An investigation of the effects of poor stem form and sawmill recovery on Coastal lodgepole pine

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INTRODUCTION

Coastal lodgepole pine LP(C) grown in the Republic of Ireland is frequently of very poor form. A small scale sawmill study was undertaken in order to answer several questions about the LP(C) material which will be produced over the next ten to fifteen years.

— How bad is the form and what are consequences in terms of sawmill recovery?
— Can sweep at the base be related to recovery?

Results indicated a loss of about 30% of the expected sawn wood return if the trees had been straight. Regression analysis indicated that there is a relationship between sweep at 1.3m and recovery.

An economic analysis revealed that at current prices and costs it is not profitable to sacrifice vigour for slower growing but straighter crops.

INTRODUCTION

In the conditions in which Coastal lodgepole pine (*Pinus contorta* Doug. Loud) is grown in Ireland, the more vigorous South Coastal provenances exhibit poor stem form. The reasons advanced for this are: fast growth rate, nursery practice, site preparation and planting methods used; all of which combine to produce instability, especially in exposed situations.

Will stands of crooked pine produce any sawlog material, assuming they reach suitable dimensions? Existing mature stands of good form are generally of slower growing provenances or were planted on sites not typical of the areas on which the tree is being planted today. As such, they cannot be considered suitable material from which to provide an answer.

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Very little information is available in the literature on the sawnwood recovery of trees exhibiting the degree of crookedness found in this country. In the United States, the lodgepole being harvested is mainly of good form (Benson 1973). Some sawmill studies of recovery from bowed logs (Dobie 1980, McDonald & Sutton 1970) do not relate results to the standing trees. In Britain, where some work has been done on the problem, reports indicate that the trees considered there were of considerably better form than those encountered in many Irish stands of lodgepole planted in the past 40 years (Moss 1971, Harding 1976).

One of the first attempts to quantify the problem in this country was made by Inventory Section of the Forest and Wildlife Service who conducted a survey of the degree of basal sweep in Coastal lodgepole pine planted before 1958. It was not known whether or not the measurement taken actually bore any relationship to the amount of sawable timber present in the tree. It could not be used, therefore, to estimate the potential sawn timber in a stand. The study described in this paper attempts to provide some answers to the following problems:

- Can recovery of sawn timber be related to basal sweep?
- If so, what sort of recovery can be expected from a typical pre- 1958 stand which will reach felling stage in the next decade or so?
- Could the assessment of sweep be improved to give a better estimate of return?
- What are the implications of the sawlog loss in terms of economics?
- Should straighter but slower growing provenances be planted?
- What is the likely effect of the loss on national sawlog production?

These questions are discussed in the light of the results from the actual conversion into sawn boards of sample trees from a stand of crooked South Coastal lodgepole pine.

MATERIAL

Twenty trees were selected from a stand of South Coastal lodgepole pine (LP(C)) in Foxford Forest. Details of the stand are presented in Table 1.

In order to obtain timber which would be representative in terms of size of that existing at the time of clearfelling, only trees with a diameter at 1.3m height (DBH) of 25cms or greater were selected. The trees were chosen at random and had a mean DBH of 28cms. This is approximately the same diameter as would be expected at clearfelling age in a stand of Yield Class (YC) 12, which is about the average YC for LP(C) in the country. The trees were more tapered than YC 12 final crop would be, having a mean height of 16m compared with 21m for the latter. However, there is no suitable material of greater dimensions available yet, as crops of this type are too young. While increased taper reduces absolute sawmill recovery, it does not effect the comparisons made in this study.

Table 1 Foxford Forest Lodgepole Pine

Species:	Lodgepole pine (Coastal)
Provenance:	South Coastal, mixed provenance, origin uncertain
Yield Class:	16. Age: 27
Mean DBH of selected trees:	28cms (Dominant trees)
Silvicultural History:	Pit planted on shallow peat. Unthinned but poorly stocked.

METHODS

As previously mentioned, Inventory Section of the Forest and Wildlife Service have conducted a survey of the degree of basal sweep in Coastal lodgepole pine planted before 1958. A frame (Fig 1) is used to measure the angle, which a line from the base of the tree to the centre of the tree at 1.3m above ground forms with the vertical. On the basis of this angle, the trees are classified as being of type A, B or C (Fig 1). The trees used in this study were grouped in the same way and the proportions falling in each class corresponded almost exactly with the proportions obtained nationally by the inventory survey (Table 2).

After the trees had been selected and assessed for basal sweep they were felled. The tops were cut off at 7cm diameter overbark. Two vertical rods were nailed to each tree as it lay on the ground, one at the base and another at the 7cm point. The rods passed directly over the pith and extended about 1m above the bark at both ends. A string was drawn taut between the tops of the rods. The process is illustrated in Fig 2. The distance from the string to the surface of the tree was measured in two planes at right angles to one another, at various points along the stem. The overbark diameter at these points along the tree was also measured. This allowed a three-dimensional model of the tree to be constructed. Distortions were inevitably caused by the tree pressing against the ground;

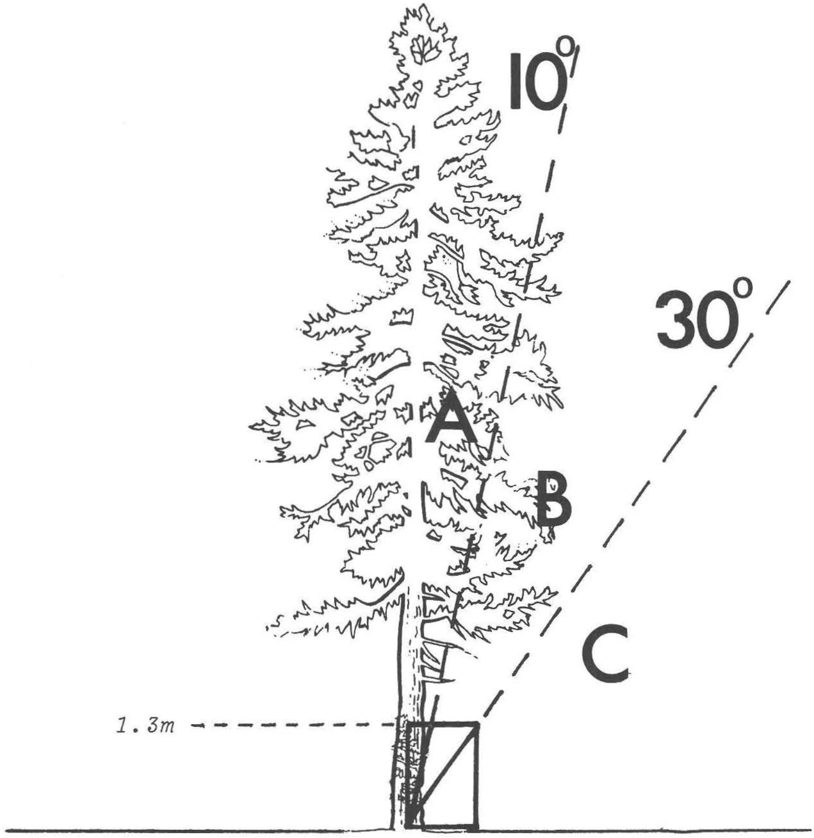

Fig 1 The protractors used by Inventory Section of the FWS for assessing basal sweep. The frame is held with its bottom left hand corner at the base of the tree in the plane of greatest sweep. Depending on where the centre of the stem at 1.3m height cuts the bar of the frame the tree is classified as A (0°-10°), B (10°-30°) or C (»30°).

however, these were not very severe as the area was mainly flat. When felled, the stem tends to align itself with its most bowed axis parallel to the ground so the main distortion occurs in the plane of least crookedness, and is probably slight.

Table 2 %Trees falling into basal sweep categories

	Category		
	A	B	C
Inventory National Survey	59	36	6
Foxford Sample Trees	50	45	5

The twenty trees were divided at random into 2 separate lots of 10 each for sawing. An experienced sawmiller was asked to section the stems in the forest using two different criteria:

Lot 1) To obtain the maximum recovery of sawn wood from each tree to a minimum of 14cm overbark diameter and subject to a minimum length of 1.2m (4 ft).

Lot 2) As above, but with a minimum length of 2.4m (8 ft).

The sections greater than the specified minimum length were then sawn into boards of various cross-sectional dimensions and the total volume recovered in boards to the specified lengths was calculated.

Using the stem profiles of the original trees and making suitable allowances for bark thickness and for loss in the form of sawdust, a theoretical maximum recovery of boards of lengths of 2.4m (8 ft) or greater was computed. This theoretical maximum was taken to be that which would be obtained if the trees were perfectly straight, perfectly circular in cross-section and perfectly sawn to obtain maximum recovery using a cant sawing with slab recovery technique. (This was the sawing method actually used on the test logs). The theoretical maximum was then reduced by 5% to obtain a "practical maximum", that is expected recovery in practice if the trees were straight and sawn correctly (Montague 1971). The actual volume recovered in boards of greater than 2.4m (8 ft) in length was compared with the calculated "theoretical practical maximum", and the difference regarded as the loss due to poor stem form.

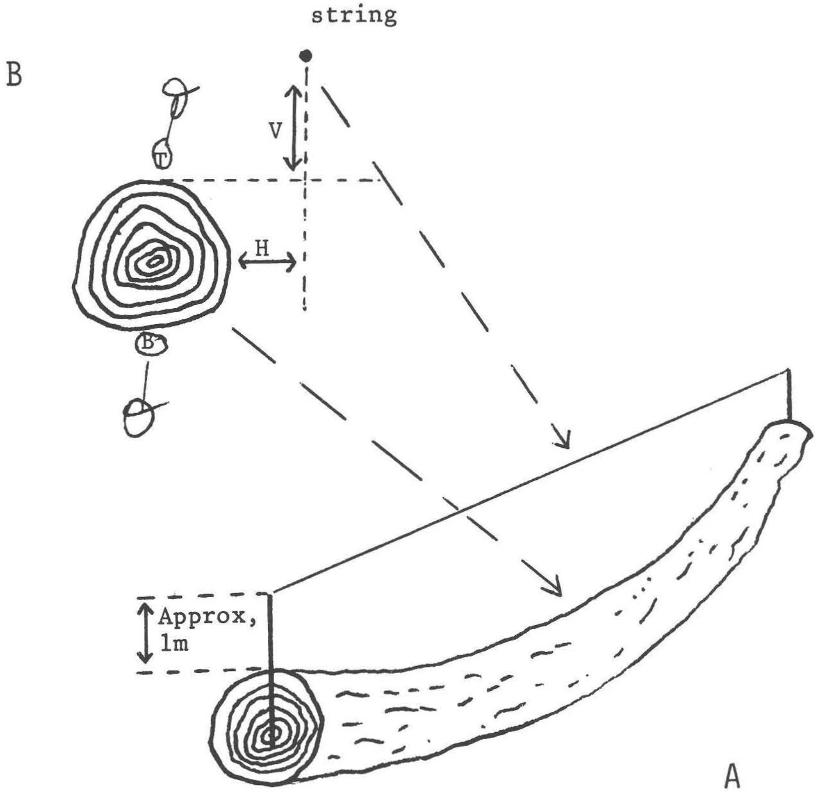

Fig 2 Measurement of tree shape (on ground).

A Rods attached to tree at base and 7cm point.
String drawn taut between the rods.

B Section through log and string near mid-point.
V is the vertical distance from string to level of upper surface of log.
H is the shortest horizontal distance from the string to the log surface.

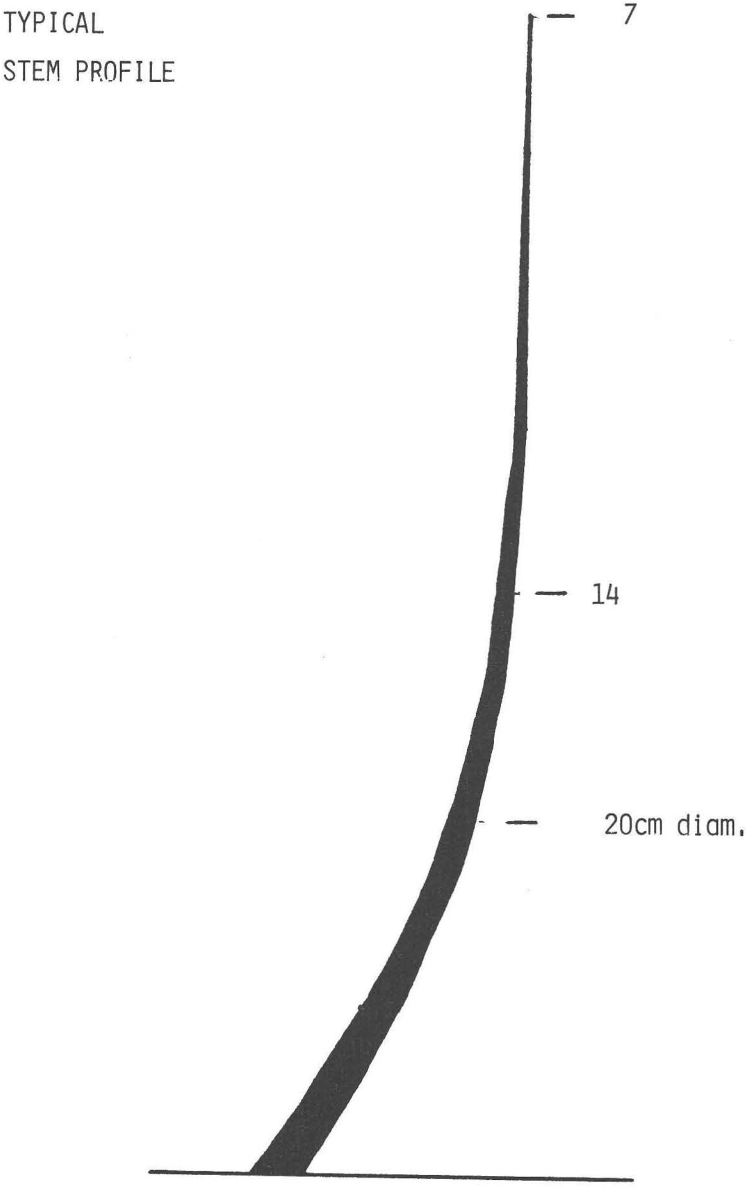

Fig 3 When viewed at right angles to the direction of maximum deviation from the vertical all stems exhibited this basic shape. Severity of the bow varied, but in all cases it continued at least to the 14cms diameter overbark point.

Recovery

The actual volume of sawn timber recovered in lengths of 2.4m (8 ft) or greater from the twenty trees amounted to 72% of the "theoretical practical maximum". That is 72% of the calculated return if the trees had been straight. There was, however, a considerable difference between the result from the trees sectioned to a minimum length of 1.2m (4 ft) and those cut to 2.4m (8 ft), as shown in the recovery figures in Table 3.

Tree Form

The method of assessment of tree shape which was used allowed two profiles of each tree to be drawn at right angles to one another. One of these profiles occurred in the plane of maximum bow of the tree, which in every case was the horizontal plane as the log lay on the ground. The second plane was at right angles to the first. Examination of the profiles revealed that nearly all the trees had the same basic shape, (Fig 3), only the degree of the distortion varied between stems. Unlike trees examined in surveys of basal sweep in Britain (Moss 1971, Harding 1976), the sweep in the Foxford trees was not confined to the lower section of the tree but continued right up to the timber height, forming one large bow. The distortion was however, most severe at the butt.

In almost all cases the displacement of the stem from the vertical was much more severe in one of the planes. This was, as expected, roughly in the direction of the prevailing wind, which is south-westerly. When the trees were assessed for basal sweep while standing it was found that in 85% of the trees the direction of greatest sweep to 1.3m height was due East. The profiles revealed that the direction of maximum displacement of the stem further up the tree was nearly always in a North-Easterly direction. In fact the trees all exhibited a corkscrew shape to a greater or lesser extent. There were successive displacements of the stem in excess of its diameter at intervals up along it in a spiral pattern (Fig 4). (Fig 5 shows a typical young plantation of crooked lodgepole pine in County Wicklow).

One of the objectives of the study was to estimate the relationship between sawmill recovery and some measure of stem form in order to help classify stands by their sawlog potential. Many possible measures of stem form and size were taken (Table 4). Recovery was expressed as the percentage of the theoretical. The correlation coefficients indicate a significant relationship between recovery and degree of sweep at 1.3m.

Table 3

Volumes in m^3 underbark Top diameters in cms underbark Percentages in brackets are % of standing UB volume		Tree sectioned to minimum lengths of:	
	Overall	Lot 1 1.2m (4 ft)	Lot 2 2.4m (8 ft)
Standing vol. to 14cm:	6.999	3.729	3.270
Vol. left in forest (m^3):		0.258 (7%)	1.361 (42%)
Vol. into sawmill (m^3):		3.470 (93%)	1.910 (58%)
Mean top diam. of logs≥ 1.2m:		18.8cms	
Mean length of logs≥ 1.2m:		2.45m	
Total vol. of boards recovered »1.2m in length:		1.916 (51%)	0.971 (30%)
Mean top diam. of logs »2.4m:	20.6cms	19.9cms	21.1cms
Mean length of logs »2.4m:		3.21m	2.78m
Total vol. of boards recovered »2.4m in length:	2.352 (34%)	1.381 (37%)	0.971(30%)
Total vol. of boards recovered »2.4m expressed as a percentage of standing vol. 14 overbark:	29%	32%	26%
Mean length of boards recovered »2.4m:		3.07m	2.74m
Theoretical 'practical' max. recovery:	3.246 (46%)	1.666 (45%)	1.580 (48%)
Actual recovery as % of above:	72	83	61

The 'Theoretical Practical maximum recovery' incorporates a loss in the form of sawdust of 15% of the underbark volume. It includes another 5% to allow for the non-circular logs and imperfect sawing which will be encountered in practice.

Lots 1 and 2 were sawn to *minimum* lengths of 1.2m (4 ft) and 2.4m (8 ft) respectively, no maximum was specified. Lot 1 produced more sawn timber in boards greater than 8ft long than did Lot 2, illustrating the subjective nature of the sectioning process.

Stepwise regression was used to scan the variables in order to find how best to predict the sawlog recovery. The only significant independent variable was the degree of sweep at 1.3m. The sample size is quite small however and the results should therefore be treated with caution. Some of the independent variables are correlated, but as these variables do not contribute significantly to the regression it does not affect the analysis.

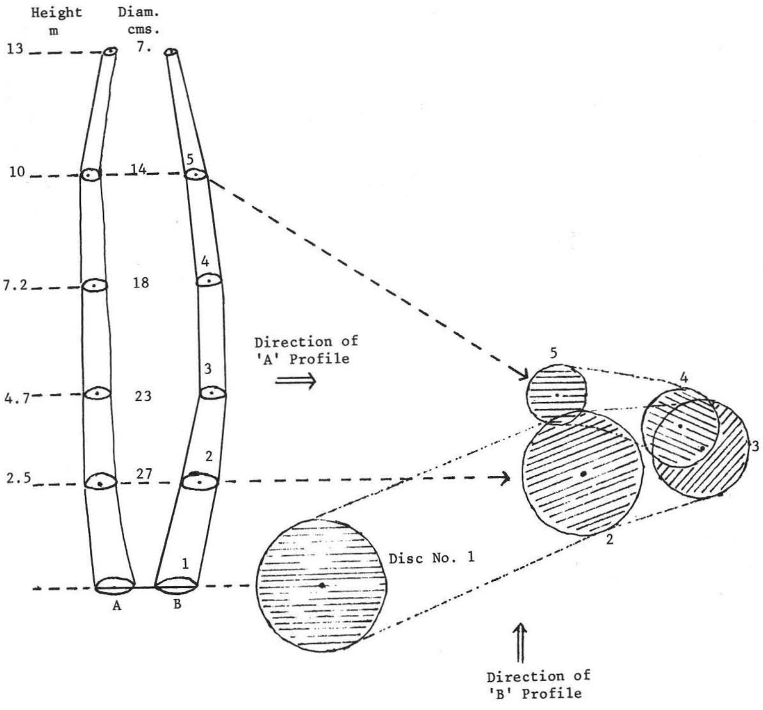

Fig 4 Diagram of Typical Stem Shape based on one of the trees from the study. On the right, above, is a plan view of discs taken at intervals up along the stem, as they would be viewed from above if it were in an upright position. On the left are two stem profiles showing how the tree would appear if viewed from directions A and B, as indicated. Discs are numbered to indicate their place in the stem profiles.

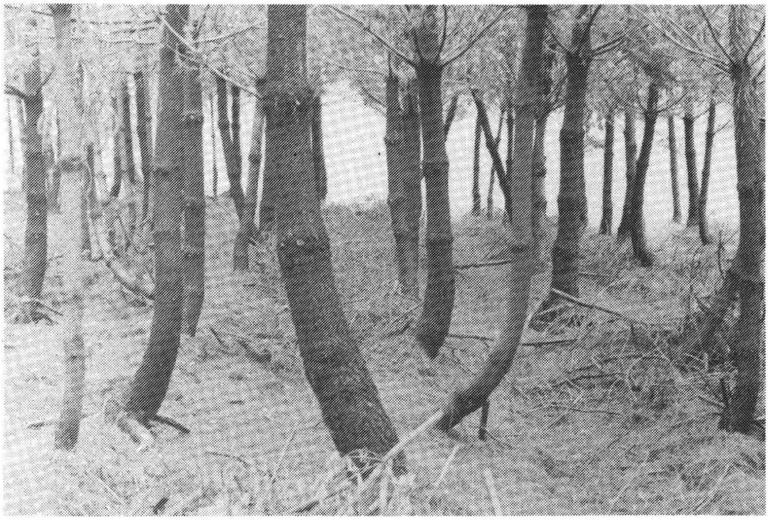

Fig 5 A young stand of crooked Coastal lodgepole pine.

Discussion of Results

The two lots of trees sectioned in the forest were very similar in terms of DBH, taper and stem crookedness, yet produced significantly different volumes of boards recovered in lengths of 2.4m (8 ft) or greater (Table 3). The reasons were apparently the different criteria for sectioning used, combined with the subjectivity involved in this operation. Had the stem profiles of the trees been examined before they were sectioned, and the optimum cuts calculated, results which were both more efficient and consistent could have been achieved. Firmer relationships could have been established between recovery and the various parameters of stem form. In practice, however, such a process would be much too cumbersome and costly for any timber harvester to consider. Its use in this study would have led to unrealistically high returns from the type of material under consideration. The most likely procedure for dealing with crooked stems in practice is that the chainsawman would simply section the tree rapidly on a purely visual basis, as was done in this case. The selected sections would be gathered into the sawmill and the crooked portions left behind, perhaps to be sold as firewood as they would not be acceptable for use in pulpmills. Making the assumption that the sawmiller would accept lengths as short as 1.2m for palletwood, the amount of material left behind in this study (from the trees sectioned to 1.2m minimum length, (Table 3)) was 7% of the standing volume.

Table 4

A. Relationship between recovery and measures of stem form (All twenty trees included in this analysis)

Variable	Correlation Coefficient	Significance level	Order of entry into stepwise regression	Proportion of sums of squares reduced by inclusion of variable
Degree of sweep at 1.3m (Basal sweep)	–0.51568	5%	1	0.266
Degree of sweep at 2.0m	–0.39084	NS	6	0.026
Degree of sweep at 3.0m	–0.35667	NS	9	0.001
Maximum deviation (cm) in the worst profile	0.09812	NS	4	0.017
Mean of the deviations (cm) in the worst profile	0.08877	NS	3	0.086
Sum of the 2 largest deviations in the worst profile	0.08214	NS	8	0.001
Taper (mm/m)	–0.06513	NS	7	0.007
Sum of 2 largest deviations in each of 2 profiles at right angles	–0.04924	NS	2	0.050
Diameter at breast height	–0.00861	NS	5	0.024

B. Regression equation for % recovery (Arcsin transformation) versus degree of sweep at 1.3 metres

		Std. Error of regression coeff.	T. Value
Intercept	61.003		
Regression Coefficient	–37.363	14.63	2.55

'Degree of sweep' refers to the distance in metres from the centre of the base of the tree to a perpendicular dropped from the centre of the stem at 1.3m, measured along the ground.

'% Recovery refers to the actual recovery in lengths of 2.4m (8 ft) or greater expressed as a percentage of theoretical recovery.

The subjectivity of the sectioning process was demonstrated by the results from the sawing. Lot 1 was sawn to produce the maximum volume of boards subject to a minimum length of 1.2m (4 ft). No maximum length was specified. Lot 2 was to produce the maximum volume of sawn boards subject to a minimum length of 2.4m (8 ft). For analysis purposes boards of only 1.2m length could not be considered as having "sawlog" value. So it was decided to accept only sawnwood greater than 2.4m (8 ft) as representing sawlog recovery. Lot 1 actually produced a greater volume in lengths of 2.4m (8 ft) and greater than did Lot 2 (Table 3).

Some of the 30% of the sawlog volume estimated lost due to crookedness was included in the timber left behind in the forest and some of it was recovered in shorter lengths as palletwood. As the trees in Lot 2 were not sawn down to palletwood sizes assumptions about the amount of material not suitable for this purpose must be based on Lot 1.

Averaging for the two lots the amount of sawn timber recovered in minimum lengths of 2.4m, it can be roughly stated that the loss of sawn timber due to bad stem form is about 30%, that about two-thirds of that can be considered as usable for palletwood and the remainder is suitable for firewood.

In regard to the shape of the trees the two points most clearly emerging were firstly that the sweep was not confined to the lower sections of the tree but continued up to timber height and secondly that most of the trees were of corkscrew shape. There is a poor relationship between recovery and the shape of the stem above 3m. This is largely because almost 50% of the estimated return from the trees occurs below this point. Measurements of stem form above 3m do not seem to hold much promise of improving on basal sweep as a potential estimator of sawn timber yields. The correlation between angle of sweep at 1.3m and recovery is significant (Table 4) but not strong enough to give a reliable estimate if small lots of timber were involved, and could with confidence be used only as a very rough indicator for forecasting purposes. However, it does appear to show promise as a potential indicator of sawmill returns. It could probably be improved if used in conjunction with one or more other measurements from the bottom 3m section.

A more extensive study would be required if a useful relationship were to be established, e.g. for sales purposes. Nevertheless, the correlation is strong enough to allow reasonable confidence that as the trees used here coincide in terms of ABC grouping with the Inventory National Survey, they may also be representative in terms of sawmill return. The major reservation to making this assumption is caused by the nature of the survey. It included stands of all ages, not just at clearfell time. Where thinning is practiced the average stem form would be expected to improve, thus the survey may overestimate the degree of sweep at felling time. Knowledge on any change in sweep over time of the individual tree is also lacking, but it must certainly get worse rather than improve. The net effect of these factors is unknown.

Some Economic Implications

If the losses in sawlog caused by stem crookedness are sufficiently severe then it might become more profitable to grow straighter but less vigorous provenances or perhaps a different species altogether. In a recent paper comparing the profitability of Sitka spruce and lodgepole pine under different sets of conditions, Carey and Griffin (1981) made allowances for loss of sawlog volume in lodgepole based on the results of this project. They concluded that in certain circumstances, such as on blanket bog and on Old Red Sandstone sites with no furze present, lodgepole pine was still a viable alternative option to Sitka spruce despite the loss of sawlog. To determine whether or not it would be justifiable on economic grounds to plant slower growing but better formed trees, such as might be achieved with more Northerly provenances, I have calculated the returns in terms of Net Discounted Revenue (NDR) for a range of Yield Classes of Coastal lodgepole pine.

A list of the assumptions used in the calculations is presented in Table 5. The volume figures are based on the Forest and Wildlife Service Yield tables for the species. It is assumed that selection thinnings only will be carried out, and that these will be done with a view to improving the overall stem form of the crop by removing the worst trees. The proportion of recoverable timber in a log decreases as the degree of sweep increases; this trend becomes more pronounced with smaller top diameters (McDonald and Sutton 1971, Dobie 1980). Therefore the sawlog element in thinnings has been assumed to be reduced by 40%. This is only a rough estimation and may well be overly optimistic.

The sawlog content of the stand at clearfelling is reduced by only 30%, on the basis of the results of this study. It is possible that tree selection at thinning could improve this figure and as such this may be a conservative estimate of the return. In the case of both thinnings and clearfellings 10% of the boxwood is assigned a pulp value only. This is loosely based on the results from the sawing of Lot 1, where 7% of the total standing volume was left in the forest.

All the remaining portion of the stand still considered as sawlog (i.e. 70% of expected clearfelling volume) is reduced in value by 10%. This is to compensate for the reduced lengths available to the

Table 5 Assumptions for Net Discounted Revenue Analysis

Straight Stems: (straight Lodgepole provenance).

1. 'Normal' management, based on the LP(C) Yield Tables from the Forest and Wildlife Service (1976).
2. Costs and revenues are those of March 1981.
   The price for sawlog was approximately £21/m^3 and that of pulp £1.20/m^3.

Crooked Stems: (Typical South Coastal).

1. Management as above. Selection thinning is assumed with straighter stems being favoured.
2. Costs as above.
3. Revenues:
   A) For thinnings, 40% of the sawlog element in the trees reduced to boxwood value. 10% of the boxwood element reduced to pulp value. The remaining sawlog element reduced by 10% in value.
   B) For clearfellings, as above except that only 30% of the sawlog element was reduced to boxwood value.
   This gave an adjusted price for the sawlog element in the timber of £14.30/m^3 in thinnings and £15.30 in clearfellings. Calculations of assortments were based on tables in British Forestry Commission Booklet No. 39.
4. 'Sawlog' is taken to be the proportion of a stand of timber occurring in logs of at least 3m in length with top diameters of 20cms.
   'Boxwood' or 'Palletwood' is defined as above but with a top diameter of 14cms and minus the sawlog element.
   'Pulp' is the remaining volume up to the 7cm mark of the trees in the stand.

sawmiller from the crooked stems and also to compensate for the increased handling costs involved in the sectioning process. It is a very arbitrary figure. There is no information available on what sawmillers are likely to pay for material of sawlog dimensions but mean log lengths of about 3m. Attempts to extract longer lengths would result in great losses in overall recovery.

The results of the NDR analysis (Fig 6) indicate that even if the trees could be grown straight it would not be profitable to drop more than one yield class in doing so. With decreasing yield class or increasing interest rate the benefit gained from better form diminishes. For example, at the 2% interest rate, YC 10 'straight' provenance is better than YC 12 South Coastal but not as good as YC 14, South Coastal. At the 4% rate however, YC 10 'straight' provenance is no longer more profitable than YC 12 of the more vigorous but crooked trees.

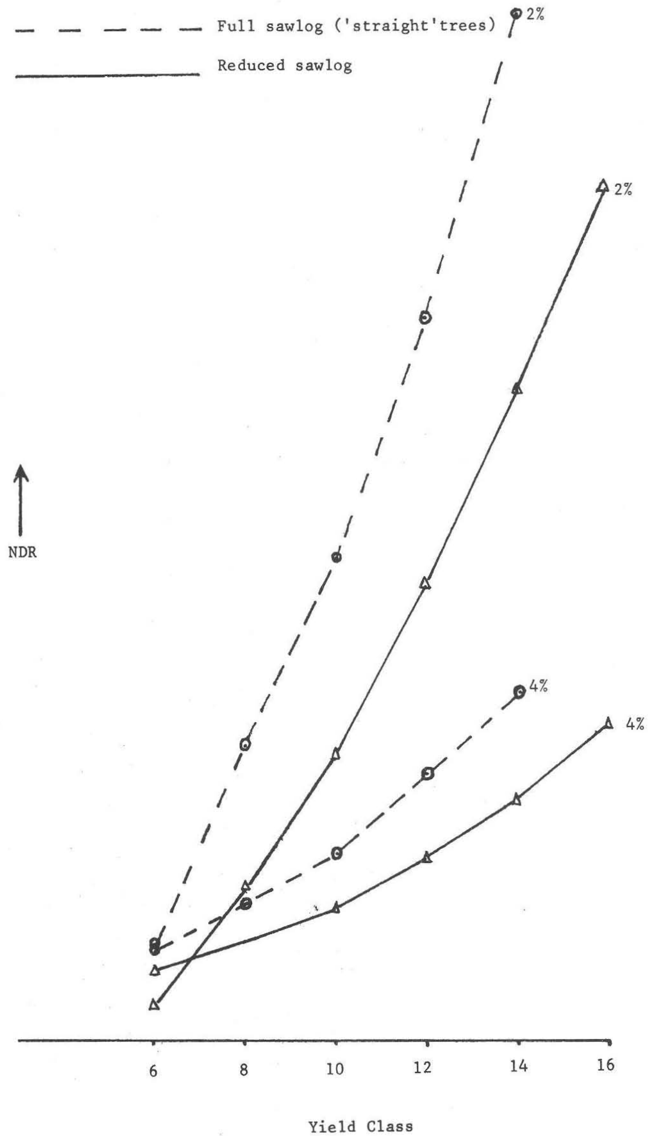

Fig 6 Net Discounted Revenues at 2% and 4% for 'normal' and 'reduced' sawlog assumptions over a range of yield classes.

CONCLUSIONS

Coastal lodgepole pine at present accounts for about 6% of the total volume to 14cms top diameter produced by the FWS. This figure is not forecast to rise during the coming decade. The losses of sawlog due to the poor form of these crops, as indicated by this study, would thus amount to less than 2% of the anticipated national sawlog production during the next ten years. The situation may become more serious afterwards as it appears that the stem form of LP(C) crops planted since 1958 is worse than that of the older crops, due to changes in provenance, site types and silvicultural practices. Without some sampling, on a national basis, of the degree of sweep present in these stands it would be impossible to make a reliable estimate of sawnwood returns from them.

If the degree of sweep in new plantings of South Coastal lodgepole pine could be limited to that present in the pre-1958 stands, then it would remain a more profitable proposition than planting less vigorous provenances. It would also, according to Carey and Griffin (1981), remain an alternative to Sitka spruce on certain sites.

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