adjacent conifer stands and the retention of older-aged seed trees for this purpose could increase the problem of unwanted conifer regeneration within riparian buffers. Guidance is required on how best to deal with these issues, including the option of leaving a wider buffer area. Conversely, the regular felling interventions operated under CCF provide an opportunity to carry out riparian woodland management on a more frequent basis than would normally be possible because of the high cost involved. Transformation to CCF could also benefit protected species such as the otter by reducing the level of disturbance in adjacent stands.

Drainage

The drainage system in some forests links into that of adjacent areas and land uses, which make up the wider water catchment. Drain alterations under CCF need to be planned to link in with these. Complications may arise where, for example, the adjacent stand to a CCF forest is designated as no thin because of high risk of windblow and consequently forms a barrier to drain re-instatement. Future guidance should advise on necessary considerations at the planning stages of drainage, as well as raising awareness of the potential for using small-scale equipment, including mini-diggers, if access within the standing crop is restricted.

2.2.3 Applicability of current best practice relating to the operational stages of CCF

The main changes to management operations involved in transforming stands to CCF have already been described under the section on soils. This part of the report considers whether the *Forests & Water Guidelines* adequately address any threats that these changes pose to the water environment.

Ground preparation

The restricted nature of ground preparation under CCF is unlikely to threaten the freshwater environment. The main cause for concern would be where CCF is pushed onto less suitable soils where conditions may not be conducive to natural regeneration without more intensive cultivation. However, the guidelines already cover the different types of cultivation that could be used under such circumstances and the risk of soil erosion and pollution is likely to be reduced by the smaller scale of operations.

The issue of the use of mechanical flails to control unwanted conifer regeneration within riparian buffer areas has already been raised and needs to be addressed.

Machinery is generally excluded from working within buffer areas but this may not be practicable where a mechanical flail is the only effective method of control. Guidance is required to highlight the risks posed to the freshwater environment from such operations and how these can be minimised through measures such as restricting the timing of operations, route alignment, tyre choice, flail height, etc. This guidance would also be applicable to non-CCF stands.

Drainage

The main aspects have already been covered under soils. An additional consideration is the restrictions that CCF can impose on the re-design of the drainage system in adjacent stands. For example, action to correct a drainage problem in a non-CCF stand needs to address the limited scope for following through any alterations within downslope CCF stands. Failure to do so could result in the overloading of receiving drains or changes to the routing of flows, leading to waterlogging, windblow and excessive erosion. Another factor is the likelihood that more frequent drain maintenance will be required on wetter sites under CCF to permit machine access for regular thinning work. However, key measures such as the need to restrict the timing of such work to minimise the impact of any siltation on fisheries, is already covered by the existing guidance.

Managing riparian vegetation

The main issues are dealt with under soils.

Road construction and maintenance

Transformation to CCF is unlikely to affect road construction and maintenance work, other than possibly requiring an extension to the road network. No changes are therefore required to existing best practice.

Harvesting

The main threat to water posed by harvesting under CCF is the potential for increased sediment delivery and siltation in receiving watercourses. This is best addressed by tackling the source of the sediment through avoiding soil degradation, as described in Section 2.1. Existing best practice adequately covers the protection of watercourse crossings since few changes are envisaged under CCF. One difference might be that the need for more frequent access for thinning operations could make the construction of permanent crossings more cost effective. Permanent crossings would provide a higher standard of protection and thus reduce the risk of water pollution.

Heavily brashed permanent access routes could present a source of organic pollution if track drainage led run-off directly into streams. There is a case for strengthening guidance on this aspect given the constraints on site drainage work under CCF.

Pesticides, fertiliser, fuel oils and lubricants

It has already been noted that pesticide and fertiliser applications are likely to decline under CCF while the use of fuel oils and lubricants will remain as before. Consequently, no changes are required to best practice.

2.2.4 Summary of information needs for water conservation under CCF

Table 2.3 Issues requiring further information at the planning stage of CCF

Future work	Description of information needs
Acidification	Effect of CCF on pollutant scavenging, including the role of altitude, and the risk of surface water acidification. Effect of CCF on base cation budget
Water yield, flows and flooding	Effect of transformation to CCF on forest water use, water yield, low flows and flooding
Riparian forestry and buffer areas	Effect of CCF on access to and management of riparian buffers, including control of conifer regeneration. Buffer zone specification for protecting waters flowing through CCF stands

Table 2.4 Issues requiring further information at the operational stage of CCF

Future work	Description of information needs
Ground preparation	Best practice for minimising the impact of mechanical flails within riparian buffers
Drainage	Guidance on linking drainage work within adjacent forest stands
	Guidance on drains maintenance under CCF
Harvesting	Guidance on construction of permanent stream crossings
	Methods of limiting the risk of organic pollution from the breakdown of brash concentrated within permanent access tracks

3 Environmental best practice for continuous cover forestry case studies

Visits were made to five of the UK continuous cover forestry (CCF) demonstration forests established by the Forestry Commission, three in Wales, one in north England and one in Scotland (Figure 1.1). This section of the report describes the environmental impacts that were observed at these trial sites and ongoing developments in best practice to deal with them. It is important to note that the comments and observations are specific to the conditions at the individual sites. The transferability of the management techniques developed to tackle the operational problems of implementing CCF remains to be fully evaluated in terms of operational costs and environmental consequences.

The information provided by forest managers during these site visits gives a valuable insight into the practical difficulties of implementing CCF and possible solutions.

3.1 Site visit: Cwm Berwyn Forest – Wales

Information was gathered during the site visit on 30 July 2003 to observe harvesting techniques used in the transformation of Cwm Berwyn forest to CCF, with a focus on access track construction and watercourse management. This is one of three large-scale CCF trials in Wales.

3.1.1 Planning and design

Forest Design Plan

The current aim involves converting a proportion of the forest to CCF with the remainder of the crop (predominantly on the edge of the forest) managed under a clearfelling regime to maintain the production forecast volume figures.

Varied slope and site characteristics make a broad-brush management prescription difficult to apply.

Site and crop

Cwm Berwyn is a 1,800 ha upland forest consisting predominantly of Sitka spruce. Elevation varies locally within the forest, but averages 425 m above sea level. Soils are poorly drained and include a mixture of peaty gleys, flushed peat bogs and unflushed peat bogs in approximately equal proportions over about 90% of the forest area. Iron pan and surface water gley soils occupy the remaining area.

Approximately 60% of the total forest area is categorised as windthrow hazard class (WHC) 4 and approximately 40% as WHC 5. The high rainfall, high elevation and fragile soils result in a high risk of site disturbance if management operations are not carefully managed.

Management objectives

- Establish a crop through natural regeneration that will be resistant to windblow.
- Reduce restocking costs.
- Change the species composition to increasingly favour broadleaf species.

The ultimate aim is to achieve a better balance between economic, biodiversity and environmental considerations.

Management history

The forest has been managed as a CCF demonstration site since 2001, although a continuous cover regime was first attempted at Cwm Berwyn around 1995 when a strip system was imposed over part of the forest. Access problems now exist due to the previously felled strips forming wet swathes of dense regeneration, which restrict machine movement. Lack of thinning over much of the remaining stand, together with a high WHC, has resulted in a crop that is very vulnerable to windblow.

The high rainfall, high altitude and soft soils encountered at Cwm Berwyn make the site unique among the CCF demonstration sites. However, such conditions are typical of much of upland forestry in the UK and the management practices and innovative harvesting techniques being developed here suggest that a much wider range of site types may be suitable for transformation to CCF.

Current published guidance from the Forestry Commission provides little information on best practice for thinning stands on such sensitive site types and soils.

Silviculture

The previous strip system involved felling roughly 18-m wide strips through parts of the forest to enable access for harvesting machinery and to encourage natural regeneration. This approach was subsequently abandoned; the main problem in relation to sustainable management of the forest was that the location of the felled strips meandered through the forest creating a wet barrier to machine access.

The current felling interventions taking place since the adoption of Cwm Berwyn as a CCF demonstration site involve transformation thinning to move the stand towards an uneven age structure appropriate for implementing CCF silviculture.

Harvesting and extraction

Harvesting and timber extraction are by harvester and forwarder, the same machinery combination as used for conventional mechanised harvesting, including both thinning and clearfell. The use of cableway extraction is prohibited over most of the site because of the high cost involved and the lack of adequate anchorage provided by the low-loadbearing peaty soils.

Tracking strategy

Because of the very variable and locally very soft ground conditions across much of the forest, emphasis is placed on selecting the driest/most firm route. Tracks and racks are specified to provide sufficient bearing capacity for machinery without causing significant damage to the soil. Maximum life expectancy is achieved by measures such as restricting forwarder load weights and the establishment of predetermined routes for one-way extraction. The latter allows a lower specification track to be used for unloaded inward travel and effort to focus on strengthening the outward route used by the loaded forwarder.

Tracks are planned to be semi-permanent features with repeated use in subsequent thinnings. This requires further fresh material to be added at each intervention to strengthen and bulk-up their construction, since the existing brash and wood material will have partially broken down during the intervening period.

Site survey

Limited resources restrict the amount of pre-felling site survey work that can be carried out. The planning team draws on a range of sources of information (such as aerial photographs) to provide a map and list of site constraints, including the location of watercourses, to the harvesting officer. The harvesting officer spends time walking over the site with the operator to flag up any issues before work begins. The operator selects the optimum route on a day-to-day basis, depending on site and crop conditions.

Riparian zones

Current management involves the felling of all conifer trees to create relatively open riparian zones; this will be adopted at Cwm Berwyn as felling progresses.

Guidance

The *Forests & Water Guidelines* and *Forest Enterprise Wales Harvesting Manual* are used as the main sources of advice for managing watercourses.

3.1.2 Site operations

Specification and access requirements for CCF at Cwm Berwyn

Methods of rack construction have been developed to suit the range of specific site conditions found in Cwm Berwyn. The normal design of thinning racks proved inadequate as there was insufficient brash to support forwarder extraction on areas of soft ground, resulting in much of the crop being inaccessible for thinning. In view of soil limitations and the need for repeated access for subsequent thinnings, access racks have had to be constructed with pulpwood to provide more support than brash alone (these are termed 'corduroy tracks'). These are regularly maintained to prevent damage to the peat surface. During transformation to CCF all access through the forest has been designed for a harvester and forwarder combination, operating a shortwood system, in a similar systematic manner to that used in conventional thinning. The effectiveness of the corduroy track specification remains to be formally evaluated in terms of soil protection, method, specification, cost, outputs, suitable construction machinery and longevity.

Uses of track network

The stone-surfaced forest road network (constructed from locally won stone) provides the main vehicular access to the forest, including that for timber wagons. This network has not been extended beyond that originally envisaged for traditional clearfelling silviculture because of the high construction costs involved. Instead, alternative, innovative methods (such as the building of corduroy tracks) have been developed to allow machine access over the site. The corduroy track network allows access into the crop for harvester and forwarder combinations, as well as for other forest machinery such as scarifiers for site cultivation and mechanised flails for respacing work. As mentioned above, further evaluation of this method would be required before it could be recommended as best practice. In particular, there is a need to assess alternative methods of route construction, especially where good markets exist for pulp and thus its use in forming corduroy routes is unlikely to be cost effective.

Track construction and location at Cwm Berwyn

The available quantities of brash from a normal thinning intervention were insufficient to support machine movement over the soft peaty ground. Consequently, higher specification access tracks have been constructed using 4-m lengths of pulp wood (<12 cm diameter) laid over brash. The poor price paid for pulpwood means that it has a greater inherent value as a track construction material; large quantities have therefore been used for this purpose. Harvesting machinery is confined to the corduroy tracks on areas of low-loadbearing deep peat soils.

The corduroy tracks (see Plate 3.1) are constructed during felling by the harvester. A built-in optimiser on board the harvester identifies each product to be cut, giving priority to the saleable products and leaving the loss-making pulp wood to be used for corduroy road construction. Saleable products include the log and bar material, as well as small roundwood products used for fencing material. Brash is added to the corduroy track to help bind the construction together and prevent the lengths of pulpwood pushing apart.

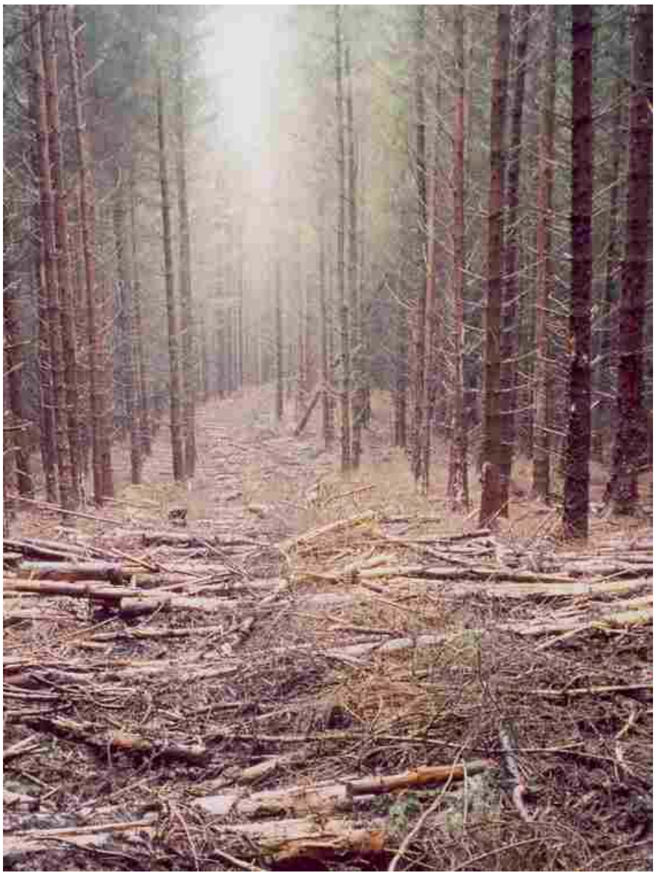


Plate 3.1 Corduroy track at Cwm Berwyn

One option where the ground conditions are especially poor is to invert the cut tree stumps and place them root plate uppermost into the ground. This provides a strong foundation for the corduroy extraction track, although it requires the use of *heavy* harvesting machinery with enough power to unearth the stumps at the time of felling.

In some areas the forwarder can travel on alternate tracks with the harvester passing felled poles through the standing trees on adjacent racks. In this way processing occurs at each alternate brash route, which concentrates the available brash. The heavier forwarder movement is then restricted to the densely brashed routes with the lighter harvester able to traverse both light and dense brash tracks. There is a time penalty for the harvester to present timber through the standing trees to the alternate racksides, although the increased speed gain and outputs observed in the forwarder may compensate for this. Precise evaluation would be required to quantify any time penalty/benefit of using this technique and the potential effects on the standing crop.

Operators are given the flexibility to choose the best route through the stand. Access racks meander to allow the driest routes to be followed and are established as permanent routes rather than changing the route of extraction with each intervention. The racking matrix is developed to be systematic, but not necessarily regimental. Machine travel is frequently organised in a circuit, which enables the whole stand to be accessed but restricts the greatest combined weights of forwarder and loaded trailer to the strongest sections of the extraction track.

Corduroy tracking is not feasible for steep slopes, as the routes provide insufficient traction for the harvesting equipment. Fortunately, this tends not to be a problem as steeper areas are usually better drained and comprise less fragile soils; conventionally constructed racks are therefore adequate.

Extraction of produce is organised so that steep slopes are accessed for downhill extraction only (Plate 3.2). In this way, when the forwarder is loaded with produce (i.e. at its heaviest) the machine is travelling downslope, aided by gravity (see Figure 3.1). The inward forwarder travel (unloaded) is on lighter brashed tracks on shallower gradients. Stoned ramps are often used on steep access points to aid machine travel and prevent rutting; entry points from the forest road are particularly vulnerable to damage as this is where turning movements by loaded machinery are often greatest.

Plate 3.2 Rack constructed on steep ground, used solely for downhill machinery movement

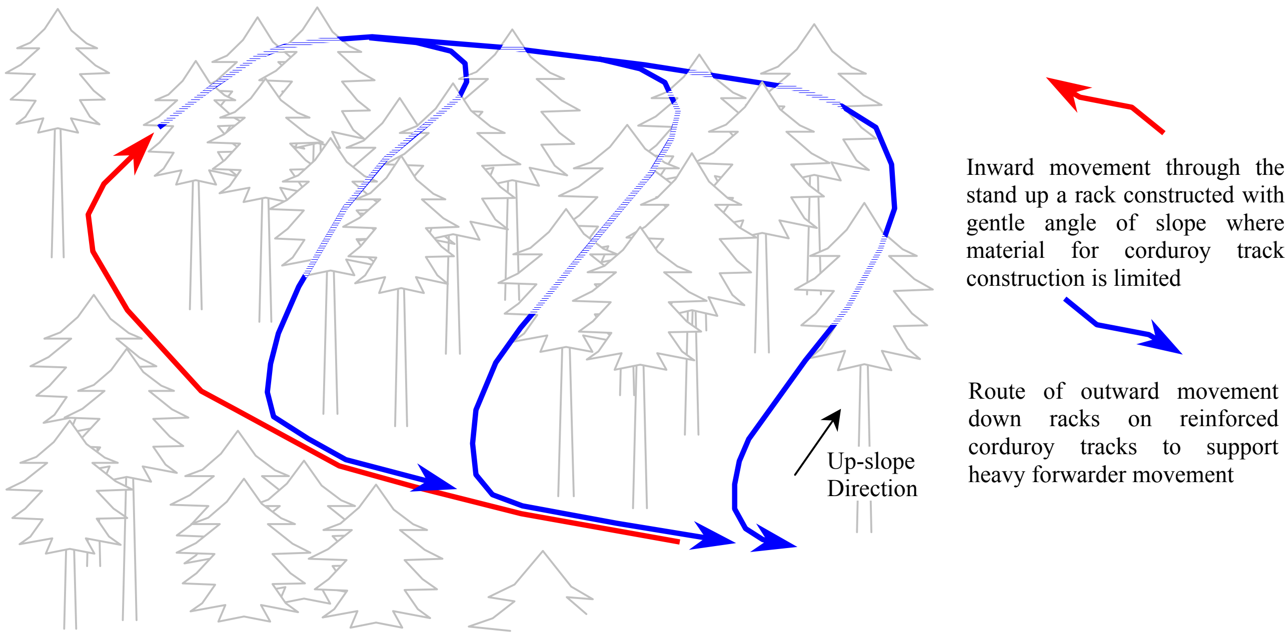


Figure 3.1 Extraction organisation on steep slopes at Cwm Berwyn

The use of saleable produce for route construction has only become acceptable in some areas in recent years, as the price of pulpwood has declined to the current very low values.

3.1.3 Watercourse management

Infrastructure

The ongoing transformation of the forest to CCF has not required any additional stream crossings. The construction techniques used are the same as in conventional forestry, involving the use of temporary log bridges or prefabricated structures supported by stone gabions.

Normal, nine-inch reinforced plastic pipes are used where corduroy tracks cross minor watercourses such as drains. The main difference is that these remain in place to provide continued protection and support for the semi-permanent corduroy access tracks. An important issue is to ensure that they do not become buried or blocked during successive thinning operations. In order to reduce the risk of this happening, the upstream ends of the pipes are angled upwards using brash, leaving them proud of the base of the drain. This also creates a small sediment trap, which helps to reduce sedimentation within the pipe. This may have implications for water flow rate and will require further evaluation to determine its effectiveness in preventing the blockage of pipes by sediment and felling debris.

Drainage

No remedial drainage was carried out prior to thinning at Cwm Berwyn because of the restricted access and high cost involved. Any pre-existing drainage problems often need to be dealt with upstream of the stand. The main drainage issue at Cwm Berwyn was inappropriate routing of road drainage during road construction and maintenance work. This resulted in the creation of new watercourses in downstream stands with associated erosion and sedimentation. Guidance is required to prevent such problems.

Timing of operations at Cwm Berwyn

Culverts are instated in the stand by the harvester operator at the time of route formation; pipes are carried on the rear of the harvester. Work is postponed during adverse weather, although so far this has only been necessary after periods of sudden thaw resulting in waterlogged ground.
Local operators have observed that windblow is more common within stands that are thinned during the autumn (September/October) rather than earlier in the year (May/June). This may be due to the remaining trees in the spring thinning having a longer period of time to repair any damage to rooting and for their canopies to start to infill open areas, before winter gales return.

Inspection

Machine operators decide where piped crossings are required and monitor conditions during thinning operations. The planning team use aerial photographs as well as mensuration data from the harvesting team to monitor the progress of natural regeneration, as well as establishing a number of permanent photographic monitoring points (as shown in Plate 3.3). This information has been entered into a GIS mapping facility with direct links to the photographic monitoring.

Plate 3.3 Marker post to locate the position of a permanent monitoring plot

Pesticide use

Respacing of natural regeneration is principally carried out by mechanical means, using a flail. The intention is not to use any herbicides, unless absolutely necessary, in line with Forestry Commission policy. Urea is directly applied by the harvester head to treat cut stumps against root-rotting pathogens.

Site cultivation

To date, cultivation has not been required to encourage natural regeneration at Cwm Berwyn. Access for scarifiers and other forest management machinery requires the pulpwood within corduroy tracks to be carefully snedded (branches removed) to remove any branch pegs, as these can act like nails and have an aggressive wearing effect on machine tyres.

3.1.4 Lessons learnt

Problems, causes and solutions

The lessons learnt at the Cwm Berwyn trial site are described in Table 3.1.

Table 3.1 Problems, causes and solutions at Cwm Berwyn

Problem	Cause	Solution
Previously constructed access tracks no longer usable	Original design inadequate for new system and tracks now covered by dense regeneration	Plan new access through the stand using semi-permanent corduroy tracks
The soft peaty ground and lack of brash presented access problems for harvesting and extraction machinery	Brash alone was insufficient to support machinery	Construction of corduroy tracks through the stand to allow access without the machine breaking through to the surface layer of peat. As machine movement was restricted to the corduroy routes these had to be sufficiently spaced to allow the harvester to access the entire area to be thinned (*c.* 18 m centre to centre distance)

Table 3.1 - continued

Some corduroy track constructions were inadequate to support machine movement	The initial design of using shorter 2 m pulpwood lengths in corduroy track construction did not fully support machine movement; pulpwood was pushed apart with repeated machine travel	Longer 4 m pulpwood lengths were used in track construction, and these were better able to withstand machine travel
Some 4 m pulpwood lengths used for corduroy track construction snapped during use	Snapping occurred where the pulpwood lengths were placed over existing plough furrows	Lengths were laid longitudinally in the plough furrow thus forming a level foundation for the corduroy track to be constructed on top
There was potential for difficulties to occur with product sorting at stacking areas	Stacking space was limited and eight product specifications were cut	The different product specifications were colour coded in the timber stacks with spray paint to aid product sorting; this feature is an optional extra when specifying harvester head technology
Difficulty in getting machine access to some areas of the forest	Proved to be a problem where slope and soil loadbearing capacity were limiting	Corduroy road specification was developed, as were methods of extraction shown in Figure 3.1
Drain crossings within the stand	Many drainage channels crossing the stand where forest harvesting and extraction machinery was required to gain access	Plastic culvert pipes were incorporated into the design of the corduroy roads to allow machine crossing over drainage channels
Difficulty constructing brash routes that would support machine movement	Lack of brash for rack construction to adequately bear the weight of harvesting and extraction equipment over low load-bearing peaty soils	The corduroy extraction route specifications were developed. ‘Double drift’ working allowed alternate racks to be used for extraction, with brash concentrated where loads were greatest
Some aggressive wear on machine tyres possible from travelling over corduroy tracks	Branch pegs on the material used for track construction cause damage to tyres running over the track surface	Increased care taken when snedding track construction material to remove branch pegs

In addition, the following innovative solutions were developed at Cwm Berwyn to overcome issues of harvesting machinery damaging forest roads and limitations on roadside stacking space:

Brash relief road

In order to prevent loaded forwarders with bandtracks damaging forest roads, a dense brash track was constructed to run directly parallel to the road (Plate 3.4). This enabled the machinery to deliver the harvested produce to the roadside without travelling on the road itself. However, such tracks need frequent maintenance to ensure that they continue to withstand the heavy trafficking. It is also important that they are sited away from watercourses, and, where this is not possible, properly bunded by brash or a sufficient buffer of vegetated ground to retain any sediment run-off.

Plate 3.4 Brash relief road running parallel to stone-surfaced forest road

Stacking area

A wide swath (*c.* 50 m long by 20 m wide) had been cut into the stand and the road extended down the centre of this in close proximity to the harvesting site. This facilitated access and provided additional stacking space in the form of two 50-m long bays on either side of the road extension.

Information gaps

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

3.2 Site visit: Clocaenog Forest – Wales

Information was gathered during a site visit on 10 October 2003 to observe harvesting techniques used in transformation of the forest to CCF, with a focus on access track construction and watercourse management. This is the second of the three large-scale CCF trial sites in Wales.

3.2.1 Planning and design

Forest Design Plan

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, dependent on soil type and DAMS score.

Transformation to CCF is being attempted over approximately 40% of the forest. Selected stands are subject to further site visits to decide on the most suitable silvicultural system.

Site and crop

Clocaenog Forest extends over an area of 4,183 ha on the Hiraethog Moor, west of Ruthin. It occupies an undulating plateau at >300 m elevation. The predominant species is Sitka spruce, followed by Norway spruce and small areas of pine, larch and mixed broadleaf species.

Management objectives

Management objectives for Clocaenog are as follows:

- Environmental: the main priority for Clocaenog is 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.
- Economic: medium priority, regarded as secondary to the environmental objectives.
- Social: although an important consideration, this aspect has the lowest priority because of the low recreation demand in the area.

Management history

Although parts of the forest have been thinned in the past, detailed records are not available. Conversion to CCF began in 2001 following Clocaenog's designation as a demonstration forest.

Silviculture

Current felling involves transformation thinning based on a crown-thinning regime, where certain trees are favoured to provide a seed supply for natural regeneration. Thinning has resulted in dense natural regeneration in some Sitka spruce stands (Plate 3.5). No supplementary planting has been carried out.

Plate 3.5 Dense Sitka spruce natural regeneration around the base of the mature overstorey

Harvesting and extraction at Clocaenog

Trees are currently felled using a Timberjack 1270 harvester and the timber is extracted using a Timberjack 1110 forwarder. The felling is based on the design plan and is carried out by a harvesting team informed by a detailed coupe plan. The coupe plan states the management objectives, the desired stand structure and transformation period, the method, intensity (including target basal area and target volumes) and timing of thinning interventions, and any monitoring required.

Tracking strategy

The forest is well served by a network of good quality stoned forest roads. In the experience of those managing CCF at Clocaenog, heavily brashed tracks provide good access for harvester and forwarder machinery within the standing crop, with little risk of soil damage. Timber is extracted along the tracks to the roadside for stacking and collection by timber lorries.

Site survey

The planning support officer carries out a site inspection as part of the initial planning process to establish the suitability of a particular stand for transformation to CCF. This initial site survey also provides an opportunity for any specific site constraints to be identified. A checklist is used to provide a structure for the site assessment, so that the inspection is conducted in an organised way (see Table 3.3 at the end of this section).

Riparian zones

Riparian zones will be managed as open land to interlink with wildlife corridors connecting the forest with heather moorland and open agricultural land. Any conifer natural regeneration will be felled, either by motor-manual means or by mechanised flail. Some native broadleaf species will be retained.

Guidance

Published guidance consulted at the planning stage includes the Forestry Commission's guidelines covering water, soil, archaeology and landscape design.

Management priorities at Clocaenog

Harvesting practice is influenced by the need to protect and enhance the red squirrel and black grouse populations. The selected soil types for forest conversion at Clocaenog are generally load-bearing and the overstorey provides sufficient brash for machine floatation.

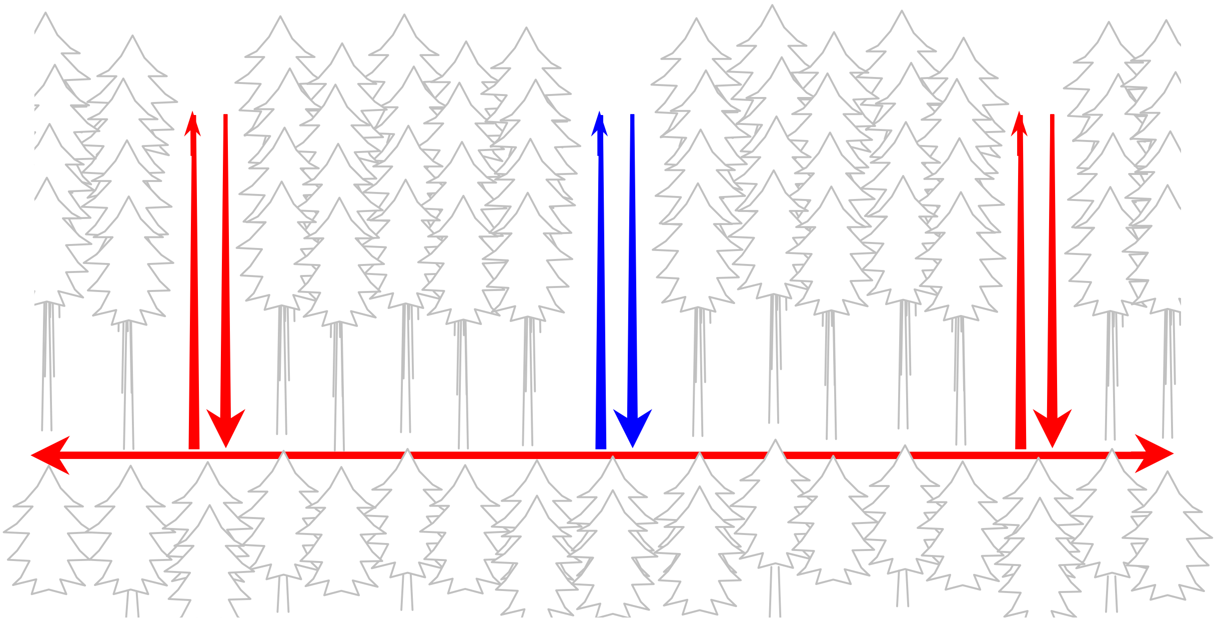
3.2.2 Site operations

The first thinning involves the removal of one in every six rows or two in every seven to permit harvester and forwarder access to the main crop (Figure 3.2).

During the second thinning the operator uses the long reach of the harvester to select appropriate trees for felling from the adjoining crop matrix and deliver these to the rack for removal by the forwarder. Forwarder extraction will be limited to every other rack by the third thinning due to the reduction in available brash for ground protection.

Access tracks

In order to support the combined machine and timber weight from thinning over an area of low-loadbearing ground, minimal lengths of stone-surfaced tracks have been constructed. These tracks join the existing forest rack network to the forest road, and will provide access for stacking at the roadside (Plates 3.6 and 3.7).



Key:

Red arrow: Alternate routes used for continued thinning throughout the transformation period. Harvester moves through the matrix and processes the timber at the rackside, for extraction by forwarder

Blue arrow: Additional routes used for machine access during first and second thinnings, allowing harvester to reach all crops from the edge of the matrix

Figure 3.2 Extraction rack use at Clocaenog

Plate 3.6 Access track construction

Plate 3.7 Newly constructed stone-surfaced access track connecting the existing forest road (foreground) to the forest rack network

Specification

Strengthening involves the addition of a layer of stone to a compacted depth of 0.5 m and a width of around 5 m. Sections are selected for strengthening based on anticipated volumes of harvested timber, forwarder load weights and number of passes. Stoned tracks are built to a lower specification than forest roads and are intended only for use by harvesting machinery.

Access requirements for CCF at Clocaenog

Since transformation to CCF is mostly undertaken in stands on good load-bearing soils most access racks are constructed only from brash. Experience to date of operators at Clocaenog suggests that there will be sufficient brash to support timber extraction during the initial thinning interventions.

Permanence of tracks

Access tracks are laid out as semi-permanent features, although they will require additional thatching with fresh brash at each thinning intervention. Stone may also be required to strengthen key sections.

Brash

Sufficient brash is expected to be available from the first and second thinnings to protect access tracks from trafficking; brashed tracks show good machine floatation with very little soil disturbance (Plate 3.8).

Plate 3.8 Brash rack extraction route

Brash will be concentrated on alternate tracks in the third and subsequent thinnings and the movement of loaded forwarders confined to these access routes.

Track location

Soil and slope factors are fairly benign and therefore have little influence on track layout. Sections of track crossing localised areas of more vulnerable soils have been strengthened with a layer of stone.

3.2.3 Watercourse management

Infrastructure

The proposed track route is inspected prior to construction and culvert points are identified. Culverts are made from double-skinned corrugated plastic pipes and installed by excavator at the time of track construction. Plate 3.9 shows a typical culvert constructed at Clocaenog.

Plate 3.9 Culvert instated as part of new track construction at Clocaenog Forest

Limiting disturbance

Minor watercourses do not influence track layout. These are simply culverted at the point of intersection. Where major watercourses are encountered they are either bridged or the location of tracks re-routed to gain alternative access to the site.

Timing of operations at Clocaenog

The timing of harvesting is site specific and determined by factors such as ground conditions and exclusion periods for protecting Scheduled species under the Wildlife and Countryside Act 1981. Operational experience at Clocaenog has shown that it is generally not necessary for work to be stopped during periods of heavy rainfall. The view of management is that felling should ideally be undertaken just before seeding during a good seed year.

Inspection

Harvesting operators monitor the condition of tracks and watercourses throughout the progress of the transformation thinnings. No problems have been noted to date. If any problems are encountered, the District Office will be informed immediately.

Pesticide use

Respacing of natural regeneration will be required to ensure good stem form and increase stability but will be carried out by motor-manual means, using clearing saws. No herbicides will be used unless absolutely necessary. Current transformation felling by Timberjack harvester involves the direct application of urea to cut stumps to protect against butt rot. The reliance on natural regeneration for restocking reduces the need to use insecticide-treated planting stock or for top-up spraying.

Site cultivation

Cultivation has been attempted on a trial basis during the spring within three treatment plots in a Norway spruce stand. This involved the use of a tracked excavator to scrape away the soil surface to a depth of about 10 cm, exposing the mineral soil to provide a better seedbed for natural regeneration. Norway spruce seed has been broadcast by hand over two of the plots and the third plot was left to assess the success of natural regeneration.

3.2.4 Lessons learnt

Problems, causes and solutions

In general, the areas within Clocaenog that have been designated for CCF are on good load-bearing soils that are well suited to mechanised harvesting using harvester and forwarder combinations. This has resulted in few problems arising to date.

Table 3.2 Problems, causes and solutions at Clocaenog

Problem	Cause	Solution
Insufficient brash available for access track construction	Many of the stands over which the transformation to CCF is being attempted are nearing maturity and will provide limited quantities of brash	Brash is concentrated onto alternate tracks and forwarder movement restricted to these wider spaced access routes. The lighter harvester machines are able to access the standing trees in between, travelling on less densely brashed racks and processing timber to within forwarder reach
Difficulties with operators seeing the base of trees from machine cabs because of tall dense regeneration; this poses a problem with large dimension timber where two or three cuts are required to fell the tree. Also reduced visibility of produce when forwarding potentially reduces harvesting outputs (Plate 3.5)	Dense regeneration at rackside obscures the view of the operator during harvesting	As yet no satisfactory solution has been developed

Information gaps

Some of the management aids provided to foresters require much information gathering and inputting. There is a view that this is not justified by the outcomes in relation to the size of the threat/risk involved.

Care is required to ensure that any guidance provided to managers is easy to interpret, practicable and robust, and that the collection of any input information is not overly time consuming.

Table 3.3 Checklist used by Forestry Commission Wales at Clocaenog for site inspections to guide CCF transformation

Compartment/coupe	Yes	No	Comments
1. Is tree species clearly suited to site and of good genetic quality, i.e. straight single stems, lightly and flat branched, quick growing?			
2. Has stand been thinned in the past, and what type of thinning, i.e. line, low, crown, intermediate?			
3. Are tree crowns well developed to act as seed bearers, deep and full, between half and quarter the total height of the tree?			
4. Are the stems of adequate quality, e.g. free of bark stripping, harvesting damage or disease?			
5. Is there evidence of recent windblow, i.e. within the last 5 years? Is it scattered, or localised within a certain area?			
6. Is there advanced natural regeneration, i.e. seedlings and saplings, and % of each species?			
7. Is pattern of regeneration regular, consistent and abundant, or sporadic and in groups?			
a. <100 seedlings/ha <20 cm			
b. <100 seedlings/ha >20 cm			
c. 100–1000 seedlings/ha <20 cm			
d. 100–1000 seedlings/ha >20 cm			
e. 1000–2000 seedlings/ha <20 cm			
f. 1000–2000 seedlings/ha >20 cm			
8. If no advanced regeneration is present what factors do you think are responsible?			
9. Is ground vegetation likely to compete with regeneration, i.e. more than 75% dense vegetation cover, and % cover of different vegetation types?			
10. Is leaf litter depth greater than 5 cm?			
11. Is there evidence of browsing damage to seedlings?			
12. Is there evidence of seed predation, e.g. squirrels, crossbills?			
13. Does a suitable network of internal rides or racks exist?			
14. Would soils and slopes permit creation of additional access?			
15. Is stand suitable for transformation in present rotation?			
General notes:			

3.3 Site visit: Trallwm Forest – Wales

Information was gathered during a site visit on 29 January 2004 to observe harvesting techniques used in transformation of forest to CCF, with a focus on access track construction and watercourse management within a private sector forest. This is the third of the three large-scale CCF trials in Wales.

3.3.1 Planning and design

Forest Design Plan

A management plan is currently being drawn up to include a range of objectives (see below).

Site and crop

Trallwm covers 165 ha of well-thinned spruce forest that is served by a dense network of access tracks. Some of the steeper slopes approach an angle of 45° and extraction is only possible by skidding. The forest area is covered with 3.8 km of stone-surfaced forest roads and 4.2 km of lower specified tracks. It is composed primarily of Sitka and Norway spruce with some Douglas fir, Western hemlock, Japanese larch and a small broadleaf component. Soils are predominantly upland brown earths, intergrading to shallow peaty gleys on the plateau tops.

Management objectives

The management objectives for the forest include timber production and promoting recreational use through the provision of mountain biking trails and the construction of a visitor centre. The forest also contains a number of holiday cottages and there is a desire to preserve the tree cover to provide an attractive environment for visitors. It provides a source of local employment and serves as a venue for training opportunities. Continuous cover has the potential to meet all of these management objectives.

The desire of the owner is to maintain the capital value of the woodland by improving the quality of the standing crop and the infrastructure, such as the forest road network.

Management history

The forest was purchased by the present owner in 1976 from the Forestry Commission, and has historically been thinned on a regular 4 to 5 year cycle using a mixture of direct labour on the steeper slopes and contracted labour on the gentler slopes.

Silviculture

Currently management of the forest involves transformation thinning to promote an irregular stand structure favouring frame trees. Experimental plots are being established to examine the long-term effects of a number of different silvicultural treatments, including group felling.

Harvesting and extraction

The majority of harvesting and extraction has been carried out using a harvester and forwarder combination. All steep slopes are skidded. Almost the entire area being transformed to CCF has been line thinned with the removal of one row in five.

Tracking strategy

The aim at Trallwm is to establish a track network with adjacent access tracks spaced at a maximum of 180 m apart. The track network links the racks within the standing crop, which usually run up and down slope, although rack location is influenced in some areas by past contour ploughing.

Site survey

Regular site inspections are made as part of the ongoing management of the forest, and include an assessment of felling sites prior to the commencement of operations.

Riparian zones

The aim is to manage riparian areas as conifer-free zones to improve the habitat value for wildlife. The broadleaf element within the forest is promoted and any good quality broadleaf trees are left to develop.

Guidance

Current guidance produced by the Forestry Commission, including the series of forest guidelines, serve as an aspirational standard rather than a direct source of prescriptive advice.

Guidance on management best practice is also received from local groups such as the Wye Foundation (who provide advice on watercourse management), as well as from general networking with associated individuals and bodies.

Technical development guidance on access track construction had been referenced.

Management priorities at Trallwm

The forestry industry is facing increasingly poor timber prices, resulting in a shift in the forest management priorities. Timber production remains the priority at Trallwm in order to secure the long-term economics of the forest, but environmental and recreational benefits are actively planned for and promoted.

3.3.2 Site operations

Access track specification

Access tracks within the forest are constructed using a 9 tonne excavator. Their specification is to be as narrow as possible to minimise the impact on the environment while providing sufficient running width to allow harvester and forwarder access. This is aided by using relatively small-scale machinery for extraction, including a Holder compact tractor for skidding.

Where skidding has been used for extraction on the steeper slopes, operators report that the mineral soil has borne the weight of the machinery well and the produce has been extracted with minimal site disturbance, although care has to be taken to keep the produce clean.

Repairs and the occasional blading (levelling the surface of tracks using a metal 'blade' towed tractor attachment) of access tracks is carried out as needed, identified by regular inspection by the landowner.

Access requirements for CCF at Trallwm

It is anticipated that as CCF silviculture is adopted at Trallwm there will be a need to maintain and increase the well-distributed network of forest tracks. On steep areas with restricted access skidding has been used to extract produce to the main extraction tracks, with processing at the trackside and onward extraction by forwarder.

Uses of track network

Recreational access using the track network is actively promoted, with walking and mountain biking aided by signed routes and specifically designated bike tracks through the forest.

Permanence of tracks

Tracks are constructed as permanent features.

Brash

The quantities of brash from thinning operations have generally been sufficient to allow construction of light brash mats for machine floatation. The option of confining forwarder movement to every other rack allows for brash to be accumulated on the more heavily used sections.

Track location

The forest is served by a dense track network, with a greater concentration of tracks on the steeper slopes. Borrow pits at various locations in the wood provide adequate material for track construction.

3.3.3 Watercourse management

Infrastructure

No permanent bridges have been constructed within the forest. Drains are culverted using corrugated Armco pipes where machine access is required. These are removed once felling and extraction is complete. Log bridges have been used to good effect to enable harvesting and extraction over larger drainage channels.

Drainage

Drains maintenance is carried out to ensure that the forest is well drained, in the best interests of establishing trees through natural regeneration (Plate 3.10).

Plate 3.10 Example of a drainage channel crossing the site due for maintenance work

Timing of operations

Machine movement over the site is restricted to the drier periods of the year to preserve track quality, particularly on unsurfaced tracks (Plate 3.11).

Plate 3.11 Unsurfaced track beginning to show signs of rutting

Inspection

The owner lives within and frequently travels through the forest, allowing regular inspections of the forest tracks, watercourses and ongoing silvicultural interventions.

Pesticide use

No pesticides are used, except for the application of urea to protect cut stumps against fungal infection.

Site cultivation

A small trial area has been cultivated using pigs. The pigs were brought in as piglets in the spring, kept in an enclosed area of the wood and butchered at the end of the year.

Screef planting has been used where necessary to re-establish crops following windblow.

3.3.4 Lessons learnt

Problems, causes and solutions

Windblow has occurred in some areas, particularly adjacent to a recent clearfell. WHC over the forest ranges from 3 in the valley bottoms to 4 on the more exposed upper slopes.

Squirrel damage is another problem and many potentially good quality final crop trees have been affected. Consequently, large seed-bearing tree species such as oak are not actively promoted in an attempt to reduce the resident squirrel population. Grant funding has been applied for to aid squirrel control through live trapping. Damaged trees (typically with dead tops due to squirrel ring barking) are usually removed when thinning.

There has been some rutting in extraction racks in isolated wet patches, but this tends to be the exception. The majority of the site is composed of dry soils served by an intensive (comprehensive) drainage network.

Information gaps

No information gaps specific to environmental best practice were reported.

3.4 Site visit: Wythop, Dodd Wood and Whinlatter Forest – Northwest England Forest District

Information was gathered during a site visit on 17 December 2003 to observe harvesting techniques used in transformation of the forest to CCF, with a focus on access track construction and watercourse management. This is one of three large-scale CCF trial sites in England.

3.4.1 Planning and design

Forest Design Plan, site and crop

CCF management has been implemented in three separate forests: Wythop, Dodd and Whinlatter, located in the Lake District in northwest England (Figure 3.3).

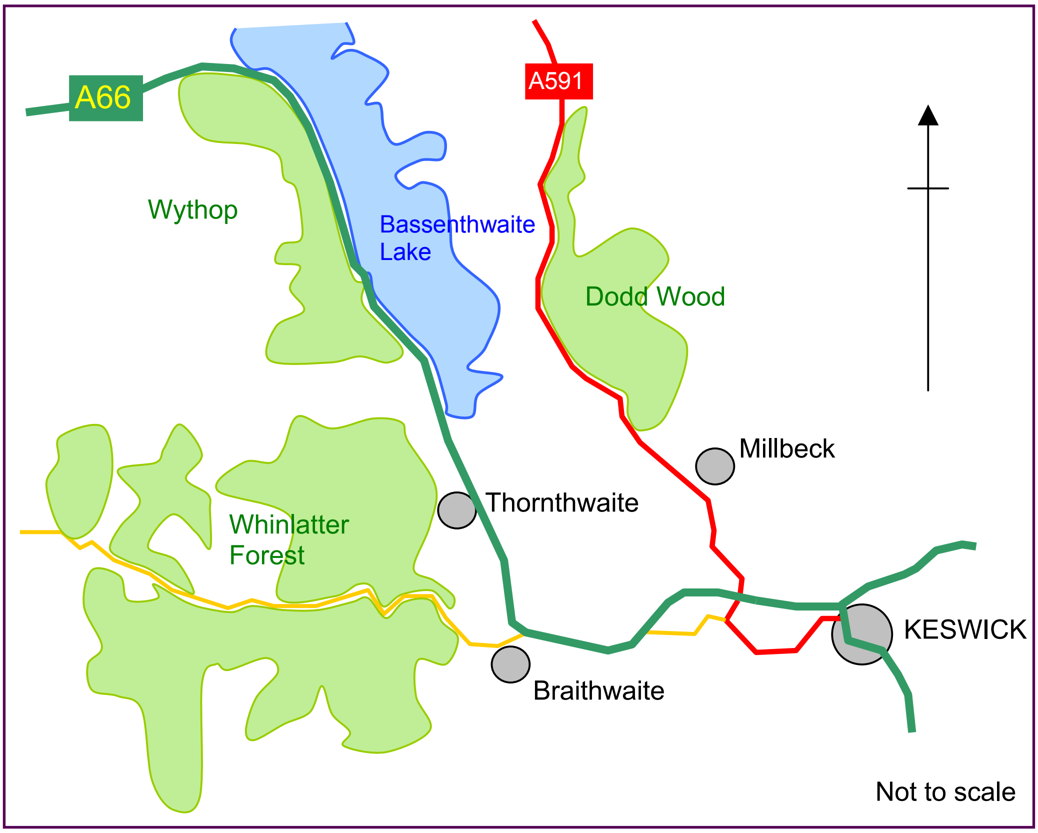


Figure 3.3 Location of Wythop, Dodd and Whinlatter Forests

Wythop Forest

Wythop occupies 275 ha with a predominantly eastern aspect, sloping steeply in places with 70% of the forest having slopes in excess of 33%. Windthrow hazard class scores range from 1 to 4. The predominantly brown earth soils promote the growth of good quality Douglas fir of Yield Class (YC) 10–20 on the lower slopes and Sitka spruce of YC 12–24 at higher elevations. There is a large broadleaf component, comprising 25% of the forest area.

Dodd Wood

The wood extends over an area of 300 ha and is composed of Douglas fir on the lower slopes with larch, beech and Sitka spruce at higher elevations. Soils range from brown earths on the lower slopes, through intergrade iron pan soils on the mid-slopes to skeletal soils on the hill tops. WHC increases with altitude from 2 to 5, but windthrow has been uncommon to date. Harvesting is aided by a well-serviced road and track network, which provides satisfactory access to the whole forest.

Whinlatter Forest

The forest extends over an area of 1,226 ha and comprises Douglas fir of YC 10–18 at lower elevations and predominantly Sitka spruce of YC 6–24 on the higher slopes, with 3% of the forest composed of broadleaves. Terrain and slope are severe in places although there is an adequate road network throughout the afforested area.

Management objectives

All three forests have high recreational use and are prominent in the landscape; future management therefore must be sympathetic to these functions. There is also a strong emphasis on improving watercourse habitat by felling riparian conifer crops and promoting open space and broadleaf regeneration.

Objectives aim to complement various statutory designations (such as SSSIs) in accordance with plans agreed with English Nature. There is also an economic objective to maximise financial return from timber harvesting. Traditionally the area has produced high quality Douglas fir and there is a desire to promote the regeneration of this species for timber. Public access will be maintained and promoted; CCF is ideally placed to create a forest structure compatible with recreation. All work is carried out in accordance with the UK Woodland Assurance Scheme (UKWAS) and the England Forest Strategy.

Management history

The continuous cover approach to management was established following the last design plan review in 2000. Prior to being designated as CCF, many of the stands on the steep slopes had been unthinned, principally because of limited cable crane resources. Historically, a road construction team has been located in Dodd Wood and consequently the forest has a dense network of roads and tracks.

Silviculture

Transformation thinnings are under way, with the priority being to commence regular thinning interventions early in the life of the stand to ensure stability. Establishing a stable crop through regular thinning is recognised as a priority to allow flexibility when selecting future silvicultural systems.

Plate 3.12 shows a Douglas fir crop planted in 1965 at Wythop Wood where racks were instated approximately 10 years ago. Further thinning has been neglected resulting in the current poor form of the crop, which is very drawn and liable to windblow. The high windthrow risk means that the only realistic option for this stand is to clearfell and restock the site; this emphasises the importance of regular thinning to give flexibility with regard to future silvicultural interventions.

At first thinning, racks are felled through the crop at a spacing of 14 to 16 m by removing on average one in six rows of trees; experience suggests that this will provide adequate access to the whole of the stand for future thinning interventions. Where the density of brash is insufficient to support machine access, thinning intensity is increased, although overthinning must be avoided as this could promote windthrow. In areas where Douglas fir is unable to naturally regenerate, continuous cover silviculture will consist of group felling and planting, an approach that has worked well in the past at Wythop.

Plate 3.12 A drawn up, unstable crop due to lack of previous thinning

Harvesting and extraction

Where possible, harvester and forwarder combinations are used for thinning work, although the steep nature of many of the areas necessitates motor-manual felling and skidder or cable crane extraction. In some parts of Wythop the degree of slope makes cable crane extraction the only option for timber harvesting. However, an absence of skilled cable operators has led to harvesting being delayed. Careful directional felling and skidder extraction is also important to avoid damaging groups of regenerating young trees.

Contractors are directly employed to carry out felling and extraction work, with timber sold at the roadside. Good communication between the forest manager and contractor is essential and the felling prescriptions are imposed on a feller-select basis to a basal area target, rather than marking the whole crop. The key to the success of this approach is accurate mensuration plot data, to provide accurate standing volume figures.

Tracking strategy

A network of extraction tracks already exists within the demonstration areas in Dodd Wood. Tracks are extensive and well surfaced, allowing excellent machine access by skidder throughout the wood.

Site survey

An understanding of the standing crop is gained through instating mensuration plots. A site survey is used to assess the past thinning and whether the site can be worked with a harvester and forwarder combination or whether alternative harvesting and extraction methods will be required.

Riparian zones

Riparian zones are managed through the removal of conifers and clearance of conifer natural regeneration to promote open space and broadleaf species.

Guidance

The *Forests & Water Guidelines* are the main source of environmental guidance used by managers of the demonstration forest.

Management priorities

Recently, concerns have been raised regarding the sediment load in Bassenthwaite Lake and as a consequence environmental protection has increased as a management priority. CCF silviculture is well placed to prevent watercourse sedimentation because of the reduction in the size of the felled area when compared to clearfelling. Some areas, such as the visitor centre at Whinlatter Forest, have very specific management objectives, including maintaining a tree canopy to provide an attractive environment for visitors.

3.4.2 Site operations

Access tracks

The specification of access tracks is based on the extraction requirements of the site and routes are upgraded accordingly and monitored to ensure they withstand the level of use during timber extraction.

Access requirements for CCF

Access tracks and racks are currently constructed (during the transformation phase) to the same specification and intensity as has been the case with clearfell silviculture. The sites where CCF transformation is under way are commonly limited by slope and thus access tracks tend to be located opportunistically as slope allows.

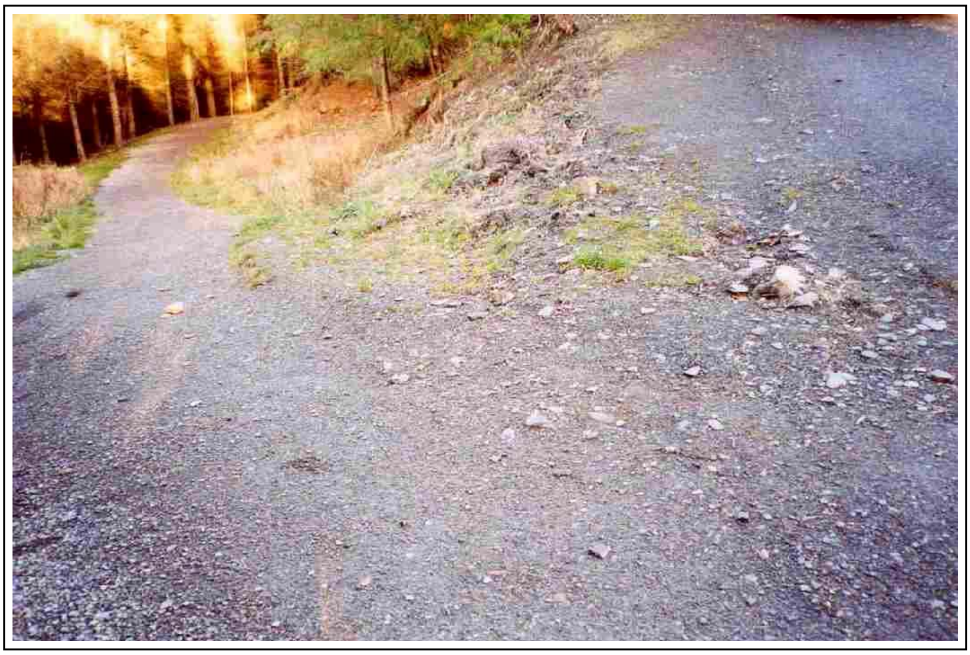


Plate 3.13 Modified access point to allow timber extraction machinery to use a recreation track from the main forest road

Any older access tracks that are in a serviceable condition are used for extraction. This even includes tracks used predominantly for recreation access, with the resulting closure of the track during the period of felling, as illustrated in Plate 3.13.

At Dodd Wood the large-dimension Douglas fir produce requires a large stacking and loading area at the roadside. This may become increasingly common as larger tree sizes result from the extended rotations under CCF.

Uses of track network

Extraction is most commonly done by skidding or cable extraction because of slope constraints. Also, skidding is often the only practical method of extracting the large Douglas fir poles that cannot be handled by a forwarder.

Permanence of tracks

All tracks are planned for permanent access.

Brash

Brash is accumulated in racks by careful directional felling and snedding, as shown in Plate 3.14.

Plate 3.14 Directional felling into racks to accumulate brash for rack construction

Track location

Track location is restricted in many areas by slope. Soils are predominantly brown earths and reasonably load-bearing. Some excavator levelling of tracks has been necessary on steep side slopes (Plate 3.15).

Plate 3.15 Excavator grading of side slope to provide skidder access

3.4.3 Watercourse management

Drainage

Extreme care is taken to reduce soil disturbance and prevent sediment being washed into Bassenthwaite Lake, which is adjacent to Wythop Forest.

Timing of operations

Given a limited contractor resource to carry out felling and extraction on steep sites in this locality, it is not practicable to constrain work to any great extent (e.g. to the driest periods of the year). So far there have not been any negative consequences as a result of working sites throughout the year. It has been possible to restrict operations in heavily used recreation areas to periods of low visitor use. This, along with adequate marshalling and signage, has allowed thinning to proceed safely in areas of high visitor access.

Inspection

The close proximity of the local Forestry Commission District Office to all three of the woodland blocks makes regular site inspections convenient; these are undertaken on a weekly or fortnightly basis by the forester or foreman. The site inspection includes an evaluation of the species type to determine whether it is best suited to meet the objectives for the forest. Where this is not the case, establishment by planting is favoured as an alternative to natural regeneration to allow a change in species.

Pesticide use

Treated plants are used for restocking to prevent weevil damage and traditionally pre-planting spraying is carried out with Glyphosate and Asulox as required. Stocking levels are currently achieving target densities without top-up spraying. No fertilisers are used. Urea application on cut stumps is done on a case by case basis but avoided in areas close to watercourses.

Site cultivation

The impracticality of ground preparation on the steep slopes with restricted access has meant that natural regeneration without prior cultivation is the favoured method of establishment.

On nearby clearfell areas a walking excavator has been used to create mounds for planting, but this is a costly option and impractical for CCF because of limited access within stands. At present, natural regeneration is abundant on the south-facing slopes, particularly under Douglas fir at Dodd Wood. Regeneration is less abundant on the shaded north-facing slopes.

3.4.4 Lessons learnt

Problems, causes and solutions

A particular problem is the lack of skilled, well-equipped, cable crane operators to carry out thinning work and timber extraction on steep slopes. The Forestry Commission disbanded its local directly employed skyline team around 1996.

Information gaps

No information gaps specific to environmental best practice were reported.

3.5 Site visit: Glentress Forest – Scotland

Information was gathered during a site visit on 5 February 2004 to observe harvesting techniques used in the transformation of regular forest to CCF, with a focus on access track construction and watercourse management in a forest with long-established CCF management.

3.5.1 Planning and design

Forest Design Plan

The management of Glentress Forest under CCF silviculture was initiated in partnership with Edinburgh University. Because of the high visitor numbers to the forest, a voluntary organisation (Friends of Glentress) has been set up and they are called upon to have an input into the planning process and the formulation of the design plan. Consultation also takes place with Scottish Natural Heritage and the Scottish Borders Council.

Within the design plan, optimum site types for conversion to CCF are stated as those at mid rotation age (producing larger produce dimensions) to minimise the revenue foregone during the transformation period. Well-thinned stands are favoured to enhance stability and increase light at ground level (stocking is viewed as more important than species type when opening the canopy to encourage natural regeneration). Stands with a high yield class are preferred so that the transformation can be achieved within a single rotation, similar to even-aged silviculture. Clearfelling is used where it is deemed to be the most appropriate management option to meet the stated objectives.

Site and crop

Glentress Forest occupies 1,366 ha across an altitudinal range of 240–650 m. The total area under CCF management is 117 ha. 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. 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.

Deer numbers are relatively low (approximately 10 per 100 ha) and thus while damage to young trees is present it is not severe. Consequently, there is no need for fencing within the forest. The planting of broadleaves in felled groups has led to some selective browsing damage.

Management objectives

- Achieve mixed species stands of irregular structure in order to maintain permanent forest conditions throughout the area.
- Achieve sustained production of high quality sawlogs of 40–65 cm diameter at breast height (1.3 m), depending on site type.
- Enhance recreation, amenity and conservation values.
- Provide information for education and research relating to the management of irregular forests.
- Recreation is a high priority with formal access provision for walkers and cyclists, including footpaths suitable for wheelchair users.

Management history

An experimental area was established in Glentress Forest in 1952 aimed at transforming the regular stand structure into an irregular patchwork composed of a mixture of age and size classes, by implementing a group felling system.

Conversion to CCF was seen as helping to conserve soils (e.g. on scree sites), providing for visual amenity through internal and external views, and enhancing conservation by increasing habitat diversity. Continuity of management is considered very important for CCF and this is aided by the production of a detailed management plan specifying the timing of all future interventions.

Silviculture

The current practice is to fell groups of trees within an area of at least twice the surrounding crop height, resulting in a minimum group size of approximately 0.1 ha (some larger groups are felled on the lower ground). The location of felled groups is opportunistic rather than systematic, expanding any naturally occurring gaps in the stands. A shelterwood system has been applied elsewhere in the forest. Windblow has not been severe and any fallen trees are removed by motor-manual techniques.

Harvesting and extraction

Transformation to CCF initially involved the extraction of timber by horse, then by skyline and now by forwarder (using a Timberjack 810 medium-sized forwarder). Forwarder extraction has posed a number of issues, including the appropriate size of machine and load capacity for the site/slope conditions.
Tracked machines were employed 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 20-m intervals and to avoid damaging younger crops. Some skidder extraction has been used on steeper slopes.

Poor quality lodgepole pine crops are harvested for wood chips to meet a local market for board products. The material is chipped in the forest using a mobile chipper and transported in wagons. This market has allowed a greater proportion of the potentially harvestable timber to be used beyond the standard top cut-off of 7 cm diameter. This has potential implications for soil management in that the ‘tops’ (<7 cm) are no longer available for brash rack construction or to provide nutrient release as they decay on site.

Felling is carried out on a feller-select basis, with a demonstration area marked to indicate the desired intensity of removal; 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 and felling work.

Tracking strategy

A permanent access track network has been established. This was constructed by an excavator using local material sourced from borrow pits (Plate 3.16).

Plate 3.16 Store of crushed stone, sourced within the forest for track construction

Site survey

The CCF stands are inspected at regular intervals to monitor progress in the development of an irregular forest. Detailed records are kept of all management interventions to aid future decision-making.

Riparian zones

Riparian zones are designed to be left open with a broadleaf component. Clearance of conifer regeneration is carried out motor-manually using a brushcutter, resulting in the development of a grass sward that hinders further conifer regeneration.

Guidance

Edinburgh University provides silvicultural guidance and Forestry Commission staff have received training courses on transforming even-aged crops from Mark Yorke (a specialist in CCF transformation).

Management priorities at Glentress

Priority is given to increasing recreation and conservation values, although timber production remains important.

3.5.2 Site operations

Access track specification

Access tracks have been instated within the forest to allow timber extraction. The specification is determined by the anticipated level of use and varies from lightly used unsurfaced tracks to heavily used stoned tracks constructed from crushed stone sourced on site (Plates 3.17 and 3.18). The use of local stone helps to reduce construction costs. Vehicle access to and from forest roads is aided by stone ramps.

Plate 3.17 Unsurfaced access track constructed to allow machine access for timber extraction during transformation thinning

Plate 3.18 Stone-surfaced track providing for heavy access by forwarders and timber wagons

Access requirements for CCF at Glentress

Appropriate rack and track specifications are guided by previous management experience gained from working similar sites under conventional thinning and felling treatments.

Uses of track network

The track network provides for a wide variety of users, including machinery for normal timber harvesting and forest management work, all terrain cycles (ATCs), walkers, mountain bikers and horse riders (Plate 3.19).

Plate 3.19 Minor track leading off the main forest track network, zoned for specific types of recreation

Permanence of tracks

Tracks and racks are constructed as permanent features.

Brash

Sufficient quantities of brash are generally available to meet the required specification for rack construction. Small group felling can occasionally lead to a shortage of brash but this is resolved by using the abundant brash generated in the felled groups, spread out along the length of the route.

Track location

The generally good load-bearing soils and favourable slopes at Glentress mean that there are few restrictions on track location.

Access points are carefully planned to minimise the turning angle of the forwarder when manoeuvring from the rack onto the track. The more acute the angle, the less likely that the turning action of the forwarder wheels will degrade the track (Figure 3.4).

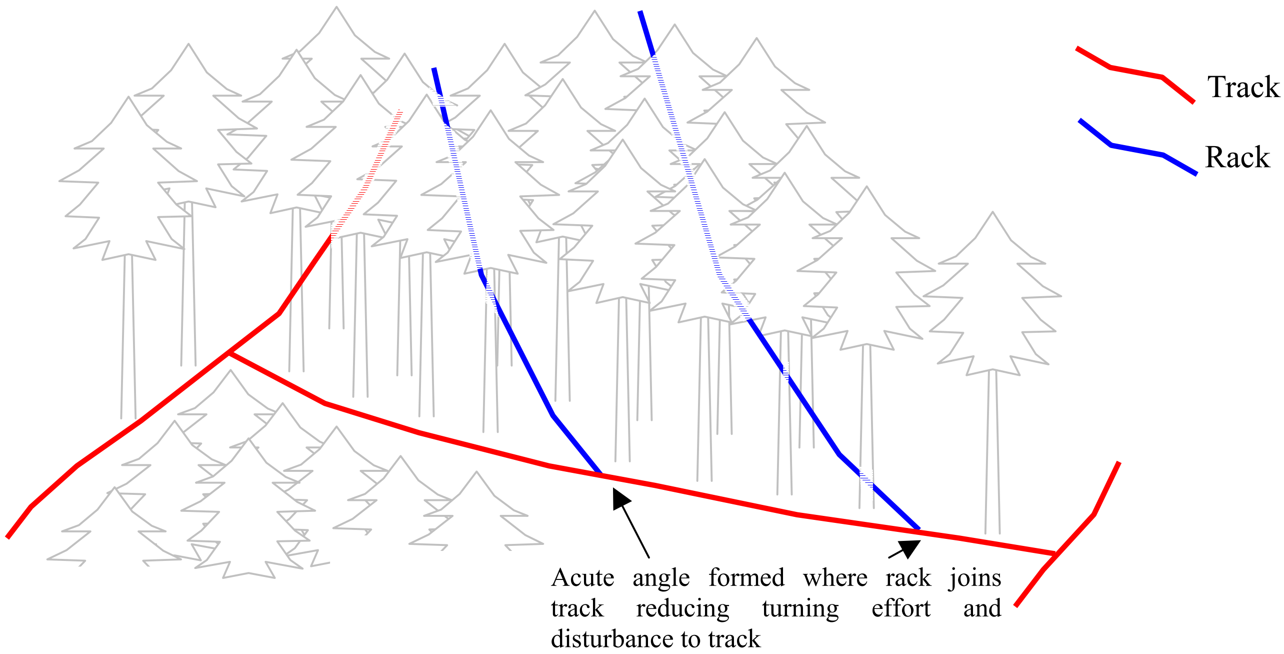


Figure 3.4 Recommended design for access and egress points between rack and track network

3.5.3 Watercourse management

Infrastructure

Glentress is a relatively dry site with few watercourses.

Limiting disturbance

The small number of watercourses means that there are few water constraints on track location or design.

Drainage

No drainage has been required in advance of management operations because of the well-drained nature of the local soils.

Timing of operations

The main restriction on the timing of operations is the high recreational demand; attempts are made to organise any major felling outside the peak visitor periods. The preferred approach is to maintain a low level of felling throughout the year, resulting in limited disturbance to recreational users.

Inspection

All sites are inspected prior to harvesting to identify any potential constraints that require specific attention.

Pesticide use

Most weeding is done mechanically and only bracken is chemically treated using Asulox. Insecticide-treated rootstock is used to protect against weevil damage when planting is the favoured method of regeneration.

Urea is applied to cut stumps to protect against fungal infection.

Site cultivation

Although natural regeneration is favoured, planting has been required in some of the felled groups to ensure desired levels of restocking. Planting necessitates site cultivation by excavator mounding, which greatly increases management costs. Prepared mounds provide favourable, weed-free conditions for establishment.

3.5.4 Lessons learnt

Problems, causes and solutions

The available pool of experienced contractors to do felling, particularly by motor-manual techniques, is diminishing, and this could severely restrict the quality and quantity of future work. Local contractors are familiar with the imposed felling intensity and therefore the initial learning curve has been scaled and overall efficiency is increased.

Managing the 117 ha CCF area at Glentress requires a high staff input, which is justified by the resulting multiple benefits. However, current resources prevent a major expansion of CCF; the site represents a minor proportion (*c.* 4%) of the total forest area managed by the Scottish Borders Forest District.

Information gaps

No specific information gaps were identified. A great deal of operational experience has been gained during the 50 years that the forest has been managed under CCF.

3.6 Summary of findings from CCF demonstration site visits

It can be concluded from the site visits that the transformation of even-aged stands on freely draining soils on sheltered sites and their management under a CCF regime is likely to pose few threats to forest soils and water (at least on an operational basis). Freely-draining soils are more resistant to damage and the greater availability of brash means that existing best practice is effective at minimising any impacts. Sites are already subject to a thinning regime and the same types of machinery are used as under conventional clearfelling. The absence of forest drains removes the need for any supplementary or corrective drainage work.

Most problems occurred where CCF was being pushed onto less suitable soils, especially wet soils on more exposed sites. The combination of soft ground and insufficient quantities of brash meant that there was often insufficient support for machine movement. This resulted in an increased risk of soil rutting, erosion and water pollution. The provision of adequate drainage was another key issue. However, the experience gained from the pilot demonstration sites is leading to the development of novel methods to overcome these additional pressures and impacts. The methods are taken forward and further developed in a Technical Information Note, which will be published by the Forestry Commission in 2006/07. Initial assessments indicate that the methods are effective in protecting vulnerable soils and waters, but there remains a need for a formal evaluation of costs and benefits. The site visits re-emphasised the importance of good site planning and the need for a thorough site survey and regular monitoring, especially during the transformation stage to CCF. In general, the results suggest that CCF can be successfully extended to a wider range of site types than was originally envisaged.

In the majority of cases the availability of skilled operators to carry out thinning and timber extraction is diminishing. This could prove to be a major limiting factor in extending the conversion of even-aged stands to CCF. It also poses the risk of unskilled operators not implementing best practice correctly or important management operations being omitted. Emphasis must therefore be given to the proper training and supervision of contractors. Another important issue is the current low prices for timber. On the one hand, this has the beneficial effect in some locations of leaving large volumes of low value pulpwood available for use in strengthening permanent access routes. However, it also makes some operations such as remedial drainage work uneconomic, which can increase the risk of site damage. These factors must be borne in mind when planning which sites are suitable for CCF.

4 Scoping of long-term monitoring needs for assessing impacts of CCF on soils and waters

4.1 Background

Section 2 of this report noted that the transformation of even-aged forests to CCF presents a number of potential threats to forest soils and waters. These require further study to quantify the risk to the environment and to help develop guidance to mitigate their impact. Among the most challenging of these is the need to assess the effects of the relatively permanent but more broken forest canopy under CCF on both forest water use and the scavenging of atmospheric pollutants, particularly acid deposition. The gradual and subtle nature of the transformation process necessitates long-term monitoring studies to determine the impact at the catchment scale.

Many long-term studies are already under way throughout Britain to measure the effects of conventional forestry on the freshwater environment. These represent a significant investment in research effort and funding, and could potentially provide a well-established baseline against which to assess the impact of forest conversion to CCF. This section of the report reviews the existing set of forest hydrology and hydrochemistry catchment studies to determine whether any of these are suitable for this task.

4.2 Method

All known long-term forest catchment studies in Britain were assessed for the potential of their forest areas to be converted to CCF. GIS software was used to create catchment boundaries for each site and details of the forest management regime and other relevant characteristics were determined from available data sets, published reports and personal contacts. A total of 49 individual forested catchments from eleven different long-term networks were assessed (Table 4.1 and Figure 4.1). All but one of these comprised conifer forest dominated by Sitka spruce, lodgepole pine and Japanese larch; the other one involved ancient broadleaf woodland.

Table 4.1 Project or site name commonly used to identify catchment streams subject to long-term monitoring of water flow and/or stream water chemistry

Project	Country	Number of forest streams
UK Acid Water Monitoring Network	UK	6
The Loch Dee Project	Scotland	3
The Loch Ard Project	Scotland	10
Halladale	Scotland	5
Balquhidder	Scotland	2
Coalburn	England	1

Table 4.1 - continued

Forestry Commission/Environment Agency Welsh Long-term Acid Waters Network	Wales	10
Llynn Brianne Acid Waters Project	Wales	8
Plynlimon	Wales	2
Beddgelert	Wales	1
Llanbrynmair	Wales	1

The majority of the long-term catchment studies are sited on acid-sensitive geology in the uplands of Scotland and Wales. This means that they tend to be exposed with a high windthrow hazard class. Forest crops are therefore usually unthinned and less suitable for conversion to CCF. Streams tend to be first or second order and mainly drain wet, nutrient-poor soils. Monitoring is generally limited to monthly sampling of stream water chemistry with the aim of quantifying the effects of conifer forests and their management on surface water acidification. Some sites are subject to annual surveys of freshwater biology but most have little or no biological data. The monitoring of water flows is largely confined to the three main forest hydrology studies at Balquhidder, Coalburn and Plynlimon.

An Access database was created to hold the site details for each catchment. The Forestry Commission owns and manages the forest in most of the studied catchments and details of the forest cover, including forest age and species, were obtained from its Subcompartment Database. Information on felling and restocking was taken from Forest District Forest Design Plans.

Tillhill Economic Forestry manage the forest in ten of the catchments, Fountain Forestry is responsible for forest blocks in another seven, and smaller private companies in two others. Their agents were approached for copies of the component forest plans and, where available, hard copies were provided. Forest plans have yet to be written for forests within seven catchments, comprising the five streams at Halladale (Baledigle Forest) and two in Wales (Afon Ceurant-y-Garenedd at Garnedd Pen-y-Bont and the lower reaches of the Afon Cwm catchment in the Coed y Cwn Forest). All of the forest plans were designed to introduce a greater diversity of conifer species, more mixed broadleaves and increased open space, especially along stream sides and at the margins of the forest.

Catchment boundaries for the area draining to each sampling/measurement point were created using digital elevation data and the Hydrology Modelling Sample Extension in ArcView 9. Since the Subcompartment Database and design plans are forest rather than catchment based, the catchment polygons were used to select the appropriate sections of these data sets so that the areas and relative proportions of forest cover programmed for clearfelling or CCF could be determined. Where only paper copies of the forest plan were available, catchment boundaries were drawn by hand and the respective areas estimated by cutting and weighing.

4.3 Results

Fourteen of the long-term study catchments were identified with forest areas programmed for conversion to CCF. These are listed in Table 4.2 in descending order in terms of the proportion of their total area to be converted to CCF. Twelve are located in Wales and two in Scotland. The results show that a minor fraction of the forest area in most of the catchments is planned for conversion, with only two catchments exceeding 10% of the total area.

Detailed maps of the six catchments with greater than 3% CCF (depicted as either LISS (Low Impact Silvicultural Systems), MR/MLTR (Managed Long Term Retention) or NI (No Intervention)) are shown in Figures 4.2 to 4.7. These maps demonstrate that CCF areas tend to comprise small isolated or fragmented blocks of forest.

Table 4.2 Areas and proportions of long-term study catchments that are programmed for conversion to CCF

Forest	Stream	Stream catchment (ha)	CCF (ha)	CCF (% of catch.)	Forest cover (% of catch.)	CCF (% of forest)
Bryn Arau Duon	Tributary of the Afon Cothi	146.4	86.6	59.1	76.0	77.8
Mynydd y Ffynon	Cefn Hendre	250.2	22.9	9.2	75.9	12.1
North Tywi	Crugnant	296.4	21.9	7.4	87.5	8.4
Hengae Forest and Ffynnon Badarn	Nant Ceiswyn	860.9	29.6	3.4	55.9	6.2
Hafren	Afon Hafren	436.2	14.8	3.4	51.4	6.6
Hedrewallog and Ty Glas	Nant Iago	606.4	19.3	3.2	57.1	5.6
Blaen cwn Mynach	Llyn Cwm Mynach	124.5	3.3	2.7	50.5	5.3
Fannog	Nant y Fannog	184.9	4.0	2.1	38.4	5.6
Hafren	Afon Hore	325.9	5.3	1.6	67.7	2.4
Rheidol	Llechwedd-mawr	463.3	3.0	0.6	42.4	1.5
Glenhurich	Allt na Coire nan Con	798.3	4.8	0.6	43.2	1.4
Round Fell and Fleet Basin	Loch Grannoch	1,507.2	5.3	0.3	55.7	0.6
North Tywi	Nant y Mean	381.3	0.7	0.2	38.2	0.5
North Tywi	Cammdwr	921.7	0.7	0.1	16.8	0.4

Since the hydrological research literature has generally found that the clearance of forest from less than 20% of a catchment results in little detectable change in water yield or chemistry, only the Afon Cothi site in mid Wales holds potential for monitoring the effects of CCF. At present, 15% of the forest has been formally designated as CCF but the plan is to thin as much of the remaining forest as possible and eventually convert all wind firm areas on suitable soils to CCF, amounting to a total of 59% of the catchment. This is one of the Forestry Commission/Environment Agency Welsh long-term monitoring network sites with monthly stream water chemistry data available since 1991. However, it was also monitored as part of the original Llyn Brianne study and stream chemical data for a range of sampling intervals are available since 1985, five years after the catchment was first planted. Some fish and benthic macroinvertebrate data are available for a few individual years. Stream flow has not been recorded to date.

Details of the remaining catchments that are programmed for conventional clearfelling are given in Table 4.3. These are largely excluded from conversion to CCF because of their high exposure and poor soil types, which result in a high risk of thinning leading to extensive windblow. The list includes the three main forest hydrological catchments and thus none are suitable for assessing the impact of CCF on water use or extreme flows.

Table 4.3 Areas and proportions of long-term study catchments that are programmed for conventional clearfelling

Forest	Stream	Catchment area (ha)	Forest cover (%)
Beddgelert	Afon Cwm Du	134.8	62.3
Caer Defaid	Nant-yr-Helyg	289.3	58.9
Llanbrynmair	Afon Cwm	296.1	84.0
Garnedd Pen-y-Bont	Afon Ceurant-y-Garnedd	291.8	36.1
Fannog	Nant y Crawflyn	78.8	93.1
	Nant Cwm-bys	32.2	76.9
North Tywi	Nant-y-Fedw	285	39.9
	Gwenffrwd	18.7	19.5
	River Irfon	1,495.4	48.1
	Nant y Bustach	258.6	100.0
	Mynydd Trawsnant	83.5	14.7
	Trawsnant	82.4	90.0
Baledigle	Lower Halladale	3,496.6	28.8
	Middle Halladale	1,911.5	36.1
	Allt a Bhealaich	368.6	40.7
	Bealach Burn	235.4	56.5
	Bealach Burn east tributary	56.4	24.3
Back Hill of Bush	Green Burn	259.3	52.7
	White Laggan Burn	255.7	10.6
	Black Laggan Burn	241.2	18.3
Brae of Balquhidder	Kirkton	738.4	31.5
	Monachyle	744.0	9.1
Corriegrennan	Allt Crioch	163.3	19.8
	Duchray Water 6	119.9	21.8
Corrie	Duchray Water 7	135.5	54.9
	Allt Chlachaniaoigh	384.9	15.7
	Corrie Burn	170.3	64.1
Drumore	Castle Burn	87.1	81.9
	Duchray Water 11	142.0	78.9
Loch Chon	Loch Chon	1,537.2	42.6
	Loch Chon 13	10.5	66.8
	Loch Chon 14	251.2	55.5
	Loch Chon 15	91.9	55.9
Kielder	Coalburn	138.9	87.4
Ashdown Forest	Old Lodge	274.9	7.9

4.4 Discussion and Conclusions

The assessment of 49 long-term study catchments found that only one was suitable for converting a significant area of forest to CCF. This reflects the fact that most of the sites comprise small headwater catchments in exposed upland areas, which are generally unsuitable for CCF. If such sites are typical of upland Britain, then it raises a question about the likely scale of forest conversion to CCF at the catchment level. This is an important consideration, since if the bulk of the forest area to be converted to CCF lies on lower ground and drains to larger third and fourth order stream catchments then the relative proportion of the catchment affected will be small.

Experience suggests that if the change involves less than 20% of a catchment then the effects are likely to be minor and remain undetectable. This is especially relevant in the context of the more subtle and gradual changes associated with CCF compared to conventional clearfelling. Consequently, there is a need for a wider assessment of forest plans to characterise the planned scale of CCF at the catchment level. A good starting point would be to determine the relative proportions of the catchments of the individual waterbodies that have been designated under the EU Water Framework Directive. As Wales is at the forefront of the change to CCF, there would be merit in focusing attention on a regional or country-wide assessment. This would help to clarify the potential risk to fresh waters and help guide the need for further research.

Notwithstanding the above, it would be sensible to consider the scope for reinforcing the monitoring work at the single catchment that was identified as being suitable for large-scale conversion to CCF. The Afon Cothi catchment in mid Wales has an excellent long-term stream water chemical record that extends back for almost 20 years to shortly after the catchment was originally planted. This provides a good baseline for assessing the effects of the future large-scale conversion of the forest to CCF. The existing monthly sampling regime is probably sufficient to monitor any chemical changes but the biological work would need to be strengthened. Annual fish and invertebrate surveys should be considered as a minimum and surveys should probably be extended to include the monitoring of other biological quality elements such as aquatic plants and phytoplankton, providing site conditions are suitable.

The main deficiency in the Afon Cothi catchment study is the lack of any flow monitoring work. This is unfortunate but not unexpected given the potential high cost involved in providing instruments in catchments to measure stream discharge and rainfall inputs. There is a need to scope the suitability of the site and the best method for monitoring catchment stream flow to determine whether the costs can be justified. This process should be informed by modelling, which would allow the predicted hydrological impact of CCF to be assessed against the errors associated with the hydrological measurements. It is possible that the latter could exceed the former, in which case there would be little justification for commissioning such work.

Figure 4.1 Location of long-term forest hydrology and hydrochemistry catchment studies

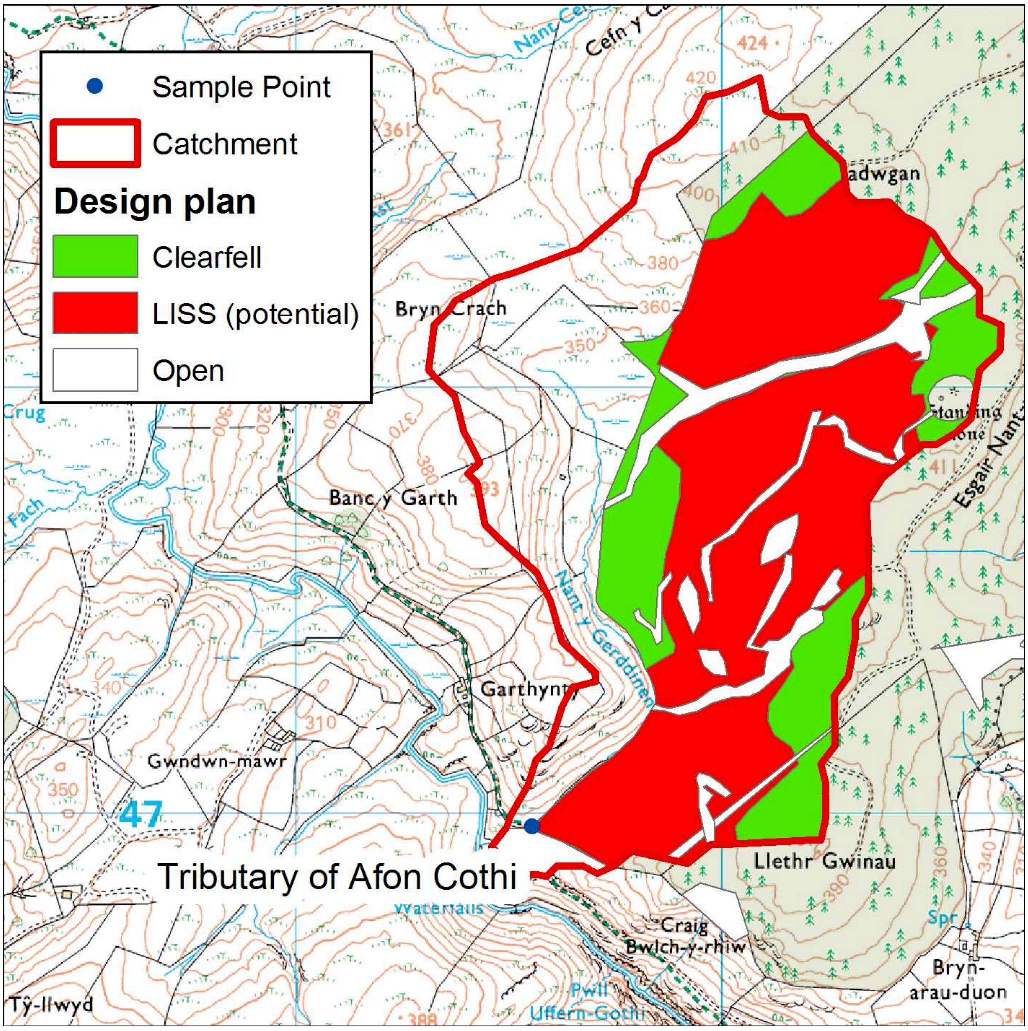


Figure 4.2 The tributary of the Afon Cothi in the Bryn Arau Duon Forest

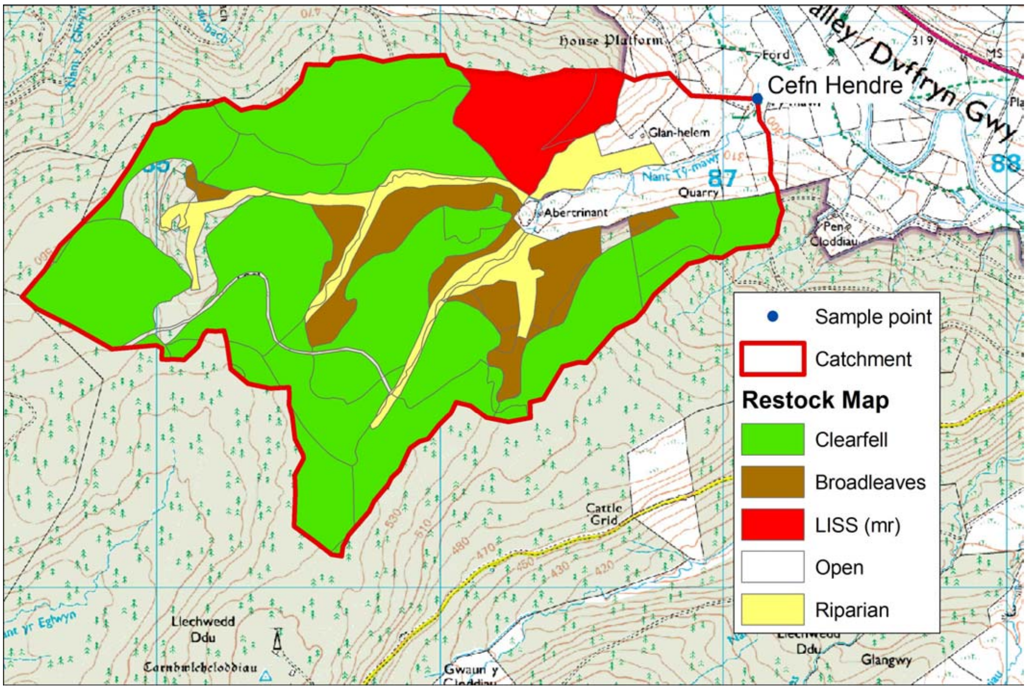


Figure 4.3 Cefn Hendre in Mynydd y Ffynon

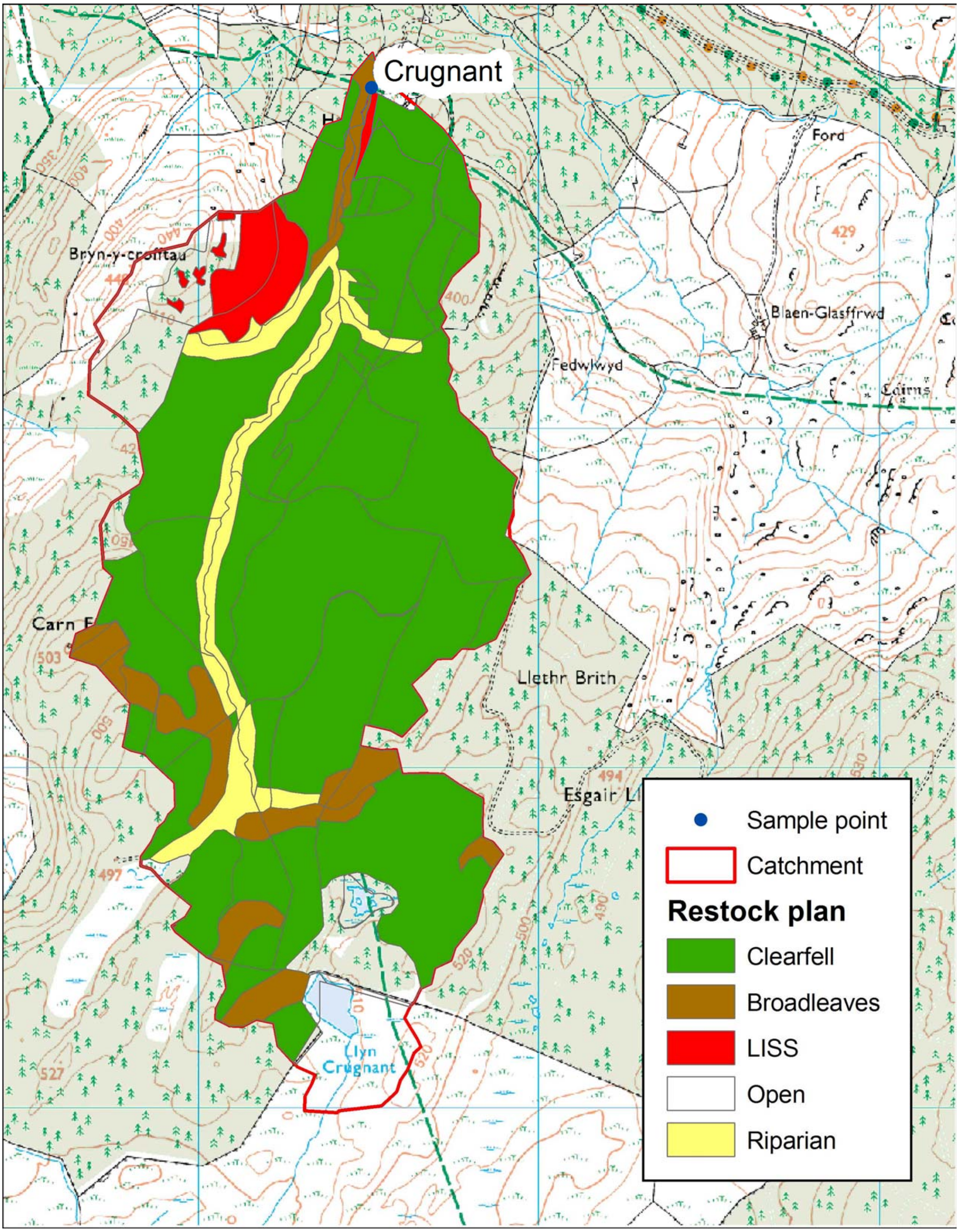


Figure 4.4 Crugnant in North Tywi

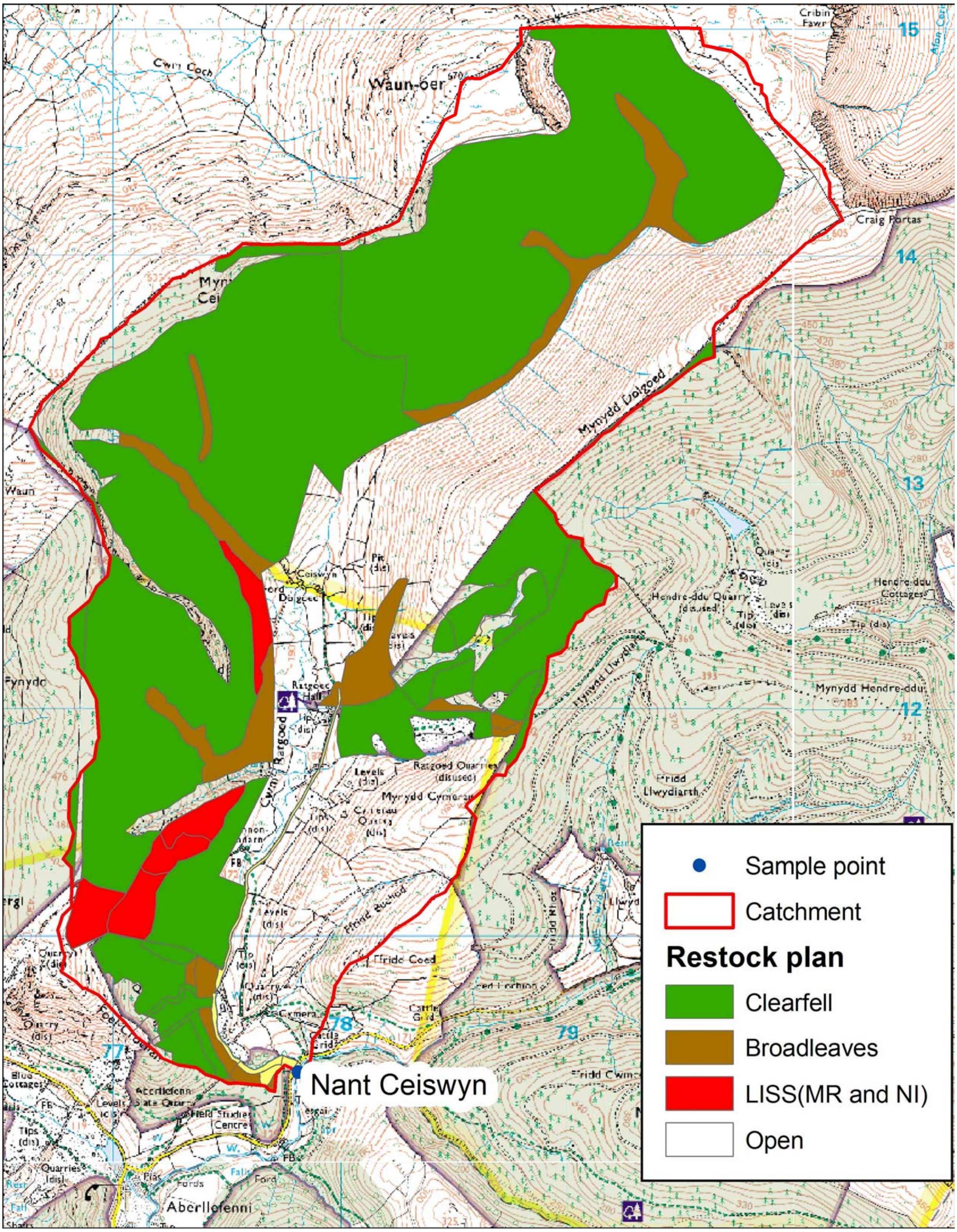


Figure 4.5 Nant Ceiswyn in Hengae Forest and Ffynnon Badarn

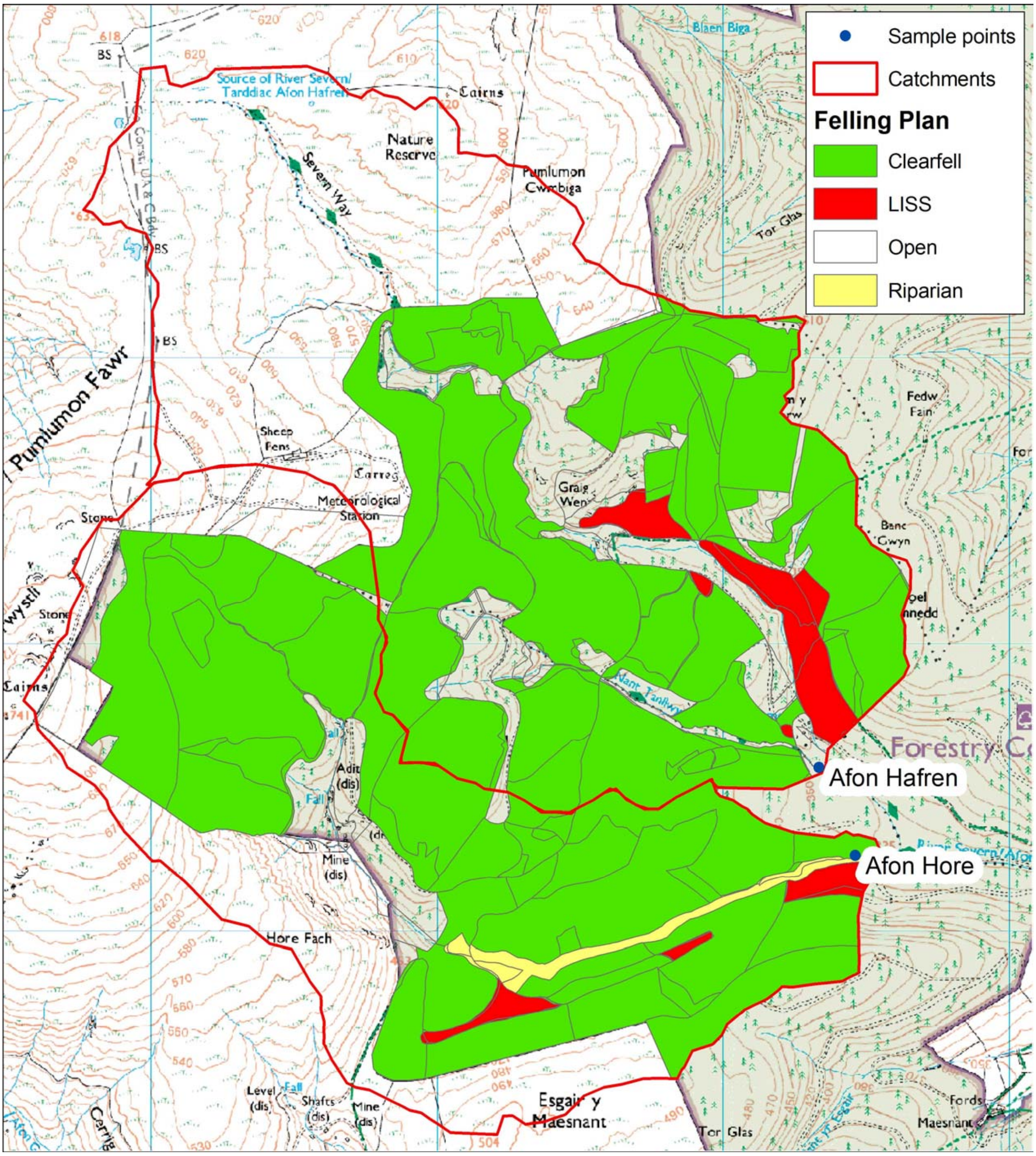


Figure 4.6 Afon Hafren and Afon Hore in Hafren Forest

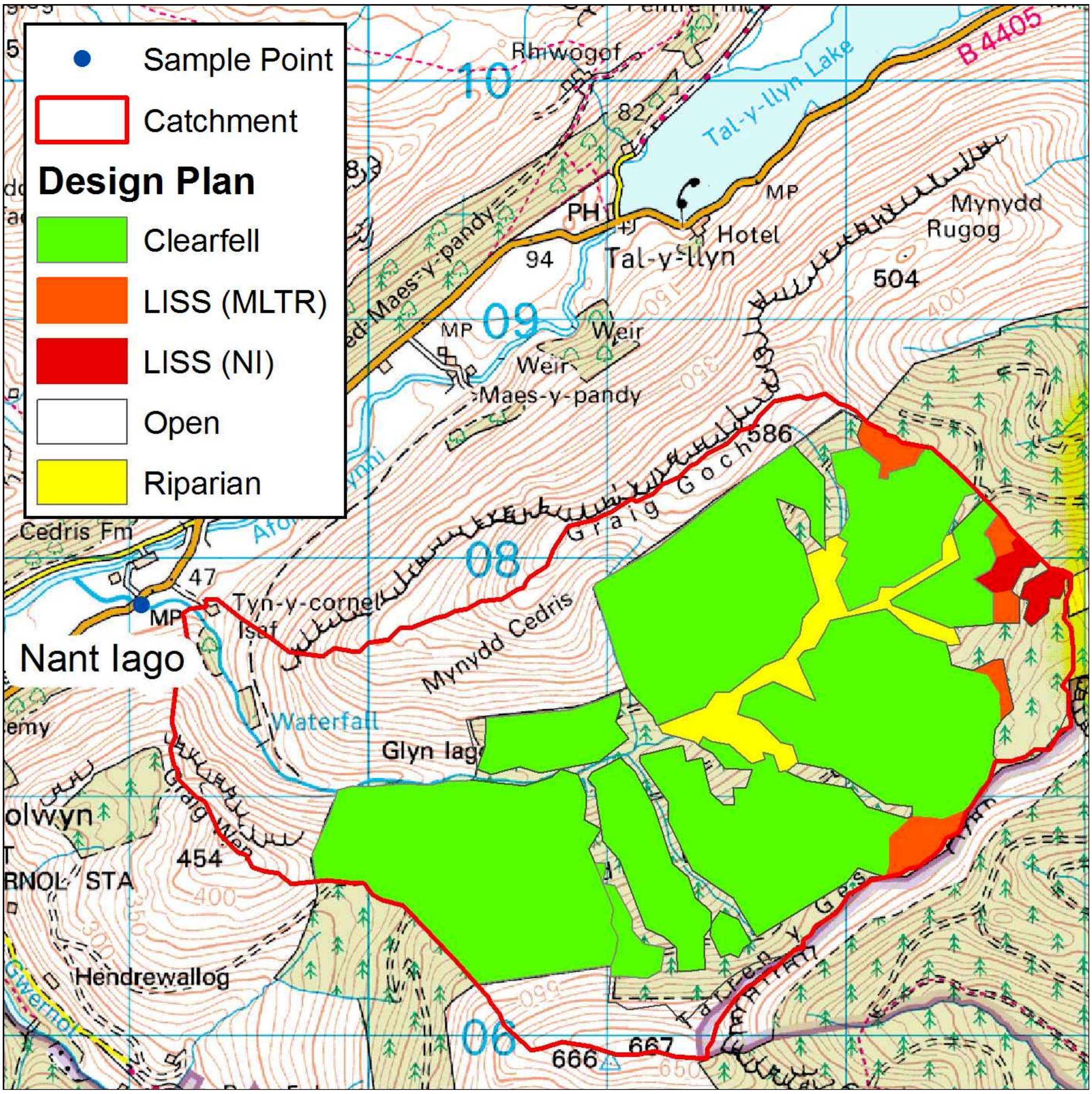


Figure 4.7 Nant Iago in Hedrewallog and Ty Glas

5 Glossary of terms

Borrow pit
A temporary excavation used to obtain soil for a construction project and normally backfilled.

Brash
The residue of branches and tops, sometimes called 'lop and top', left on site following harvesting.

Brash mat
A mat of brash placed in rows on which harvesting and timber extraction machinery travels to reduce soil damage.

Buffer area
An area that protects the watercourse from pollutants and sediment run-off from the adjacent land. The buffer area will usually include the riparian zone and may extend into the adjacent land.

Cable crane
A method of extracting timber over rough and/or steep ground using a system of pulleys and line wires. The tractor providing the power for the system does not leave the forest road.

Conversion
Cutting up of a tree into pre-set lengths.

Coupe
An area clearfelled within mature woodland and which will be regenerated.

Feller select
A type of selective thinning where the person felling the trees or operating the harvester chooses the trees to be thinned.

Forest road
Forest roads are surfaced and engineered to a specification allowing safe use by (road-going) lorries.

Forwarders
Tractors that extract timber lifted entirely clear of the ground. The timber is carried on a linked trailer or integral platform. The process of timber extraction using a forwarder is referred to as forwarding.

Group felling
Felling the overstorey crop in distinct groups usually no bigger than 0.25 ha. This approach to timber harvesting maintains a continuous tree cover with regeneration in the felled groups by natural or artificial means.

Harvester
A machine that severs the tree from its roots, debranches it and converts it to pre-determined lengths.

Harvesting system
In the UK, the five commonly practised systems of timber extraction can be defined by the way in which the produce is extracted from site: shortwood, pole length, part pole, whole pole and terrain chipping.

Matrix
Term used to refer to the standing crop in-between the rack network.

Natural regeneration
Young seedlings that have arisen from seed falling from nearby trees, either as a direct response to specific forest management or by natural seeding. Very often just referred to as regeneration, but technically this includes artificial regeneration (i.e. planting) as well.

Part-pole harvesting
A variation of the pole-length harvesting system whereby the sawlog component of the tree is removed at stump and extracted separately, aiding product sorting and providing efficient delivery of sawlogs to the customer during periods of high demand. Pulp and small roundwood can be extracted at a later stage. Outputs may be reduced using this method if product density is low, resulting in correspondingly small load sizes.

Pole length
Harvesting system that combines a three-phase operation involving felling and delimbing, extraction to roadside, and cross-cutting of various products (e.g. sawlog, pulp and woodfuel). Conversion of products may take place at the roadside or at the mill.

Pulpwood
Small diameter material comprising softwood from conifer trees that is used to make paper.

Rack
Racks are simple felled corridors through the stand. These may be reinforced with brash or other surfacing materials to withstand machine movement.

Rotation
The period between planting and harvesting under a clearfelling system.

Screef planting
The planting of trees within shallow scrapes or depressions that provide weed-free spots of mineral soil material on dry soils.

Shelterwood
Successive fellings are carried out throughout the stand to maintain a continuous covering of trees in a uniform or irregular pattern, forming two or more storeys of tree canopy.

Shortwood harvesting
Harvesting system involving felling, delimbing and cross-cutting the tree at stump; the brash is discarded and only the saleable products, including woodfuel, are handled. The technique is suitable for all tree sizes. Minimising the number of products cut will reduce the time taken for sorting at the roadside. The preferred method of extraction is by forwarder, subject to ground conditions.

Silviculture
The controlled establishment, growth, composition, health and quality of forests and woodlands to meet the management objectives in a sustainable way. Silvicultural systems are a planned series of treatments for managing, harvesting and re-establishing forests.

Skidding
The extraction of timber using a tractor to lift one end of the log or the base of the tree clear of the ground with the other end dragging on the ground.

Terrain chipping
Harvesting system in which a chipper is used in the wood, directly chipping the whole tree, poles or shortwood into a hopper. The chips are blown into a trailer and subsequently dispatched into containers for road haulage. Terrain chippers may be self-contained units mounted onto a forwarder base unit, with an integral grab to allow mobility through the stand, or simple independent mobile units.

Track
Access tracks form a transport link between harvesting racks and forest roads. Forest tracks can be defined as forwarder/tractor tracks designed for a specific use (e.g. access for extraction of produce). Forest tracks are not generally suitable for lorry access.

Transformation
The process of manipulating the forest canopy towards an irregular structure, in the interests of creating a canopy structure best suited to CCF silviculture.

Watercourse
Any natural or artificial channel through which water flows continuously or intermittently.

Whole-tree harvesting
Harvesting system in which all the above-ground components of the tree are extracted off the felling site, resulting in no crown and branch wood residues being left in the forest. This increases the volume of harvestable produce from the tree.

The above definitions are consistent with those given in the Forestry Commission's *Forests & Water Guidelines*, *Forests and Soil Conservation Guidelines* and *Forest Nature Conservation Guidelines*.

6 References

Forestry Commission 1990 *Forest Nature Conservation Guidelines*. London: Forestry Commission, HMSO.

Forestry Commission 1998 *Forests and Soil Conservation Guidelines*. Edinburgh: Forestry Commission.

Forestry Commission 2003 *Forests & Water Guidelines*. Edinburgh: Forestry Commission.

Killer, DJ 1995 *Harvesting Manual, Second Edition*. Forest Enterprise (Wales), Aberystwyth, Dyfed (unpublished).

Mason W L and Kerr G 2001 *Transforming Even-Aged Conifer Stands to Continuous Cover Management.* Forestry Commission Information Note. Edinburgh: Forestry Commission.

Nisbet, T R 2001 *Forestry Operations – A Review of Best Practice Guidance for the Protection of the Freshwater Environment*. R&D Technical Report P210. Bristol: Environment Agency.

Nisbet, T R 2005 *Water Use by Trees.* Forestry Commission Information Note. Edinburgh: Forestry Commission

7 Acknowledgements

We thank the Environment Agency and Forestry Commission for funding this work. Thanks are also due to George Johnson (Coed Trallwm), Iwan Parry and Neil Stoddart (Forestry Commission Wales), Jon Bates (Forestry Commission England) and Jeremy Thompson (Forestry Commission Scotland) for their very valuable contribution to the site visits, especially for providing access, background information and time for discussion.

We are The Environment Agency. It's our job to look after your environment and make it **a better place** – for you, and for future generations.

Your environment is the air you breathe, the water you drink and the ground you walk on. Working with business, Government and society as a whole, we are making your environment cleaner and healthier.

The Environment Agency. Out there, making your environment a better place.

Published by:

Environment Agency
Rio House
Waterside Drive, Aztec West
Almondsbury, Bristol BS32 4UD
Tel: 0870 8506506
Email: enquiries@environment-agency.gov.uk
www.environment-agency.gov.uk