Twenty years of success with continuous cover in Sitka spruce at Clocaenog Forest, Wales

Kerr, Gary; Williams, Dave; Haufe, Jens; Walmsley, James

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Twenty years of success with continuous cover in Sitka spruce at Clocaenog Forest, Wales

by Gary Kerr, David Williams, Jens Haufe and James Walmsley

Summary:
Is it possible to manage Sitka spruce using continuous cover silviculture? This is the main question that has been examined in a 42ha Trial Area in Clocaenog Forest, northeast Wales, in a joint project between Forest Research, Natural Resources Wales and Bangor University since 2001. The trial is an example of 'late transformation' because it was started when the forests were circa 50 years old and, under traditional even-aged management, would have been clearfelled in 2000. In the Trial Area a number of different methods of transformation to continuous cover have been applied: uniform and irregular shelterwood, group and strip shelterwood, underplanting and respacing of natural regeneration. Experience has shown that the uniform shelterwood system is a straightforward method of transforming Sitka spruce, and local staff quickly adopted this approach because it is so pragmatic. However, all the methods used in the Trial Area can be successfully applied to Sitka spruce with some small adjustments to existing practice. The main factors for success include: initial selection of suitable stands; good site organisation (marked racks, operational zones for working and stacking, stoning to join racks to road network); excellent machine operation and clear on-site management with professional forestry input. The success in the Trial Area has led to the adoption of various forms of continuous cover management on a much wider area in Clocaenog Forest; these now extend to some 2,000ha out of a total area of 4,000ha.

Introduction

'Continuous cover in Sitka spruce: you must be joking!' is a common contribution to the debate about how to diversify the 665,000ha of this species presently growing in Britain. Sitka spruce is an extraordinary species and has been widely planted in the uplands of Britain for good reasons: it is easy to establish; grows extremely well in the right conditions but also tolerates exposure and wet, nutrient-poor sites; and produces timber for which there is a ready market. Most forest managers in Britain are familiar with the species grown in plantations that are the result of the era of forestry expansion in the mid-twentieth century. However, much has changed recently and policy is now encouraging forest managers to diversify forests in response to the twin challenges of biotic threats and climate change. This is the reason why questions are being asked about the application of continuous cover silviculture to Sitka spruce. Fortunately, this question has been considered in the past and many people will be familiar with the pioneering work of Professor Mark Anderson who set up a number of large-scale trials of different silvicultural systems in upland forests more than 60 years ago (Kerr et al., 2010; Mason and O'Kane, 2014). In a review of the potential to apply such systems in upland Britain, David Paterson (1990) estimated that at least 25% of our upland site types were capable of being managed under alternative silvicultural systems to clearfelling. The objective of this article is to tell the story of how continuous cover has successfully been applied over 20 years in a 42ha operational trial in Clocaenog Forest.

Site description

Clocaenog Forest extends to over 4,000ha at the southern end of the Hiraethog Moor and is mainly to the north and west of Clawdd-newydd in northeast Wales (Figure 1). Elevation ranges between roughly 300m and 500m above sea level, and the area is underlain by Silurian slates, shales and grits. The forest is in the cool wet climatic zone of the Forestry Commission's Ecological Site Classification. Currently, DAMS windiness scores for the forest generally exceed 16, which indicates that wind damage is a significant risk factor to consider in management of the forest. Conifer planting began around 1930, and most stands are now in the second rotation. Clocaenog is largely stocked with conifers managed primarily for timber production; management for red squirrels is also important.

Elevation within the Trial Area ranges from 370m to 407m. Soils are mostly intergrade ironpans, but vary from upland brown earths through peaty gleys to true ironpan soils (Davies, 2010). The ground cover prior to afforestation was mostly heather dominated (Forestry Commission, 1952). This influenced the site preparation before planting, which involved ploughing, and the planting of a self-thinning

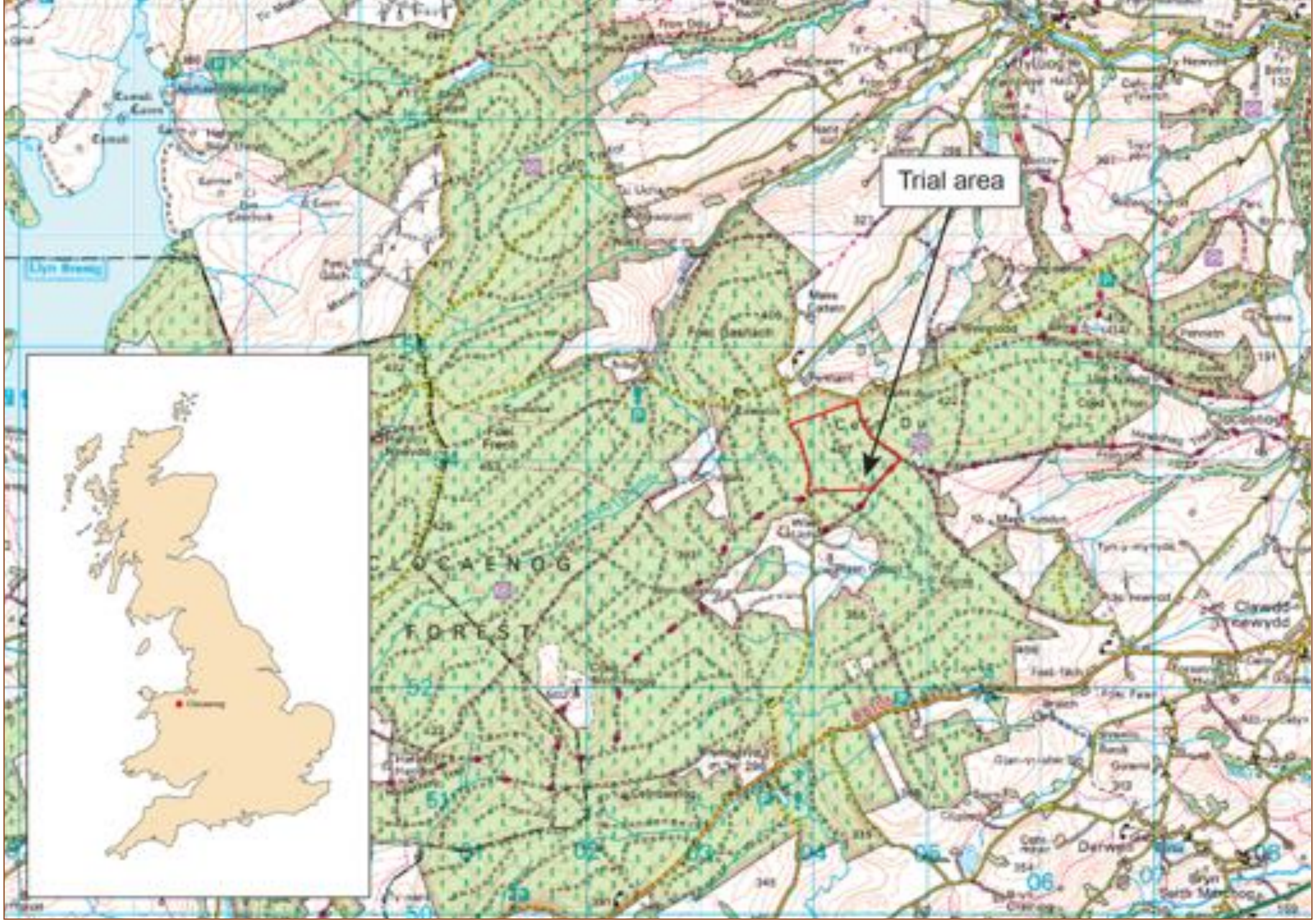

Figure 1. Location of the Trial Area within Clocaenog Forest and northeast Wales. (©Crown copyright 2021 Ordnance Survey. Media 038/21)

nurse mixture of Sitka spruce and (mainly) lodgepole pine. The Trial Area was planted between 1948 and 1951, with the simple aim of maximising timber production under a clearfelling system; Sitka spruce is generally GYC18. After the first thinning at 25 years the stands were neglected for some time. When a later thinning at about 40 years resulted in promising signs of advance regeneration it was followed swiftly by another, and this intervention succeeded in securing the regeneration without compromising stand stability.

Stand treatments

In the late 1990s the Forestry Commission made the decision to establish some trial areas to test the feasibility of using continuous cover in a range of different forests (McIntosh, 2000). As a result of this Bill Mason visited Clocaenog in 2000 and identified the potential of the site based on the presence of natural regeneration, the absence of deer, the history of thinning and the enthusiasm of the local staff. He alerted members of staff at Bangor University about its potential and in 2001 staff from the university and the Forestry Commission began to establish the Trial Area. It was decided to use large plots, each of which would investigate the application of different silvicultural systems at an operational scale (Figure 2). The following description outlines the silvicultural system used in each Block in order of increasing complexity.

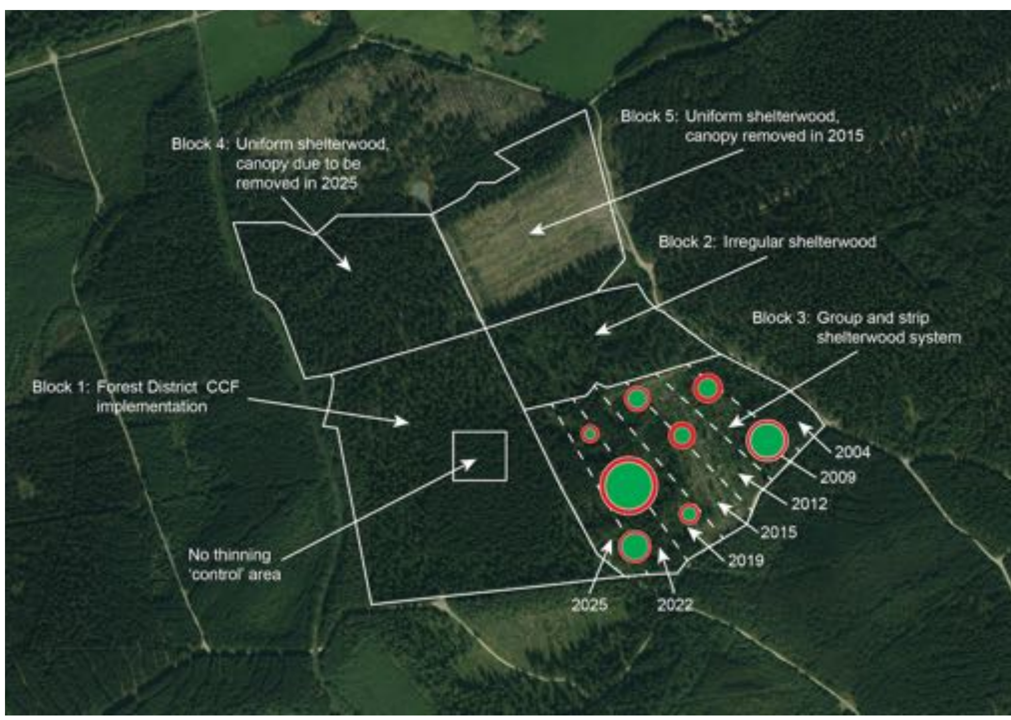

Figure 2. Plan of the Trial Area showing different Blocks and treatments.

Figure 3. Block 5 after the 2012 felling showing the trees in the underplanting experiment in the foreground.

Figure 4. The final felling of Block 5 in September 2015.

Blocks 4 and 5 (8.0 and 5.9ha respectively) have been managed as uniform shelterwoods with the intention that the canopy in Block 5 would be fully removed much sooner than in Block 4. Both areas have been thinned evenly to a low basal area (target 25m^{2}ha^{-1}) to allow recruitment of new seedlings and the growth of existing regeneration. In Block 5, a central area of 3.0ha of natural regeneration was cleared with a flail and an underplanting experiment was established in 2007 to compare the growth and survival of noble fir, Norway spruce, European silver fir, Sitka spruce and Douglas fir (Figure 3). The canopy was removed from Block 5 in 2015 (Figures 4 and 5).

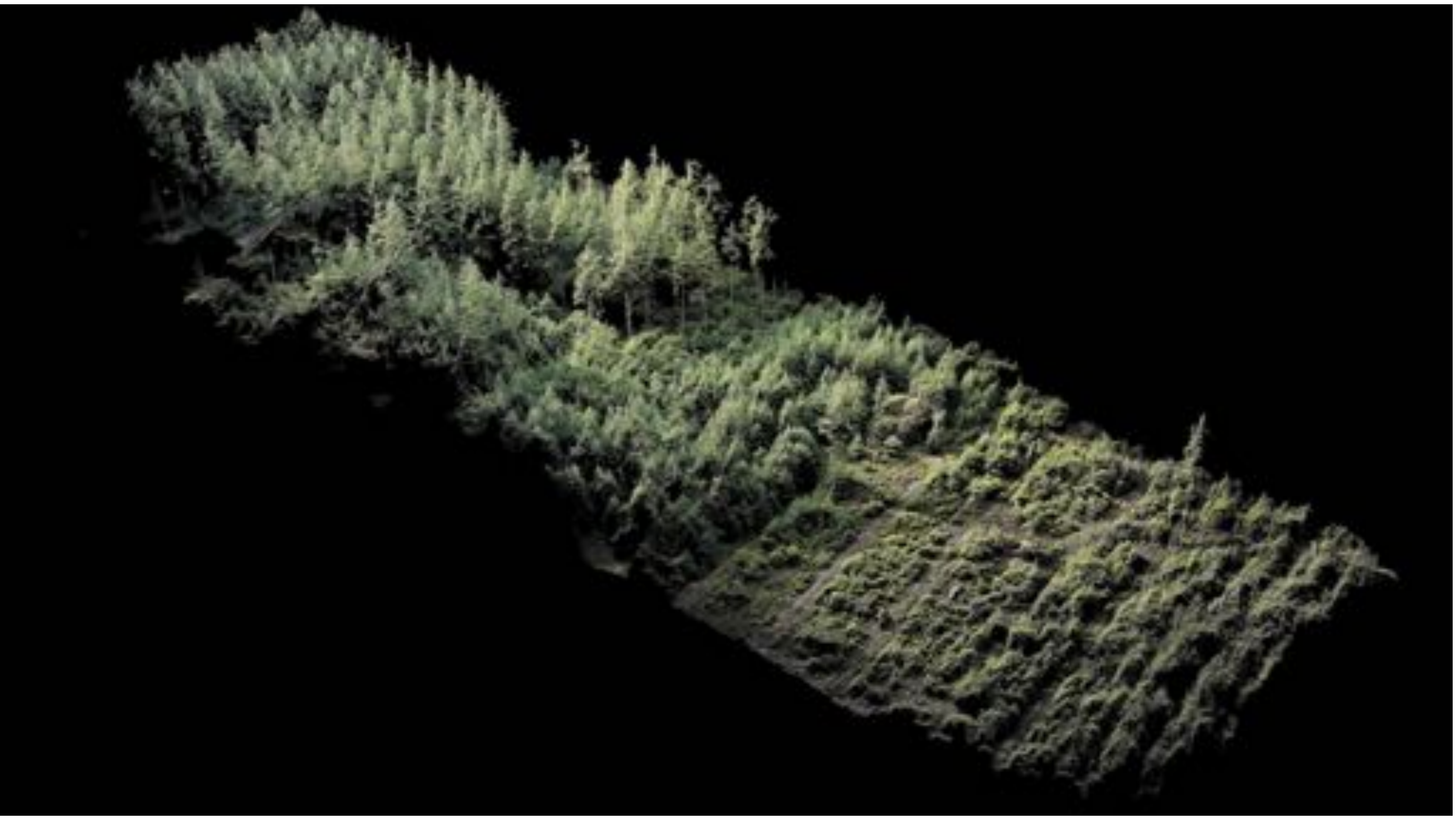

Figure 5. 3-D image captured by drone in 2019 of Block 5 (felled) and transition into Block 2 (irregular shelterwood).

Figure 6. Block 1 in November 2019 showing strong development of the natural regeneration in response to treatment carried out by the Forest District.

Figure 7. Excellent development of natural regeneration of Sitka spruce in the irregular shelterwood in Block 2.

Block 1 (14.1ha) was retained by local staff for them to develop their best practice of transformation of Sitka spruce; in effect, this has been very similar to Blocks 4 and 5 (Figure 6). This Block also contains a scientific control plot (1ha) in which no interventions in the overstorey or understorey have occurred since the trial was established.

Block 2 (4.4ha) has been managed as an irregular shelterwood, with felling varying in intensity to release particularly well-developed areas of regeneration, within an overall basal area target of $25m^2ha^{-1}$ (Figure 7). This Block also contains an experiment in which regeneration was respaced to four different densities (4000, 2500, 1000 and 400 trees ha^{-1} and an untreated control) in December 2006 to examine respacing Sitka spruce under a canopy.

Block 3 (9.7ha) is a combination of a group shelterwood and a strip shelterwood in which both operate over the whole area with no overall target basal area. The group shelterwood initially focussed on pockets of windthrow in which natural regeneration had formed. These have been developed by expanding the canopy gaps at each intervention, mainly to the west to preserve wind-firm edges on the east sides of the gaps (Figure 8). The strip shelterwood consists of a series of 30-40m wide strip fellings running perpendicular to the prevailing wind direction from the south-west (Figure 9). In each intervention, one strip is cleared except for about 10-20 Frame Trees ha^{-1}, which are a seed source and add habitat value.

It's important to note that the Trial Area is examining 'late transformation' to continuous cover because the area was established late in the life of these stands – under a traditional clearfelling regime they would normally have been felled before the trial started. Guidance on transformation generally encourages thinning to start as early as possible (Mason and Kerr, 2004; Kerr, 2008).

The results that are presented in the next section have been compiled from a number of different sources. Each of the Blocks 1-4 has a formal 1ha assessment plot nested within it and these have been regularly assessed. In addition, there have been basal area assessments of the whole Blocks to check the need for/the achieved intensity of felling. The work of Glendinning (2014) was the main source

Figure 8. Block 3 showing a group recently expanded by felling in June 2009.

Figure 9. The strip system; the recently removed strip is where the cut stumps are – the area to be felled in the future is on the right.

Figure 10. A newly stoned access point into the stands in the Trial Area (October 2007).

of information on species composition, density and size of regeneration. These data have been combined with the experiences and data collected by the local forest managers.

Results

Operational working

Fundamental to the success of the Trial Area has been the skill, dedication and communication of the team involved in work planning and implementation. There has been a 'settled team' whose members have worked and learned together since the beginning of the trial in 2001. Before 2015 all the work was carried out by directly supervised staff working for the Forestry Commission/Natural Resources Wales; after 2015 all work has been by contract using a mixture of standing sales and direct production.

From the outset it was understood that access to the stands was crucial. Hence a network of permanent extraction racks, reinforced in some places with stone to prevent ground damage, was established 20-30m apart at the start of the trial (Figure 10). In the early years of the trial most felling was carried out by harvester; as the trees have grown an increasing proportion of them have had to be manually felled. Extraction was generally done by forwarder. Two main problems of operational working to achieve transformation to continuous cover have been identified and solved. Firstly, the difficulties associated with poor harvester head visibility in dense regeneration were expected to be significant. However, with good systems of working and the use of cameras on felling heads, this has not been a major problem and there has been minimal damage to regeneration. Secondly, the lack of brash for use on extraction racks has been compensated for by using stone and the movement of brash/regeneration from outside the working area; for example, clearing roadside regeneration. An outstanding achievement has been the felling of the overstorey in Block 5 without causing damage to the young trees in the underplanting experiment. This has been due to good site organisation (using marked racks, and operational zones for working and stacking), excellent machine operation, and clear on-site management. Despite Block 5 having an experiment within it, it has not been treated very differently to the other uniform shelterwood areas.

Felling

Tree selection has been based on the Frame Tree method (Mason and Kerr, 2004) in which about 70-80 trees ha^{-1} showing good form, vigour and apparent wind stability were identified and competing neighbour trees marked for felling. Other trees of poor quality or health were also removed in order to achieve the target basal area. Trees killed by the great spruce bark beetle were usually left as a deadwood habitat unless there were safety concerns, and trees being attacked were preferentially marked to remove. Frame Trees

Table 1. Summary of fellings and basal area changes (m^2ha^{-1}).

Date of felling	Pre or post fell	Block 1[1]	Block 2	Block 4	Block 5	SS GYC20[2]
June 2004	Pre	30	30	32	31	39
	Post		25	25	25	
May 2009	Pre	44	34	33	31	40
	Post		28	27	26	
July 2012	Pre	51	33	34	29	43
	Post		29	31	24	
June 2015	Pre	54	32	30	27	43
	Post		25	24	0[3]	
August 2019	Pre	59	28	25		43
	Target		29[4]	22[5]		

[1] Figures are for the unthinned plot in Block 1.
[2] Figures from Forest Research M1 model (intermediate thinning) supplied by C. Arcangeli (pers. comm.).
[3] Block was given the planned final felling.
[4] No felling planned in 2019.
[5] Light felling to improve uniformity after some windblow.

Table 2. Summary of regeneration in September 2013.

	Saplings: Density (N ha^{-1}) Large saplings (>3cm DBH)	Saplings: Density (N ha^{-1}) Total	Saplings: Mean height (cm)	Seedlings: Density (N ha^{-1})	Total Density (N ha^{-1})[1]
Block 1	125	11625	208	29500	41125
Block 1 – unthinned	0	14125	216	19625	33750
Block 2	111	4274	206	32226	36500[2]
Block 3 – strip 1	518	5481	306	1112	6593[3]
Block 3 – strip 2	307	2923	217	17846	207693
Block 4	222	3854	197	40699	44820

[1] Generally >97% of regeneration was Sitka; other species recorded included rowan, birch, holly, western hemlock, beech, larch and pine.
[2] The assessment was carried out after saplings and seedlings were removed in respacing.
[3] These assessments were for the strip fellings avoiding the dense cones of regeneration in pre-existing canopy gaps; strip 1 was felled in 2004; strip 2 was felled in 2009.

have been marked with white paint bands. A similar approach to felling was used in Block 2 but here a lower density of Frame Trees (40 trees ha^{-1}) was marked. In the assessment plots (1ha plots in Blocks 1-4), trees to be removed were marked with paint spots by staff; outside the plots, trees to be removed were selected by the harvester operator following the same selection criteria.

There have been five felling operations in the Trial Area since 2002 (Table 1) and the target for the residual basal area has been 25m^{2}ha^{-1} (based on Table 7.2 in Kerr (2008)) in Blocks 2, 4 and 5 (Block 1 has had similar treatment). In order to try to reduce and then maintain basal area to such a relatively low level an attempt was made to use a three-year thinning cycle. However, because of operational constraints this has not always been possible and hence generally basal areas have been higher than the 25m^{2}ha^{-1} target. Block 3 has not had a target basal area because the treatment has involved such different elements that an overall basal area target was deemed to be unhelpful.

> "Fundamental to the success of the Trial Area has been the skill, dedication and communication of the team involved in work planning and implementation."

Regeneration

The assessment carried out in September 2013 showed that the density of regeneration varied between 6,593ha^{-1} and 44,820ha^{-1} and was >97% Sitka spruce (Table 2). It is worth noting that even the lowest density of regeneration is much higher than the 2,500ha^{-1} typically used in restocking. The highest density of regeneration was in Blocks 1 and 4 which had >40Kha^{-1} following three fellings in 2004, 2009 and 2012. In Block 1, 28% of the regeneration was saplings (i.e. >1.3m height) but in Block 4 it was much less advanced (only 9% >1.3m height). There was a lower density in Block 2 but this is mainly attributable to the fact that some areas have been respaced in an experiment. The parts of Block 3 assessed for regeneration were where there had been fellings in 2004 and 2009. The data clearly show that the density of regeneration was much lower in the older strip created in 2004. However, it had responded to the removal of the canopy and was about 1.0m taller than regeneration that was assessed in other parts of the Trial Area. In the other areas of Block 3 there is a high density of regeneration under the canopy gaps, but under the closed canopy there is a low density.

Table 3. Summary of wind damage following gales in 2005 and 2007.

Block	Part of Block/Silvicultural system	No. trees ha^{-1}	Wind damage (No. trees ha^{-1}) 2005	Wind damage (No. trees ha^{-1}) 2007
1	Unthinned	292	0.3	1.0
1	Frame trees removed	265	14.7	12.0
1	Uniform shelterwood	260	0.9	0.7
2	Irregular shelterwood	270	2.3	1.1
3	Strip	60	5.8	0
3	Group shelterwood	530	2.6	0.7
4	Uniform shelterwood	225	1.6	1.1
5	Uniform shelterwood	224	1.5	1.7

Wind damage

Winds in the Trial Area are mainly from the west. The area has been subjected to numerous storms since it was established; for example, it experienced 12 storms between 2014 and 2018. Severe gales crossed the area in January and February 2005 (unusually, from the north) and again in January 2007, both of which caused some windthrow and windsnap. The average number of overthrown and snapped trees amounted to 2.8ha^{-1} in 2005 and 2.3ha^{-1} in 2007 (Table 3). One severe gale in February 2014 caused very minor damage in the Trial Area; however, in the wider forest 40ha were damaged including one area of 7ha.

The most noticeable result from Table 3 is the amount of wind damage in 2005 and 2007 in an area of Block 1 in which the marked frame trees were accidentally removed in the exposed south-west corner of the Trial Area. This was a mistake in the early history of the Trial Area where lack of communication and on-site supervision caused confusion about which trees to remove in a thinning operation. Unfortunately, the removal of the most stable frame trees led to more than ten times the amount of damage here than elsewhere in Block 1. Important lessons about communication were learned from this event but in hindsight and due to the growth rate of the remaining trees it is pleasing to report that the area has recovered and has not been subject to 'creeping windblow' after the initial loss. The resilience of the Trial Area to wind damage has been a significant learning point in its history.

“Results from the Trial Area provide clear evidence that it is possible to transform Sitka spruce to continuous cover using a range of different silvicultural systems.”

Discussion

The results for each of the Blocks 1 to 5 are discussed here in the context of the original plan for the area, and then some general conclusions are presented concerning results from the Trial Area and their relevance to forestry policy and practice in Britain.

Block 1

The original intention for this Block was for it to be an area where local staff developed their best practice of transformation of Sitka spruce. However, with time the system applied has become quite similar to the uniform shelterwood used in Block 4. There is a good reason for this: the uniform shelterwood system is straightforward to apply assuming the area regenerates naturally and remains windfirm for the duration of the transformation. Following the felling in 2019 the plan is for one more felling to a basal area of 15-20m^{2}ha^{-1} in 2022 and a final intervention in 2025 which will leave 10-20 trees ha^{-1} to act as a seed source and add landscape and habitat value.

Block 2

The original intention was to aim for an irregular shelterwood, a process that arguably needs far longer than 20 years. The idea of an irregular shelterwood (Troup, 1928) is to remove the overstorey in an uneven manner over an extended period (compared with a uniform shelterwood) to produce a much more diverse structure in the understorey. However, this is not really apparent and in hindsight it was possibly a mistake to try to use the same basal area threshold in Block 2 as in Blocks 4 and 5. Although felling has been targeted to release selected areas of regeneration, the result has been that the regeneration has developed well over the whole area. To achieve an irregular and more gradual removal of the canopy it would have been better to not have adopted a basal area target, which has had the effect of producing a more regular understorey. However, in terms of a simple method of transforming Sitka spruce to continuous cover, rather than specifically an irregular shelterwood, the Block has been a success.

Block 3

When first described to the local forest managers the combination of the group and strip shelterwood system seemed to be confusing and possibly over-complicated. However, the experience of application has been quite different; both the 'strip' and 'group' elements of the system have worked and they have also worked together. The strip system has been applied in the classic manner described by Troup (1928) with strips being taken from the forest on the leeward side of the prevailing wind leaving scattered frame trees. The group shelterwood has also been successful in terms of the expansion of the groups to encourage more regeneration and release the original replacement trees in the middle of the group. The great success of the system has been the stability of the trees on the side of the group most exposed to wind, where any felling was done very carefully, with most of the group expansion focussed on other parts of the group. The one questionable element of the system applied has been the decision to not fell trees in the matrix between the groups until the trees are felled in the strip system; in hindsight it would have been better to fell trees in these areas to develop regeneration in advance of the strip being removed. The plan is to remove the last two strips in 2022 and 2025.

Blocks 4 and 5
Both of these areas have been a great success. In 2015 the canopy of Block 5 was removed and the combination of the underplanted trees (in the experiment) and natural regeneration of Sitka spruce has the potential to form a new stand. The removal of the overstorey did cause problems, such as instability observed alongside declining health, for some of the trees in the underplanting experiment, mainly Norway spruce and Douglas fir. This was examined by Trimble (2019) and attributed to below ground factors probably caused by poor planting. What is perhaps more remarkable was that the carefully underplanted trees survived three separate fellings before the canopy was removed, highlighting the skill and care of the operators involved with the Trial Area. The plan for Block 4 is to remove most of the canopy within 10 years.

Conclusions

1. Results from the Trial Area provide clear evidence that it is possible to transform Sitka spruce to continuous cover using a range of different silvicultural systems.

2. The uniform shelterwood system is a straightforward method of transforming Sitka spruce and local staff quickly adopted this approach because it is so pragmatic. Ideally, transformation should start much earlier than in the Trial Area. Late transformation of Sitka spruce is possible but only where stands will remain windfirm.

3. The Trial Area has provided useful experience of applying the irregular shelterwood, group shelterwood and strip shelterwood to Sitka spruce in the uplands of Britain. In particular, the strip shelterwood (part of Block 3) has many positive attributes and further work to produce guidance on this system in Britain is required.

4. Guidance available to forest managers in Mason and Kerr (2004) and Kerr (2008) incorporates many of the lessons from the Clocaenog Trial Area and no major changes or updates are required.

5. Experience from the underplanting experiment informed the guidance in Kerr and Haufe (2016) and results have been published in Stokes et al. (in press). Further work will focus on the respacing experiment, which is the only trial we know of on respacing of Sitka spruce under a canopy.

6. The work at Clocaenog has been the result of active engagement of staff in Natural Resources Wales, Bangor University and Forest Research to achieve a common aim: to challenge traditional even-aged management of Sitka spruce on an upland site. The experience from the Trial Area has altered the way in which some 2,000ha of Clocaenog forest has been managed and quite possibly several thousand hectares elsewhere, as a result of the training events that Jens Haufe has delivered at the site.

Acknowledgements

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Dr Gary Kerr is the Principal Silviculturist in Forest Research based at Alice Holt Lodge near Farnham in Surrey. Gary also holds two significant posts that supplement his research activities: he is Editor-in-Chief of *Forestry: An international Journal of forest research*, published by Oxford University Press, and he is vice-Chair of the Scientific Advisory Board of the European Forest Institute.

David Williams was a forest manager with Natural Resources Wales until his retirement in March 2020. He was responsible the management and operational delivery in the Trial Area at Clocaenog Forest. His pioneering work on the application of continuous cover to the forests of northeast Wales was an outstanding professional contribution to forestry practice in Britain.

Dr Jens Haufe leads the Technical Development Branch of Forest Research, based at Ae Village near Dumfries. His main work areas include the provision of technical training, research and consultancy services, especially on silviculture, forest mensuration, and forest growth and yield.

James Walmsley is Senior Lecturer in Forestry at Bangor University and course director for various degree programmes. James's teaching and research interests span forest management, silviculture, forestry education, forest bioenergy and forest history. James is a committee member of the North Wales Division of the RFS and is also trustee of the charity Woodland Heritage.