Stem straightness in Sitka spruce

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The successful large-scale establishment of Sitka spruce has lead to this species becoming the predominant source of timber in many parts of the UK. The pace of establishment increased in the 1960–70s, bringing with it the need to plant on more demanding sites; at the same time wider initial spacings were being used, more fertiliser was needed for establishment and, latterly, a greater proportion of sites managed under a non-thin regime. As these sites come to be felled increased concern has been voiced by the sawmilling industry that the quality of timber coming onto the market has been declining and that this trend is set to continue for the next 10 years. Given this concern and the opportunities afforded by restocking to alter basic silviculture, growers need to become more aware of the potential to improve timber quality through silvicultural management.

Inspecting dried spruce timber at a sawmill in Aboyne, Scotland

Using a medical CT scanner to measure the density of Sitka spruce discs

Logs from experiment on timber quality of wind blown spruce at a sawmill in Carrbridge, Scotland

Introduction

The objective for improvement of quality is to increase the amount of construction grade material available from the forest since this is a market with potential to grow, and within which market penetration by UK timber is still relatively weak. The market for lower quality timber, used in fencing and pallets, is currently close to saturation and unlikely to expand sufficiently to absorb the predicted increase in volume becoming available (McIntosh, 1997). The main criteria for construction grade timber are that it should be straight, strong and competitive economically. These three broad criteria are a function of a myriad of other factors ranging from the cellular structure of the wood to management decisions such as rotation length, most of which can be altered either by silviculture or genetic manipulation (Macdonald and Hubert, 2002). However, for a stand that is about to be felled there is little opportunity to alter the state of the crop and the assessment of quality commonly undertaken is subjective. For Sitka spruce this is essentially an estimate of the proportion of straight stems in the crop since branch size, and hence knots in the timber, is rarely a problem (Forestry Commission, 1993).

Methley (1998) initially developed an objective method of assessing stem straightness in Sitka spruce based on visually estimating the number and length of sawlogs that could be cut in the first 6 m of the tree. The definition of sawlog used was based on the green log classification; namely that bends must be less than 1 cm deviation in a metre length (Forestry Commission, 1993). The minimum log length was 2 m and the maximum was 4 m. Her initial work demonstrated that consistent results could be obtained from different assessors and that assessments undertaken in the field provided a reasonable method of predicting relative out-turns from stands once processed at a sawmill. Macdonald *et al.* (2001) further developed the methodology, adding another log class, 5 m, and undertook a number of trials to establish a fast, consistent method of assessment that could be used for surveying a large number of sites.

Survey methodology

Three surveys of stem straightness in Sitka spruce have been undertaken using the assessment protocol developed by Macdonald *et al.* (2001). The first surveyed South Scotland, Dumfries and Galloway, and the Borders; the second covered Kielder Forest District, Argyll, Grampian and Highlands regions, and the third covered Wales (Stirling *et al.*, 2000; Mochan *et al.*, 2001; Mochan *et al.*, 2002); see Figures 1 and 2. In all the surveys site selection was undertaken randomly after stratification by planting year, yield class, thinned or not and, where available, initial stocking. The area surveyed in each stratum was balanced so that the survey as a whole assessed a similar percentage of the total cover of Sitka spruce regardless of age or ownership types (e.g. FC or private). The stratification criteria are listed in Table 1. For all the surveys, sites were selected to allow replication within each stratum to facilitate statistical modelling of the data. In some instances certain combinations of planting year, yield class and thinning history could not be found.

Figure 1

Survey sites in Scotland and northern England. The first survey covered Dumfries and Galloway and the Borders, and the second the other regions.

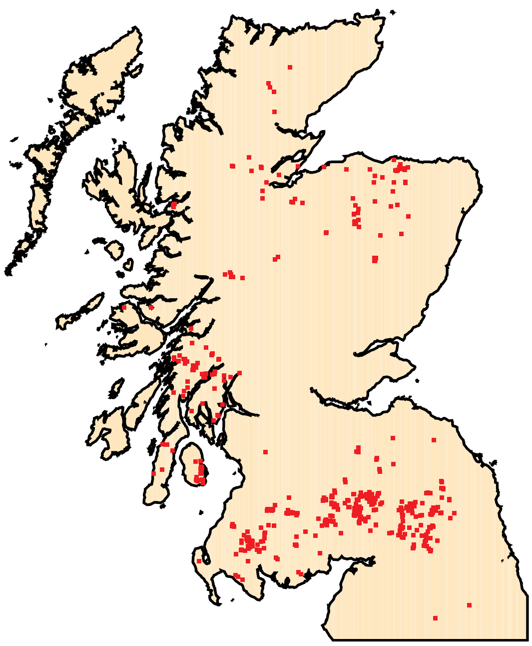
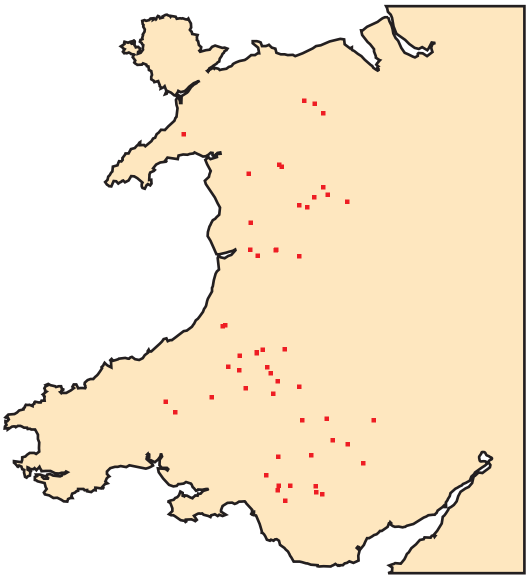


Figure 2

Sites for the third survey in Wales.



At each stand stem straightness was assessed using randomly located 3 m wide linear transects following random bearings. Each linear plot consisted of the first 10 trees encountered with diameters greater than a set minimum. The minimum diameters were based on assumptions of growth for an average stand of YC 14 such that at felling age (estimated to be 55 years) the trees assessed would all be of sufficient size to yield a 6 m sawlog. Each site contained 8 or 10 plots depending on its area. In addition to assessing stem straightness the sites were measured for dbh, forking, top height, between and within row spacing plus slope for correction, and thinning history. Additional information on elevation and DAMS (windiness) was obtained using the grid reference. In order to provide consistent scoring across the survey the number of assessors was kept to a minimum and a sub-sample of sites was reassessed by the person who had originally trained all the assessors.

Results and discussion

The scale of the surveys can be judged from Table 2. The South Scotland survey was the most intensive and replication was higher than in the subsequent two surveys in order to provide sufficient data for modelling. The Rest of Scotland survey data were used to validate the model developed in South Scotland, but it was found that regional differences were too great and hence different regional models needed to be developed.

Table 1

Survey stratification criteria.

Survey	Location	Stratification criteria
South Scotland	Dumfries and Galloway; Borders	Pyear: Pre-1961, 1961–70, 1971–75 YC: >6≤12, 14–16, ≥18 Thinning: thinned, non-thin Initial spacing: ≤1.7 m, 1.8–2.0 m, ≥2.1 m
Rest of Scotland	Argyll, Grampian, Highland and NE England	Pyear: Pre-1961, 1961–70, 1971–75 YC: >6≤12, 14–16, ≥18 Thinning: thinned, non-thin
Wales	All regions of Wales	Pyear: Pre-1961, 1961–70, 1971–75 YC: >6≤12, 14–16, ≥18 Thinning: thinned, non-thin

Table 2

The number of sites, trees and the percentage of Sitka spruce surveyed in each survey of stem straightness.

Survey	Number of sites	Number of trees	Area of Sitka surveyed (ha)	% area of Sitka cover assessed
South Scotland	257	23 100	FC: 1,618 Private: 1,160	FC: 3.9 Private: 2.5
Rest of Scotland Argyll, Highlands NE England and Grampian	212	18 319	FC: 1,897 Private: 915	FC: 1.9 Private: 1.9
Wales	54	4 490	FC: 614 Private: 279	FC: 1.9 Private: 1.8

Planting year and diameter

In all the surveys planting year was the factor most strongly associated with stem straightness. In all cases the more recent planting years were linked to poorer form trees. When looked at in terms of dbh, smaller trees tended to have poorer form than larger diameter trees. Interestingly, this could be observed both between stands and within a stand. This apparent connection between dbh and stem straightness in Sitka spruce suggests two possible mechanisms. Either that leader loss was the cause of bending in Sitka, having lost a leader the tree was less able to compete with its straighter neighbours, or that as trees become suppressed they tend to bend towards gaps in the canopy. Once competition had started in the stand the shorter, bent trees would become suppressed and hence lead to the observation. Since the survey was assessing trees of a minimum diameter size the suppression of poorer form trees would provide a strong link between form and planting year, with the older stands having experienced a longer period of within-stand suppression and mortality. This raises the possibility that stands might improve with age but as yet this hypothesis has not been tested.

Thinning

For all the surveys thinning had a positive effect on the overall stem straightness of a stand. This is as expected since some of the thinning was selective in nature. Interestingly, when modelled with all the other factors there was a negative interaction with DAMS, i.e. exposure (Quine and White, 1993), for the rest of Scotland survey. This suggests that on more exposed sites thinning can reduce stem straightness, possibly by increasing the exposure each individual tree experiences and increasing the overall risk of leader loss.

Yield class

The association between yield class and stem straightness is not clear except in Wales where there is a positive correlation between increasing yield class and better stem form. The fact that this is not the case further north, and indeed in some areas the reverse is true, suggests that other environmental factors are dominant. For instance it is possible that the more severe wind climate or earlier autumn frosts are causing greater damage to the faster growing leaders of higher yield class stands in Scotland than in Wales, where the trees are growing in a generally more favourable environment.

Initial spacing

Again the association between initial spacing and stem straightness is not clear-cut. In general, for Scotland and northern England, where there is a clear trend, it appears that higher initial stocking densities provide straighter trees. However, this is not uniformly the case, for instance in Argyll it appears that higher stocking densities are associated with poorer form. In Wales there is no statistically significant relationship between initial stocking density and form. Where stocking does contribute towards a model it is always a very minor contributor to the overall prediction of mean stem straightness for a site.

Wind exposure and altitude

Wind exposure and altitude are significant factors for the two surveys conducted in Scotland and Northern England but not for the survey in Wales. In all the cases where they were significant factors, an increase in wind exposure or altitude was associated with a decrease in stem form. The most likely explanation for this observation is that increased exposure, especially to summer gales when new growth is less lignified, will lead to greater leader damage or loss resulting in the promotion of a branch to a leader. This will cause a permanent kink in the stem. The effect of a summer gale on a fast growing plantation of Sitka spruce was reported by Baldwin (1993) who examined the levels of leader loss at a fertiliser experiment. He found significantly greater damage in the fertilised plots than the non-fertilised control plots, indicating one of the controlling factors for stem straightness and also the potential drawback of a high yield class site in an exposed location.

Forecasting quality in Sitka spruce

At present the Forestry Commission provides long-term production forecasts, which allow users to estimate the volumes (broken down by species and size categories) of timber coming on to the market over the next 20 years; see for example, Rothnie and Selmes (1996). One drawback of the current forecasts is that they cannot predict the quality of the timber that will be produced. This is particularly important for sawlog size timber since this is the largest fraction produced and also the most valuable. Providing an estimate of both the volume and the quality of the timber coming onto the market, and hence an estimate of the value, will assist the industry when making long-term investment decisions.

The stem straightness surveys produced a variety of statistical models that allow the mean straightness score of a stand to be predicted from factors such as planting year, yield class, thinning

Figure 3

Relationship between estimated % green log volume per plot and plot mean standing straightness score from work at four different sites: Wauchope, Rosarie, Clatteringshaws and Tywi.

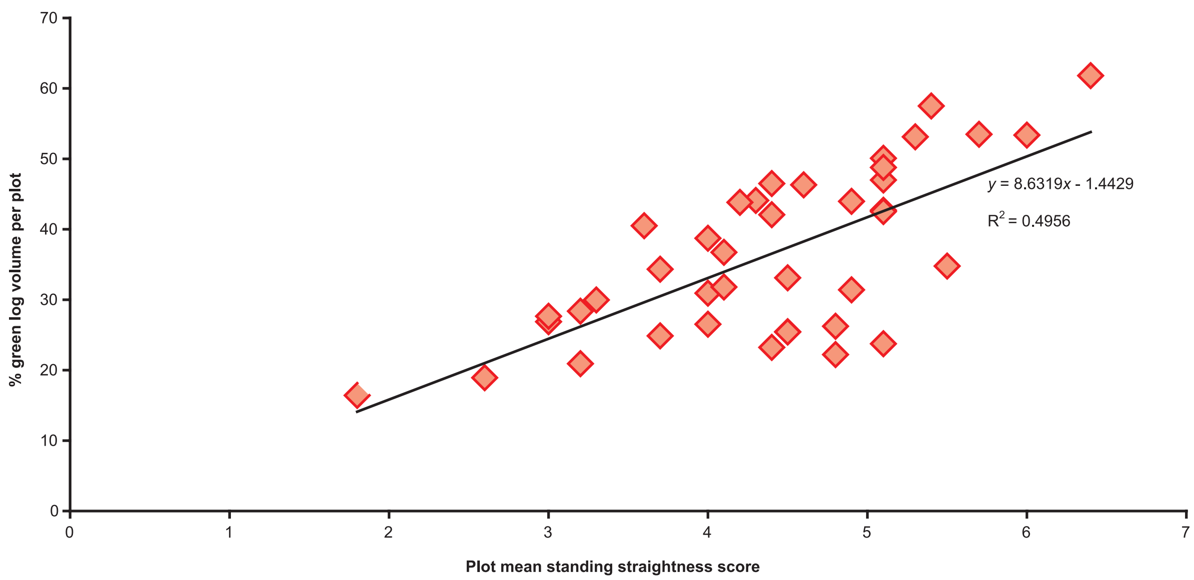


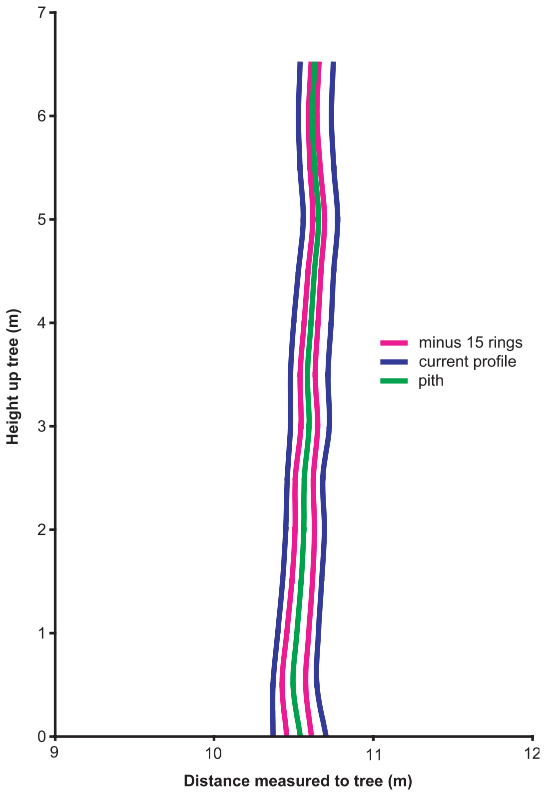
Figure 4

Using a laser relascope to create an accurate external profile of the tree on two sides (north and west).

history, stocking density and wind exposure (DAMS score). Since the mean straightness score of a stand is based on the assessment of green logs in the first 6 m of the tree, it should be linked to the proportion of green log volume in the stand. Work undertaken at four sites of different quality and located in different parts of the country has shown that this is the case (Figure 3). Hence it should now be possible, within the limits of the accuracy of the statistical models, to estimate the proportion of green logs as part of the total volume for any stands of Sitka spruce planted prior to 1975. However, one limitation of the models is that they provide an analysis of the situation at the time of the survey. Hence using them to predict stem straightness in the future requires the assumption that the trees themselves do not alter form over the period of the forecast and that the quality of the stand as a whole does not alter due to stand dynamics.

Figure 5

Recreating the shape of the trunk at half-metre intervals up the stem.



In order to test the first assumption, that the individual trees do not alter shape sufficiently to change their straightness score over 10–15 years, a pilot study was carried out (Macdonald and Barrette, 2001). This study examined 10 trees of differing straightness score in a stand using a laser relascope to create an accurate external profile of the tree on two sides (north and west; Figure 4). The trees were then felled and disks taken at 0.5 m intervals up the trunk to coincide with the laser measurement points.

Accurate measurement of ring widths from pith to bark along the two perpendicular radii (north and west) made it possible to recreate the shape of the trunk at 5 yearly intervals in the past (Figure 5). Analyses of these profiles showed that in all but one case the trees did not straighten sufficiently to alter the straightness score over 15 years of growth and the single tree that did improve did so by only one score. This suggested that on an individual tree scale it was possible to predict stem quality 15–20 years in the future.

The second assumption, that stands will not alter their mean straightness score over the forecast period, is still undergoing testing. The fact that there is a pronounced association between planting year and stem straightness and a similar link both between and within stands for dbh indicates that suppression and mortality is more common for trees of poorer form. Since poor form in Sitka spruce is likely to be due to leader loss and hence a loss of a season's growth there exists a plausible mechanism to explain the observation. Currently research is ongoing to explore the rate at which this occurs and hence the time-scale over which a forecast would be valid.

Conclusions

For all the surveys, the main observation is a very strong link between planting year and stem straightness, with the more recent planting years showing poorer straightness. The survey provides a snapshot of the situation at present but this is unlikely to alter greatly over the next 5 years. Hence, as a greater number of these more recent plantings are harvested, the general trend in log out-turn will be to see an increase in the proportion of red logs and short green logs in the total production volume. One of the challenges for the forest industry will be to market short green logs. However, as the total volume is currently predicted to increase until 2020 the actual volume of green logs is also likely to increase in this period.

Managers should aim to extend rotations and thin where possible, although the wind climate in some regions will place obvious limits to these options. Another factor to consider when restocking is to design felling and restocking coupes to maximise shelter in the restock sites using existing crops. This, and striving to attain full stocking for mutual shelter, should reduce the extent of wind damage to the leaders and therefore reduce the level of stem defects.

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