Towards a timber quality model for British grown Sitka spruce

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INTRODUCTION

Sitka spruce (P*icea sitchensis* (Bong.) Carr.) is the main commercial tree species in Great Britain providing over half of the total volume of timber produced. The mild wet oceanic climate of western Britain leads to extremely rapid growth, producing large growth rings and relatively low density wood. It became necessary to test British grown Sitka spruce's suitability for construction timber by introducing machine stress grading because traditional grading systems, which use ring width as a strength criteria were found to be unsuitable.

The huge expansion of forestry in Britain during to 1950s to 1970s is leading to an increasing volume of timber coming onto the market. With many timber markets saturated it is becoming necessary to target the higher value construction timber market to absorb this additional timber. At the same time tree breeding programmes have led to the selection of progeny with increased vigour while at the same time producing changes in wood density and branching properties.

Furthermore, there are large changes in silvicultural practice taking place in Great Britain at the present. In particular there is increasing pressure to move away from the traditional clearcut/replant systems to more "nature-like" systems such as continuous cover forestry and to increase the amount of thinning practised in order to meet UKWAS guidelines for sustainable forestry. This will lead to more mixed age and mixed species stands with larger variation in tree size and inter-tree spacing than the traditional even-aged monocultures.

In order to inform the forest and wood processing industries about the likely quality and potential usability of Sitka spruce timber coming onto the market it was decided that it was necessary to develop a timber quality model. It was planned that this would provide a link between existing spruce growth models developed in Forest Research and batten performance models predicting distortion and strength developed by the Building Research Establishment. The approach taken has been to follow the methodology pioneered by INRA, Nancy for predicting the timber quality of French grown Norway spruce (*Picea abies* Karst) (Leban et al., 1998; Saint-André et al., 1998).

MATERIALS AND METHODS

The amount of existing information on the distribution of wood density, knots and grain angle within British grown Sitka spruce stems, which is necessary for developing a timber quality model, was extremely sparse. Some pioneering work had been carried out by Brazier (1967, 1970a and 1970b) and more recently at Bangor University by Simpson and Denne (1997), Mitchell and Denne (1997) and Tranquart (1995). Therefore, a wide-ranging field programme has been instigated in order to obtain the necessary information. Table 1 provides details of the sites chosen, the age of the trees selected, the measurements taken and the position on the trees of the measurements. Trees ranged in age from 13 to 65 years old and a total of 231 trees have been sampled. A range of initial planting spacings were sampled from 0.9 to 5.0 m. All trees were of Queen Charlotte Island provenance, the normal provenance of Sitka spruce grown in Britain.

Wood Density

There were differences in the method by which data were obtained in the Clocaenog experiment (Simpson and Denne, 1997) compared with the other experimental sites. At Clocaenog 5 co-dominant trees were selected in each of three spacings (1.4, 1.8 and 2.4 m) and discs cut from the centre of every 4^{th} internode. Density was measured on a strip cut from the NW-SE direction for every ring from the pith to the 20^{th} and then every 4^{th} ring out to the bark. The density was measured using the maximum moisture content method.

Table 1: Details of Experimental Sites

Experiment	Tree Age	Measurement	Tree Spacing (m)	No. of Trees	Location of measurements
Kershope 34	32	Density and ring width	1.8, 2.4, 3.5, 5.0	9 at each spacing	0, 1.3, 3, 4.5, 6, 7.5, 9 m etc. up stem
		Grain angle	1.8, 2.4, 3.5, 5.0	9 at each spacing	0, 1.3, 3, 6, 9 m etc. up stem
		Branching	1.8, 2.4	6 at each spacing	Every whorl but in detail only on alternate whorls
Kershope 50	13	Density	2	48	0, 1.3, 3, 4.5, 6 m up stem
		Grain angle	2	48	0, 1.3, 3, 4.5, 6 m up stem
		Branching	2	6	Every whorl but in detail on alternate whorls
Glengarry 5	65	Density	0.9, 1.4, 1.8, 2.4	9 at each spacing	0, 1.3, 3, 4.5, 6, 7.5, 9 etc. up stem
		Grain angle	0.9, 1.4, 1.8, 2.4	9 at each spacing	0, 1.3, 3, 6, 9 etc. up stem
		Wood strength	0.9, 1.4, 1.8, 2.4	9 at each spacing	3 locations up stem
		Branching	1.8, 2.4	6 at each spacing	Every whorl but in detail only on alternate whorls
Clocaenog	52	Density and ring width	1.4, 1.8, 2.4	5 at each spacing	Every 4th whorl
Glentress 67	30	Density	2	12	0, 1.3, 3, 4.5, 6, 7.5, 9 m etc. up stem
		Grain angle	2	12	0, 1.3, 3, 4.5, 6 m up stem
		Branching	2	6	Every whorl but in detail on alternate whorls
		Wood strength	2	12	3 locations up stem
		Growth rate	2	12	0, 1.3, 3, 4.5, 6, 7.5, 9 m etc. up stem
Kielder (Hawkhope Burn)	35	Branching	1.7	6	Every whorl but in detail only on alternate whorls
Kielder (Harecairn Moss)	46	Branching	1.7	6	Every whorl but in detail only on alternate whorls
Kielder(Highfield)	36	Branching	1.7	6	Every whorl but in detail only on alternate whorls
Eddleston	16	Branching	2.0	6	Every whorl but in detail only on alternate whorls
Kilmichael	46	Density	1.6	60	6 positions up stem to minimum diameter of 14.5 cm
		Grain angle	1.6	60	1.3 up stem
		Wood strength	1.6	60	Butt log from base and top log with minimum diameter of 14.5 cm

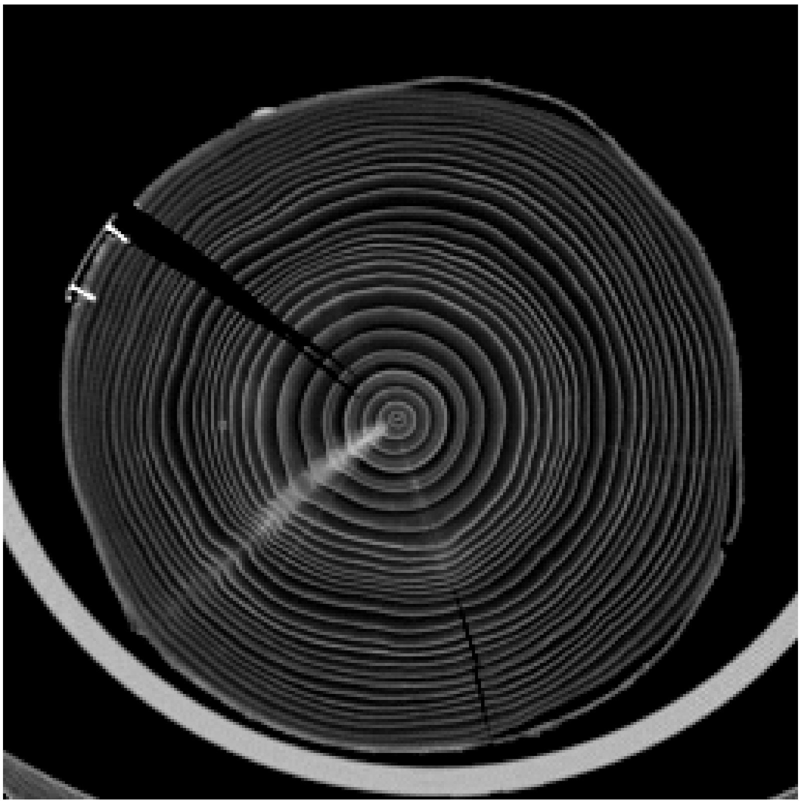

Figure 1: Computer-aided tomograph showing density variation across a Sitka spruce disc

In the other experimental sites (Glengarry, Kershope, Glentress and Kilmichael) the density was measured using computer-aided tomography (see Figure 1) after the discs were air-dried to 12% moisture content. At Glengarry, Kershope and Glentress 2cm thick discs were cut at the tree base, 1.3m, 3.0m and then every 1.5m up the stem avoiding whorls. At Kilmichael 6 discs of similar thickness were cut at the bottom and top of three 3m logs cut from the stem (Brüchert and Gardiner, 2002) down to a minimum diameter of 14.5cm. The standard scanning resolution was 2mm but on at least 2 discs from each tree the disc was scanned at higher resolution in order to identify as many growth rings out from the pith as possible. Density was measured along north-south and east-west transects across the discs ensuring that any areas of abnormal density such as that due to compression wood or knots such as is illustrated in Figure 1 were avoided. At Glengarry and Kershope 2 subdominants, 2 codominants and 2 dominants were selected. At Glentress and Kilmichael the trees were all chosen to have diameters as close as possible to the mean tree diameter.

Grain Angle

Grain angle was measured on trees from Glengarry, Kershope and Glentress. Discs of 5cm thickness were cut just above the discs used for density measurements. The discs were dried to 12% moisture content and then split using a hydraulic ram and blunt blade. The grain angle was measured every 5th ring from the pith on east-west transects as shown in Figure 2. Grain angle was measured on a total of 132 trees.

Branching

The measurement of branching followed the protocol established by Colin and Houllier (1992). At every other growth unit from the top of the tree downwards measurements were made of branch horizontal and vertical diameter, insertion angle, azimuth, position relative to the top of the growth unit, whether a whorl or interwhorl branch and whether dead or alive. In the intervening growth units only the numbers of branches and their status were recorded. In addition the taper of the tree, height of tree, height to first dead branch, height to first live branch, height to first live whorl, the green weight of each whorl of branches and the weight of a 1m section of the stem were measured. The crown competition of neighbouring trees was also determined. To select the trees to be measured at each site the diameter of 100 trees were first measured. From this information 2 subdominants, 2 codominants and 2 dominants were selected. To provide information on the stem form of the trees within the stand the taper of a subsample of 24 of the 100 trees were measured.

Figure 2: Measurement of grain angle

RESULTS

Wood Density

In Figure 3 the variation of wood density for trees at Clocaenog forest are shown as a function of ring number from the pith. In Figure 4 the same information is presented as a function of ring width. The typical characteristics of a type II wood (Panshin, De Zeeuw and Brown, 1964) are shown with the density initially decreasing from the pith and then slowly increasing towards an asymptote. At the same time the wood density is seen to be strongly correlated to the width of the growth rings. In the same figures the predictions of a non-linear model similar to that used by Leban (1995) for Norway spruce are shown. The model was of the form:

$$Density = \alpha_1(1+\alpha_2 \exp(-RN/\alpha_3)) \cdot (1+\alpha_4 RN + \alpha_5 RW)$$

where: RN = Ring Number, RW = Ring Width and

$\alpha_1 = 446.660$, $\alpha_2 = 0.571893$, $\alpha_3 = 5.53971$, $\alpha_4 = 0.00208166$, $\alpha_5 = -0.0544899$

Branching

A total of 60 trees were selected and over 16000 individual branches measured. The size of branches for the 65 year old trees at Glengarry are presented in Figure 5 as a function of their distance from the top of the tree. The live branches are predominately located in the top 25% of the height of the tree showing how elevated the canopies are in these forests. The largest branches are found at the base of the live canopy.

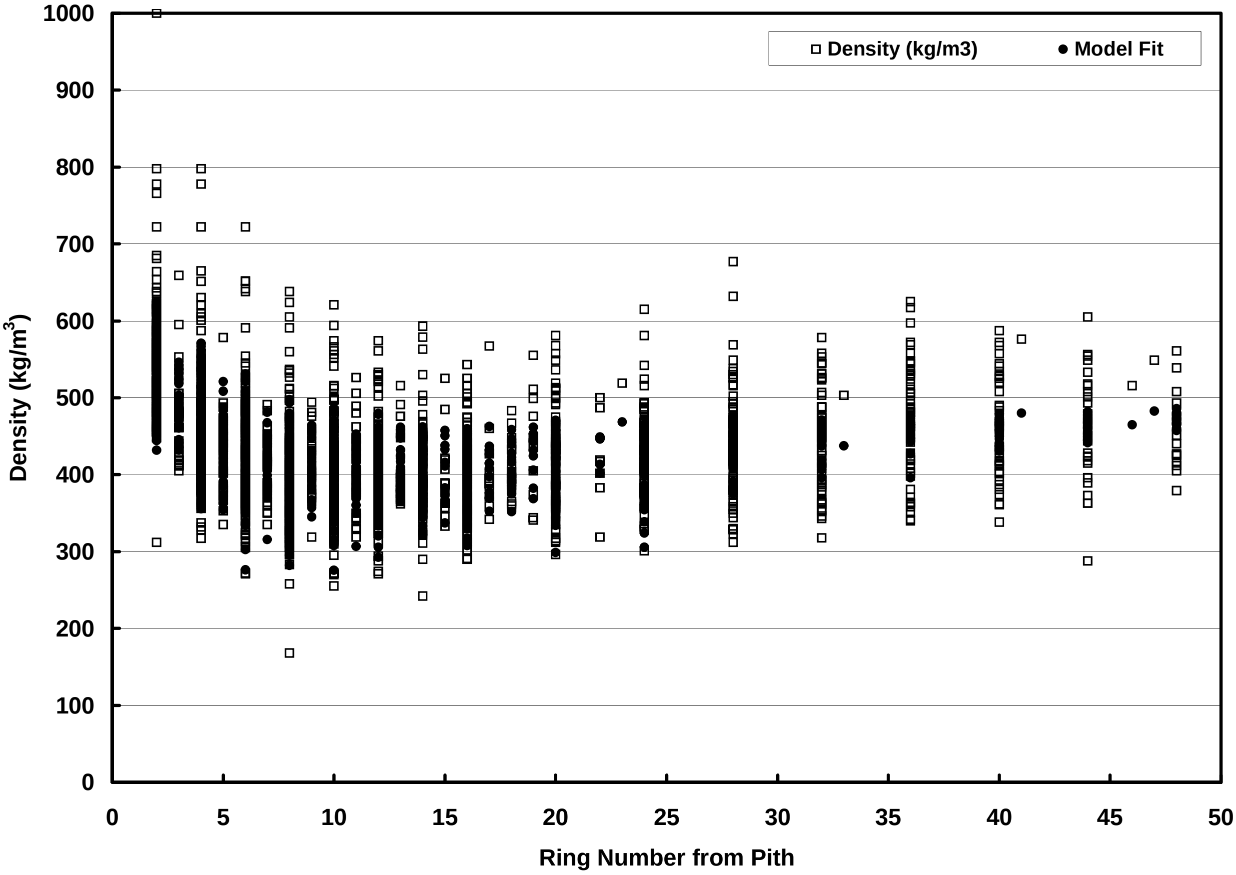

Figure 3: Sitka spruce wood density as function of ring number

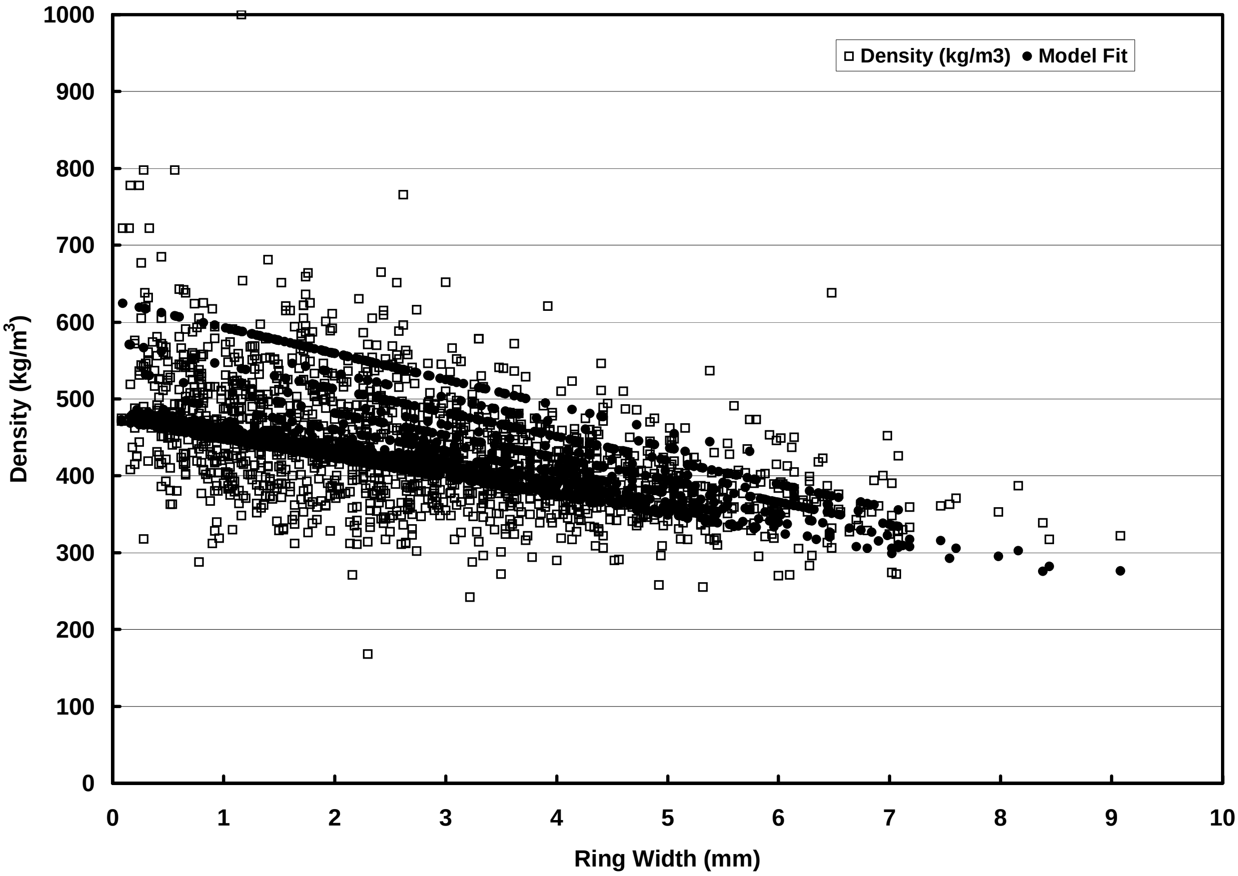

Figure 4: Sitka spruce wood density as a function of ring width

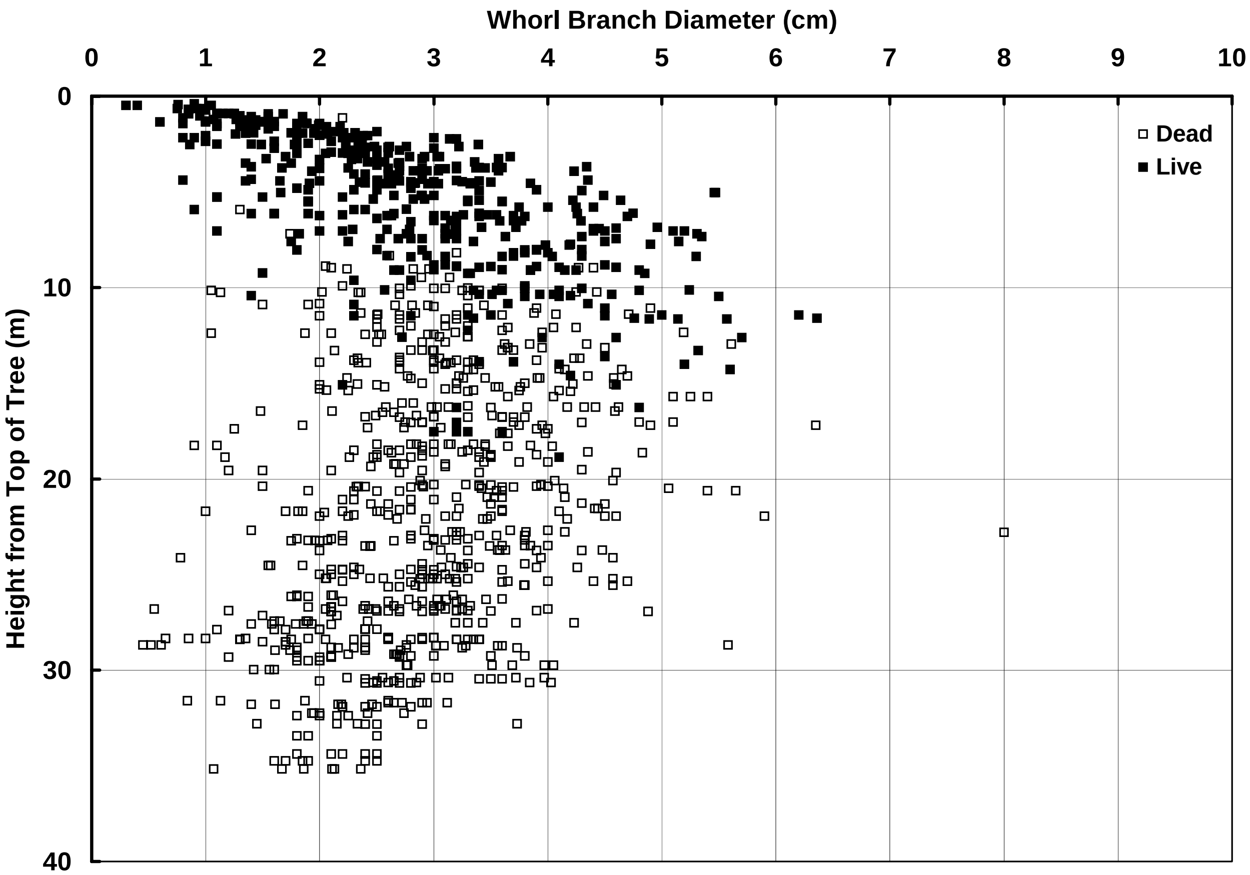

Figure 5: Whorl branch diameter as a function of height on 65 year old trees at Glengarry forest

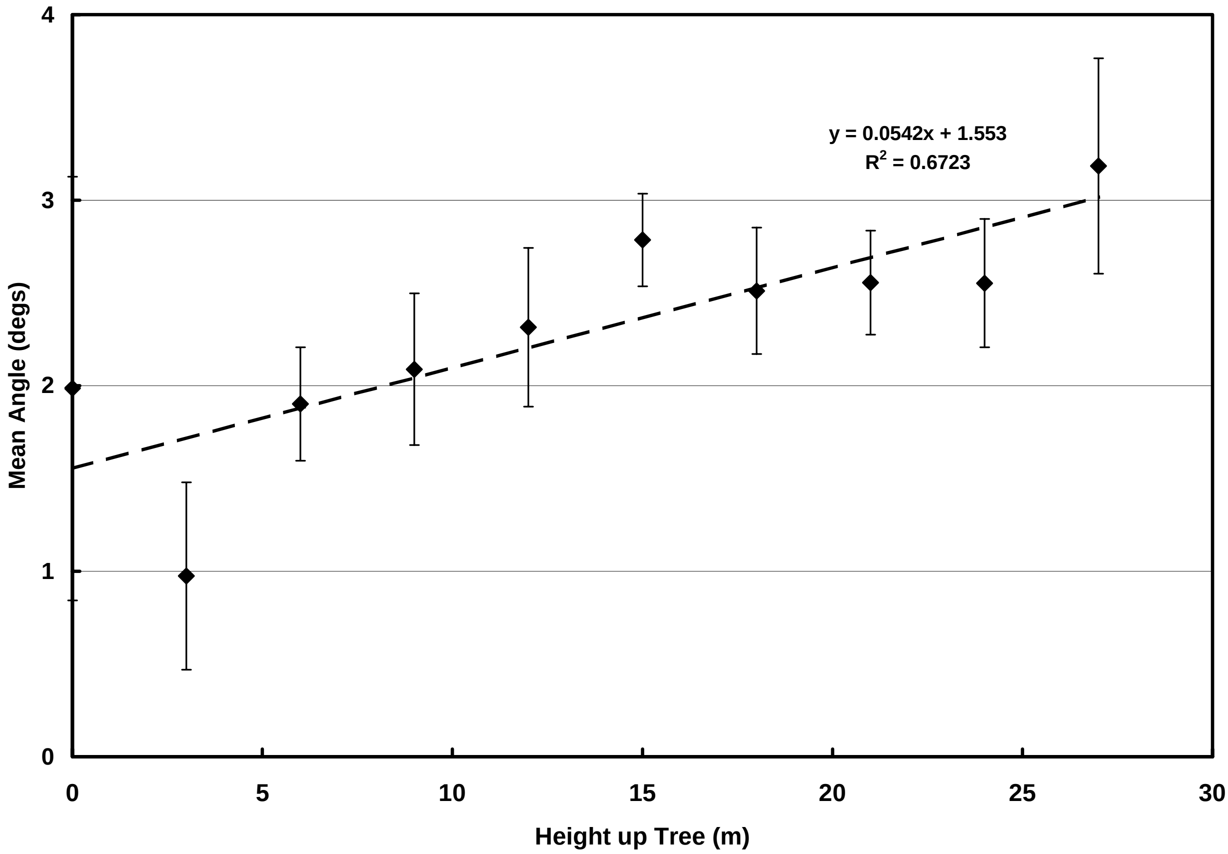

Figure 6: Average grain angle as function of height for trees from Glengarry forest

Grain Angle

The average grain angle across discs from all the trees sampled at Glengarry forest as a function of height up the tree is shown in Figure 6. The increasing grain angle with height is due to the fact that the grain angles in the juvenile core are large but within the mature wood the grain angle tends to straighten and eventually changes direction.

DISCUSSION

A number of large scale field experiments have been completed in 6 forests throughout Scotland, England and Wales to provide the data necessary to construct a timber quality model for Sitka spruce growing in Great Britain. Data on wood density, branching, grain angle and wood strength have been gathered from 231 trees aged 13-65 years old.

Currently the data are being quality assured but some initial data analysis has begun. The results of the modelling of density as a function of ring width and position relative to the pith are similar to those previously found by Leban (1995) for Norway spruce.

The next stages will be to complete the modelling of density and to model spiral grain as a function of position in the tree. Key branch characteristics such as branch diameter, angle and position and the location of live and dead knots within the stem will also be modelled. These model expressions will then be linked to the growth models developed by Matthews and Methley (1998) to provide predictive tools for forest managers, which will enable them to assess the probable timber quality of their standing crop.

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