Session 2
Paper (a)

WOOD QUALITY, NOW AND IN THE FUTURE

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What is Quality?

In the simplest sense, quality can be defined as "suitability for the intended use". For forest products, the intended uses can be varied, ranging across broad categories such as roundwood (posts, poles), solid wood (structural, packaging, appearance), composites (veneer, plywood, board products) and pulp and paper. In the broad sense these end uses are met globally through the use of a range of species with distinctive and well-recognised features. Cultures have developed around the use of particular species and with international trade many are renowned for their ability to meet specific needs, eg, structural - Douglas fir; furniture - oak, mahogany; pulp and paper - spruces and more recently eucalypts.

New Zealand also has its own culture of wood use, at first revolving around the locally available tree types - kauri (stability), rimu (appearance), totara (stability and durability) etc. Since the native species have long been recognised as not economically sustainable, and certainly not suitable for the development of long term exports, their replacement with exotics has resulted in another local success story. Two species have become the mainstay of the forestry sector and should remain so for the foreseeable future - radiata pine and Douglas fir.

Radiata pine, and to a lesser extent Douglas fir, have proven to be highly suited to the New Zealand environment and being productive, healthy and amenable to relatively short rotations. It is worth noting, however, that the local industry did not respond enthusiastically at first to the substitution of native timbers with "weak, knotty, decay-prone" softwood. It was only through the application of research and the development of appropriate technologies that radiata pine has become the preferred species for most uses in New Zealand. It is debatable whether the same degree of development would have been expended on radiata pine had the native woods still been available in abundance. "Perceived quality" is an important factor in market development, as evidenced by the relatively slow acceptance of radiata pine for "high quality" uses in Asian countries.

We are now beginning what we hope is the third planting boom, and it is appropriate to examine some of the quality characteristics of the plantations now being established.

Quality characteristics of radiata pine

Radiata pine is commonly referred to as a "medium density, general purpose" softwood. The intent of the phrase "medium density" is to convey an impression that it is not "low" like balsa or western red cedar, nor "high" like many hardwoods, and is therefore suitable for solid wood uses where both light weight and strength are required (structural), and as a source of fibre for reconstituted products. In fact, the term "medium density" has little meaning in practice, as radiata wood can range from corewood of 300-350 kg/m3 (definitely low density) to outerwood at 450-500 kg/m3 (medium density). The corewood zone comprises about 10 growth rings around the pith. There are however large between site and between tree differences in wood properties which affect the suitability of the wood for different uses. One of the main reasons that the term "general purpose" is so apt for radiata is the ability of users to segregate wood of different qualities for different products.

Table 1 shows some of the uses for radiata pine and comments on how well radiata pine is perceived to meet the requirements for these uses.

Plantation-grown timber in general has gained a reputation for being of inferior quality to natural stands because of the rapid growth, leading to a high proportion of corewood (juvenile wood) and knotty timber. In countries where "fast grown" plantations are being harvested, there is a lower "perceived quality" for the resulting timber (Pedini, 1990; Gorman, 1985; Senft *et al.*, 1985).

The basic wood quality of radiata pine (and to a lesser degree Douglas fir) grown in New Zealand has been the subject of extensive research which will not be reviewed in detail here. Publications such as Harris and Cown (1991) and Cown (1992) cover this area in detail. Suffice it to say in summary that our major species behave in a similar manner to plantations grown wood anywhere else in the world - fast grown softwoods harvested on a short (<30 year) rotation produce large amounts of juvenile wood with predictable performance characteristics.

New Zealand plantations are different mainly in the extent to which stands have been tended. New Zealand silviculture has been developed with the intention of improving the economic returns from growing trees. The approach taken has been to prune to produce long lengths of clearwood on the butt log. In order to maximise the growth of clearwood and to increase the size of logs higher up the tree early thinning has been widely practised. Rapid growth of the crop trees makes shorter rotations possible if log size is a criteria for assessing harvest age.

The properties of major importance to solid wood uses include:

1. Wood density (strength, stiffness, hardness, machinability and finishing)
2. Grain angle (stability and machinability)
3. Knot size and distribution (appearance, strength and recovery of cuttings and clears)

Density is also an important property for pulp and paper manufacture although not all products and processes require high density. Other properties are also important but the value of these attributes is still being assessed. It is worth noting however that the prices for logs that are suitable for solid wood processing are well in excess, by two to three times, of prices for logs of only pulp wood quality.

Influences of Site

Site can have a significant impact on forest profitability. Much of this is due to the wide variation in growth rates found between sites and to the wide differences in silvicultural and harvesting costs between different sites.

The impact of site on wood quality has been well documented for density. Other properties are not so well known.

A broad trend to longer internodes with increasing latitude has been observed. This trend is however masked by genetic differences and there may be local effects.

The incidence of resin pockets can have a considerable impact on the recovery of clear timber of any length. Areas of high resin pocket incidence have been identified and these are shown in figure 1. This regional pattern suggests that these regions produce logs that are less suitable for many products, especially for clears, than other regions and if growers are intending to grow specialised crops then this pattern will be significant.

Influences of Silviculture

With wide spacings and resulting fast diameter growth there is considerable scope for high variability within a stand. Inevitable variations in spacing, site and genotype will result in a wider range of tree sizes where overall stockings are low. With large diameter trees and wide spacings taper is greater leading to wide size variations up the tree. This leads to a more variable log supply in terms of size and also shape than was the case for old crop.

A result of early thinning and wide spacings has been to increase the size of branches further up the tree. Again there can be considerable variation. This has a major impact on the suitability of these logs for a number of different processes. For applications where strength is a major consideration the size of branches is critical.

The impact of density and branch size on the recoveries of structural timber are well known. The impacts of these are illustrated in figures 3 to 5. Within limits there is a trade-off between density and branch size for recoveries of machine stress graded timber. Density is related to harvest age (itself a reflection of growth rate and tree size), site and log height class. The trade-off of density and branch size required to maintain a recovery of greater that 50% of F5 and better timber logs can be seen in figure 3. If log density is less that 400kg/m^3 then the BIX (Branch Index) and maximum branch allowed for reasonable recoveries of structural grades becomes increasingly difficult to meet.

Rotation Age

Rapid diameter growth has enabled large trees to be grown and harvested on short rotations. The rotation age in New Zealand has changed with the demise of "old crop" radiata pine. There are other factors that have contributed to lowering the harvest age and there is concern about low harvest ages in some areas. With the uneven distribution of ages in the forest some harvesting before an "optimal" harvest age is inevitable. The decision on planned harvest age is now more heavily dominated by economic considerations than in the past. These considerations include the costs of holding capital in unharvested stands and the current high prices for logs. Finally some stands have to be harvested before the planned age owing to damage, such the as wind damage caused by cyclone Bola, leading to a salvage harvest.

The planned average age of harvest has reduced in New Zealand recently. In past projections of harvest volumes the NZFS used a harvest age of 30 years. (Burrows et al, 1986). More recent projections have used younger ages (Edgar et al, 1992) or has included younger aged scenarios (NEFD in McEwen, 1993, included a scenario with a target age of 25 years). A major constraint on lowering harvest ages is the perceived and real wood quality aspects of young trees.

Many of the impacts of a lower harvest age are well known and are well documented [see for example Cown (1992) and Kininmonth and Whitehouse (1991)]. The basic density of the wood of younger trees is lower especially where there is a high proportion of corewood. Moisture contents are however considerably higher in young trees than older trees which increases the volume and weight of green wood to be tranported for a given mass of dry wood.

Spiral grain can also cause problems in young wood. While the pattern of spiral grain is still being investigated, it is most pronounced in corewood at rings 3 to 4 from the pith and is greater higher up the tree than near the butt (figure 6). Grain deformation increases drying degrade and gives problems with machinability. High levels of corewood will increase drying degrade and the higher moisture content of younger wood will result in higher drying costs.

The decrease in density occuring as a result of lower harvest ages will have an impact on the suitability of the wood for many solidwood uses. Compared with logs of higher density, logs of lower density but with the same branch size the recoveries of higher strength timber will be lower. With low densities the machining properties of radiata pine are not so good. The lower density will also increase the volume of furnish required to make up the same volume of yield for many pulping processes and for reconsituted products.

On the other hand for some pulping processes, especially the production of mechanical pulps for printing grades, young material can be an advantage.

While many of the effects of low harvest age on wood quality are well known and well documented some are less well known and research on these is a major priority at present.

Influences of Genotype

Radiata pine has been the subject of an intensive breeding programme which through time is changing the genetic make-up of the resource. The main selection criteria have been for growth and form. That is the trees that have been selected have been fast growing and have a straight bole.

There have been a number of other results from the selection criteria. Growth rates are in general higher for multinodal trees than uninodal ones so the faster growing stock is generally multinodal. This means that the tree has many small branches relatively close together in contrast to uninodal trees that produce fewer but larger branches. An example of the variability between breeds is given by Horgan (1991) and is shown below.

Percentage Distribution of Internode Length for Two Seed lots.

Internode length (cm)	Short internode Seed lot 268	Long internode Seed lot 870
<31	22.1	7.1
31-60	46.3	10.3
61-90	13.0	10.3
91-120	6.4	15.4
121-150	3.2	23.9
151-180	1.3	17.3
181-210	0	6.7
>210	0	3.9

In the future it is intended that the breeding programme be able to select for wood properties. Before this can be done however further work is required on the effects of different wood properties on processing, on the variation of these properties between different genetic stock and on the correlations between properties and other selection criteria. Increasing the number of selection criteria, when they are not correlated, greatly increases the cost of a breeding programme and can reduce its ability to achieve gains in any one attribute. This means that including a wood property which is found in slower growing trees in the selection criteria for future trees can reduce gain in growth from the breeding programme.

The branching habit of trees has a considerable impact on the type of timber being produced. Multinodal trees are best suited for framing and utlity grades of timber owing to the large number of knots and to the relatively small sizes of these. Uninodal trees, which are slower growing, on the other hand produce better recoveries of cuttings grades. With the development of the US market for random width timber which is used for clear components the ability to produce a significant volume of clear components is critical. This is illustrated in table 2 which shows the results of recent FRI sawing trials.

End Uses and Processing Technologies

The changes being outlined above have a number of implications for the different solid wood uses of radiata pine.

Packaging

Radiata pine will continue to be suitable for packaging uses. It is ideally suited to these uses because of its density, colour and good fastening properties. The changes in silviculture should not affect the suitability of radiata for this use as corewood is suitable. The markets are, however highly competitive and demand a high standard of presentation.

High Value Uses

These uses demand clear wood. Tightly defining clearwood to being long lengths from pruned logs can lead to opportunities being missed here. If clearwood is taken to mean full log length clears greater than, say, 5.5 metres in length then we have very little clearwood. Much clearwood is however used in short lengths. If shorter lengths are recognised then we have large volumes of clearwood in our unpruned logs. All logs comprise clearwood, knots and pith. The difference between unpruned logs and pruned logs is that the knots extend to the surface and the long lengths of clearwood resulting from prunning are not present.

Radiata pine is an extremely good species for working and finishing. The medium density and even texture, specifically the low contrast between early wood and latewood, gives very good machining characteristics. This superiority to most commonly used species is clearly shown in comparative tests done by FRI and others, with only Parana pine being superior. There are density limits for many clearwood applications. Our research indicates that the machining properties of wood below 300kg/m^3 are extremely poor. The European recommendations for the minimum density required for window joinery is 350 kg/m^3 and 380 kg/m^3 for furniture. Much of the wood within the corewood will have a density below these levels and this will limit its acceptability for these uses.

It is now recognised that pruned logs need to be sawn differently to unpruned logs to maximise recovery. Techniques which can improve recovery include scanning and improved log positioning, full taper sawing, thin kerf sawing, random width sawing and saw-dry-ripping. Without maximised recovery, mills will not be able to afford logs which will then go to local or foreign competitors.

With the sawing of clear components and clearwood from unpruned logs different approaches and careful selection of logs must be used. Much of the future log resource will be of larger branched L grades of logs. The branches of these logs are sufficiently large to preclude high recoveries of structural timber. For a proportion of these logs the recoveries of component grades (remanufacturing grades) can be high. It is clear from sawing trials that by sawing and grading to the requirements of the market recoveries can be improved. New Zealand grading is heavily influenced by knot size whereas clearwood content is more important for many overseas grades.

Sawing for component markets will however require selection of suitable graded logs. For good recoveries of clear wood from unpruned logs the most important criteria are the length of the internodes (or alternatively a low number of whorls for a given log length) and a large log diameter. Sawing unsuitable logs is poor economics and results in low returns to both the processor and the grower.

Structural Timber

Structural timber has been a traditional major use of New Zealand radiata pine. An estimated 40% of all timber used in New Zealand in the early 1980's was as framing timber (Maughan and Clough, 1986). A further 14% was used in packaging and pallets. Exports of sawn timber to Australia includes high proportions of framing timber. In addition much of the wood exported in log and flitch form to Asian markets is used for formwork and other construction uses. All of these uses require reasonable strength.

Radiata pine wood of the correct grade has been accepted for virtually all structural applications in New Zealand and Australia. Its performance characteristics can match those of the softwoods used in foreign markets. Structural uses require timber to have strength, stiffness, stability and workability. These are determined by density, grain angle and the size and location of knots in the piece of wood.

In order to recover reasonable volumes of F5 and better timber a softwood with a basic density of at least 400 kg/m^3 and a maximum knot diameter of less than 5 cm is required. Only S grade (small branched) logs will provide this. There will be problems in meeting the quality required on short rotations. On a medium density site the average ring density may reach 400 kg/m^3 after 10 to 12 years. It will take 15 years before 95% of the new wood will be at least 400 kg/m^3 and 20 years before any of the sawn timber will be F5 equivalent, provided the knots are small. In summary fast grown crops harvested on short rotations (less than 25 years) will give only low recoveries of good structural timber. Even with logs above this age mills will be experiencing a drop in grade recoveries with the change in the resource to younger new and transition crops. The adoption of Australian grading stantards, with machine stress grading, has been a two edged sword. Timber must meet mechanical as well as visual criteria, something which is increasingly difficult with wood from low to medium density zones with short rotations.

Another feature of fast growing short rotation crops is the larger core of spiral grain. This reduces the propotion of acceptable pieces after drying because of the high level of drying degrade found with this type of material.

On the sawing technology side much development of high throughput mills has occurred in both North America and Europe. This mills are designed essientially for small logs and are highly automated having very high lineal throughputs and make use of complex technologies, including improved positioning, chipping headrigs and multiple saw systems, to maintain recoveries from smaller logs. Softwood logs are now routinely sawn down to a diameter of 75 mm SED in northern hemisphere mills.

There are real difficulties in introducing all of these technologies into New Zealand. The way we grow radiata pine means that most small logs, especially those of 75 mm SED, have very few growth rings. This means that the density is low, some 300 to 350 kg/m^3 with spiral grain of 5 to 10 degrees. Virtually none of the timber from such a log will be in structural grades. Wood properties are not greatly affected by growth rate. A larger log only has improved properties if there are more growth rings resulting in there being more wood outside of the low density, high spiral grain corewood zone. If the large log is all corewood then it will be no better than a smaller log. It could even be worse if the fast growth has also resulted in large knots. The result of this means that New Zealand mills cutting structural timber will need to saw logs that are larger than those commonly sawn overseas, and for which the new sawing technologies are designed, and will get more variable logs and grade recoveries.

The end result is that we do not see much of the resource being sawn for structural timbers. While a proportion of the harvest will be suitable for structural uses much of the resource will only give low recoveries. There will be increasing competition in these markets due to Australia's increasing harvest, which is grown on longer rotations and higher stockings than ours, and low cost competition from North America.

Conclusions

The natural attributes of radiata pine are suited to many major end uses. The species is however very variable so the different logs from individual stands have widely different processing characteristics and widely differing potentials for particular end uses. The silviculture practised, the breed grown and the stands location and harvest age can all significantly enhance or detract from the suitability of different logs from a stand for particular processes.

It is critical that the seller grade logs so that they may be matched to process and end product.

The impacts of modern silviculture with its emphasis on producing large pruned butt logs on relatively short rotations has narrowed the options for processing the outturn from plantations considerably.

The silviculture practised has made the production of structural timber on a large scale less attractive. The combination of large branches above the butt log coupled with harvest ages in the mid-twenties and corresponding large corewood zones have combined to make recoveries of structural grades low. This part of the international market is relatively competitive so the low recoveries are a critical problem in achieving success in sawing this type of timber. The knotty logs are more suited to packaging uses than structural timber.

Radiata pine has a number of advantages which are most appropriate for high value uses such as interior and exterior joinery, mouldings, millwork and furniture. The advantages include the trees ability to produce large volumes of clearwood with appropriate silviculture, rapid timber drying, ease of treatment, workability and good finishing. These uses require good pruned logs or unpruned logs which have internodes of reasonable length. It is perhaps ironic that given radiata's advantages for these end uses that the widespread use of high growth rate tree breeds which are also multinodal makes unpruned logs less suitable for clearwood markets.

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Table 1 : Radiata Pine - Uses, Requirements and Conformity to Requirements

USE	REQUIREMENT	CONFORMITY
Export Pulplog	Size	Good
	Shape	Fair
	Density	Good
	Freedom from stain	Poor
Export Sawlog (Unpruned)	Size	Good
	Shape	Fair
	Branching	Poor
	Density	Fair
	Freedom from defect	Excellent
	Freedom from stain	Poor
Export Sawlog (Pruned)	Size	Good
	Shape	Fair
	Defect Core	Variable
	Freedom from defect	Excellent
	Freedom from stain	Poor
Solid Wood (Structural)	Density	Fair
	Small knots	Poor
	Stability	Poor
	Ease of drying	Excellent
	Treatability	Good
	Grade yield	Poor
Solid Wood (Appearance)	Density	Good
	Machinability	Excellent
	Figure	Good
	Stability	Poor
	Hardness	Poor
	Grade yield	Variable
Veneer	Density	Good
	Peeling/slicing	Good
	Grain	Fair
	Ease of drying	Good
	Grade yield	Variable
Plywood	Density	Fair
	Stability	Fair
	Peeling	Good
	Grade yield	Variable
Composites	Density	Good
	Colour	Good
Pulp/Paper	Density	Good
	Energy consumption	Fair
	Fibre properties	Good

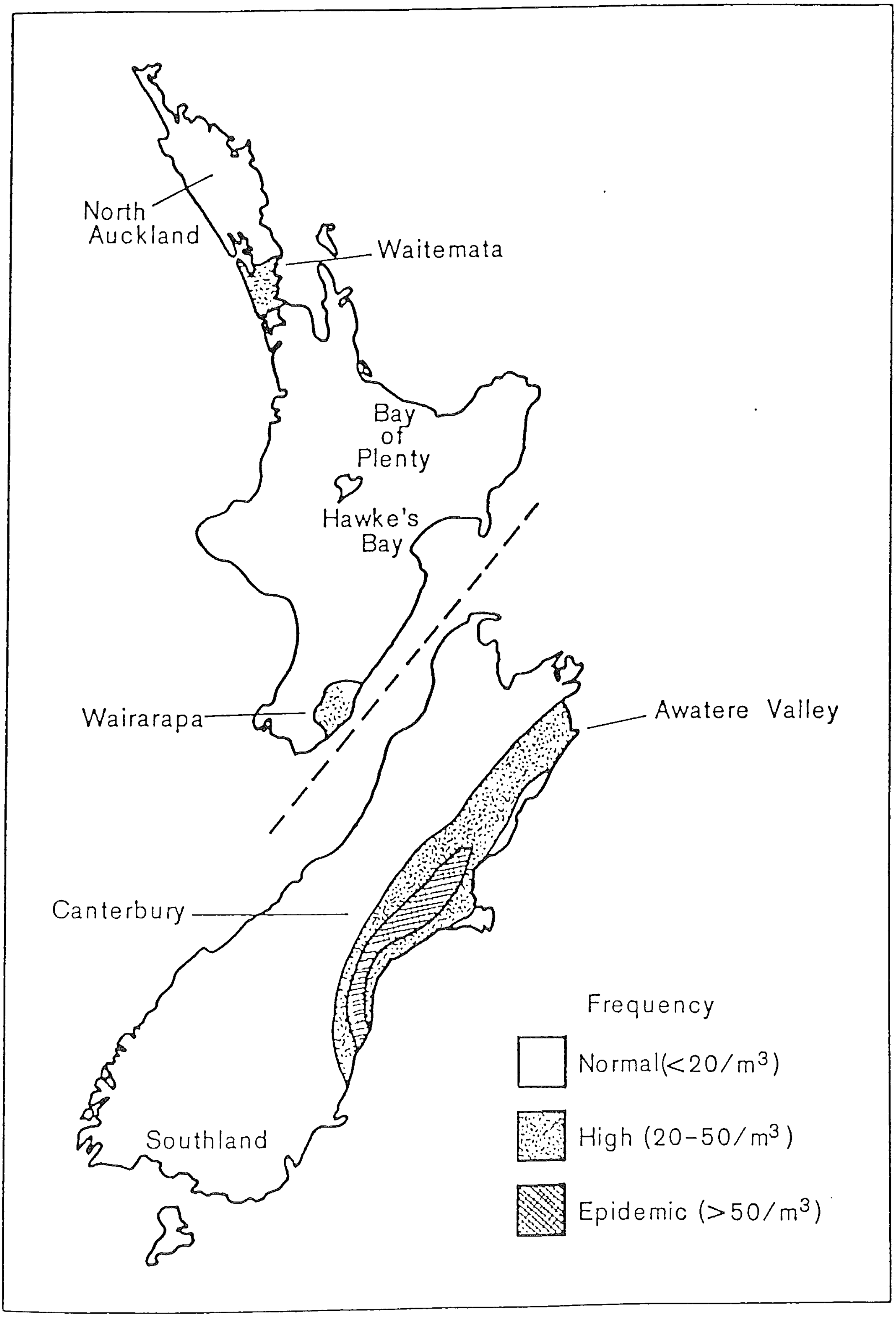
TABLE 2 - Random Width Sawing - Selected Logs

Log Grade	SED (cm)	BIX (cm)	Internode Index	Grade Outturn - US Grades						Conversion %
				Moulding and Better	1 Shop	2 Shop	3 Shop	Commons	Other	
				(% of outturn)						
INT	30.0	5.6	0.76	7	41	21	12	12	7	52.4
INT	50.5	6.8	0.77	1	36	30	7	27	-	58.8
SI/INT	48.5	2.0	0.7	41	9	7	27	14	2	48.3
S2	31.5	3.5	0.14	-	-	-	35	45	20	53.7
L1	49.5	5.9	0.33	-	-	13	48	32	8	55.0
S1	47.0	4.6	0.3	-	-	7	83	5	5	56.3

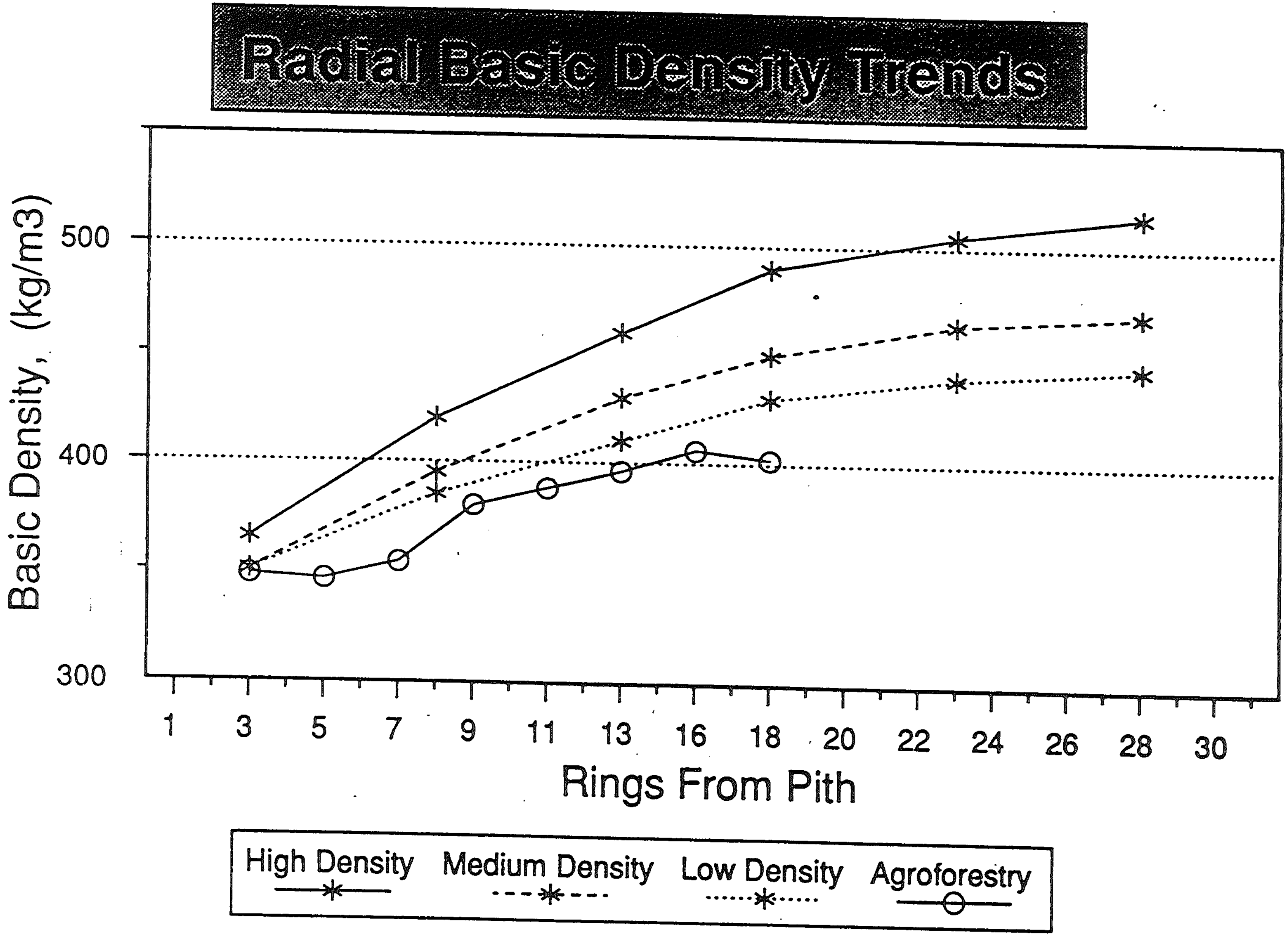
Notes:

1. Individual logs from trials in 1993 sawn to random width and graded to US Grades.
2. Internode index is the ratio of the total length of all internodes greater than 0.6 m log over the length of the log.

Source: Turner J.C.P. and McConchie, D.L. (1993 - in preparation). FRI Project Record.

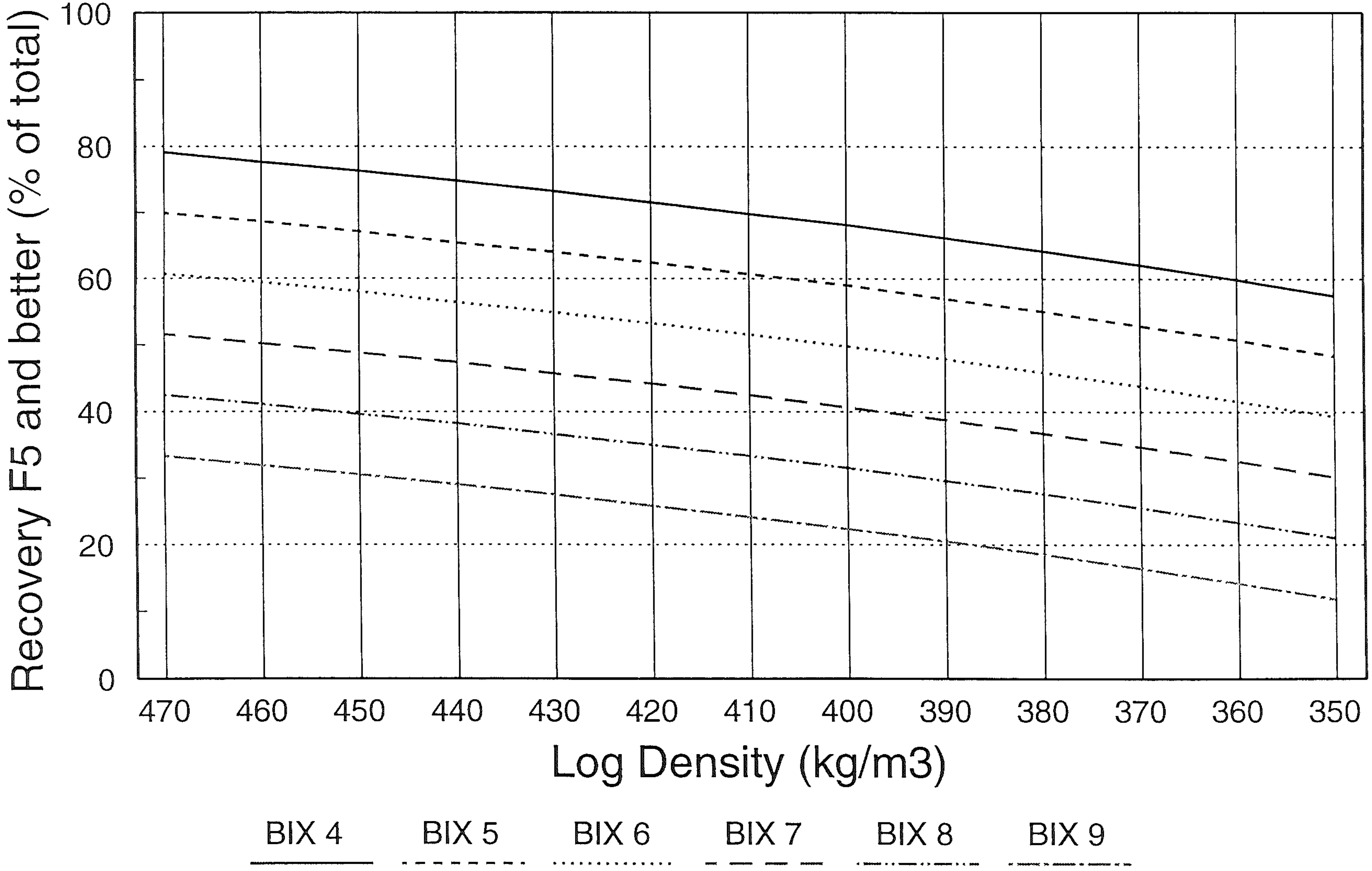


Distribution of resin pockets


Radial Basic Density Trends
Basic Density, (kg/m3)
500
400
300
1
3
5
7
9
11
13
16
18
20
22
24
26
28
30
Rings From Pith
High Density
Medium Density
Low Density
Agroforestry

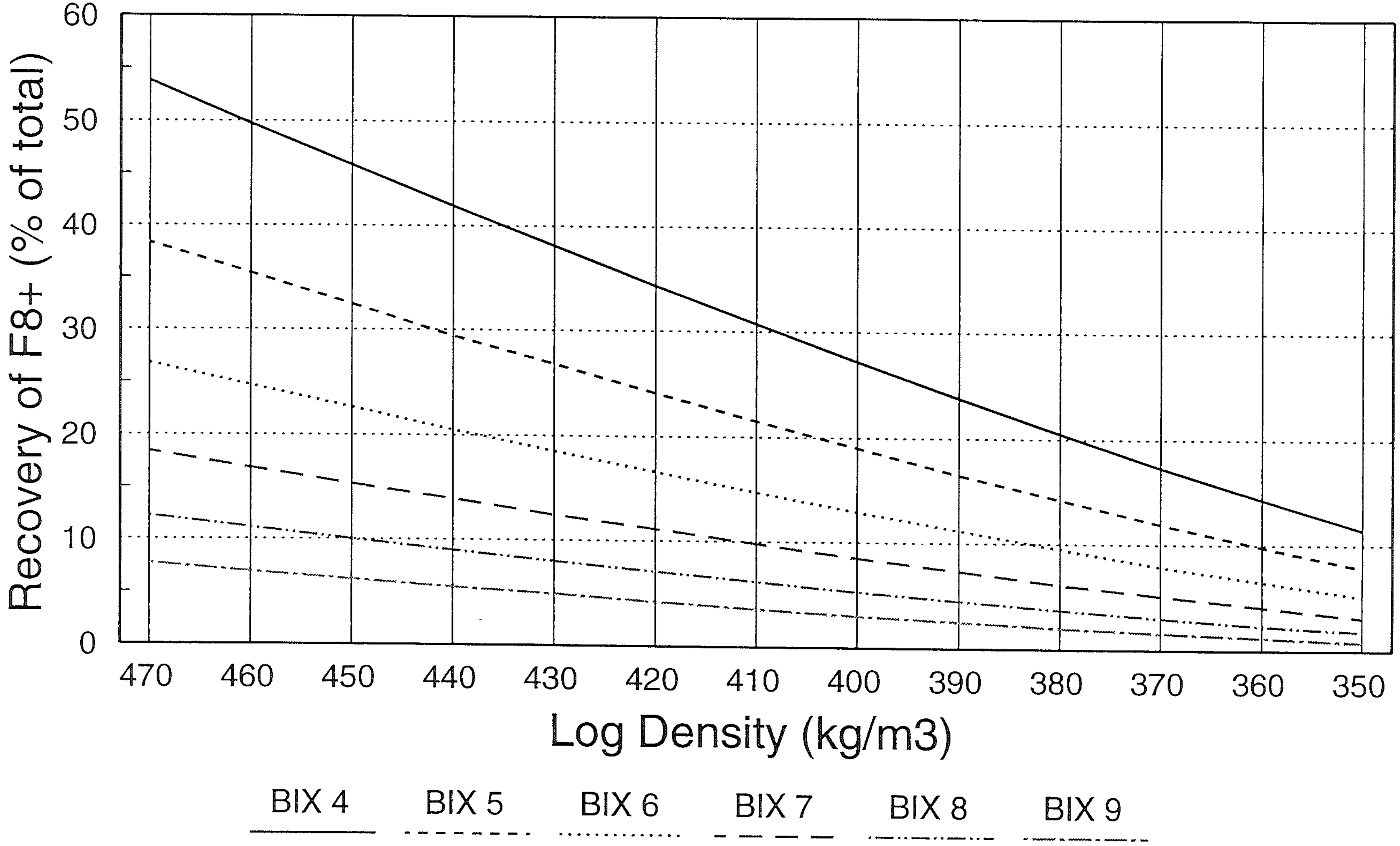
Recovery of F5 and Better Using Machine Stress Grading

Saw pattern 7 (100x40) : SED 350



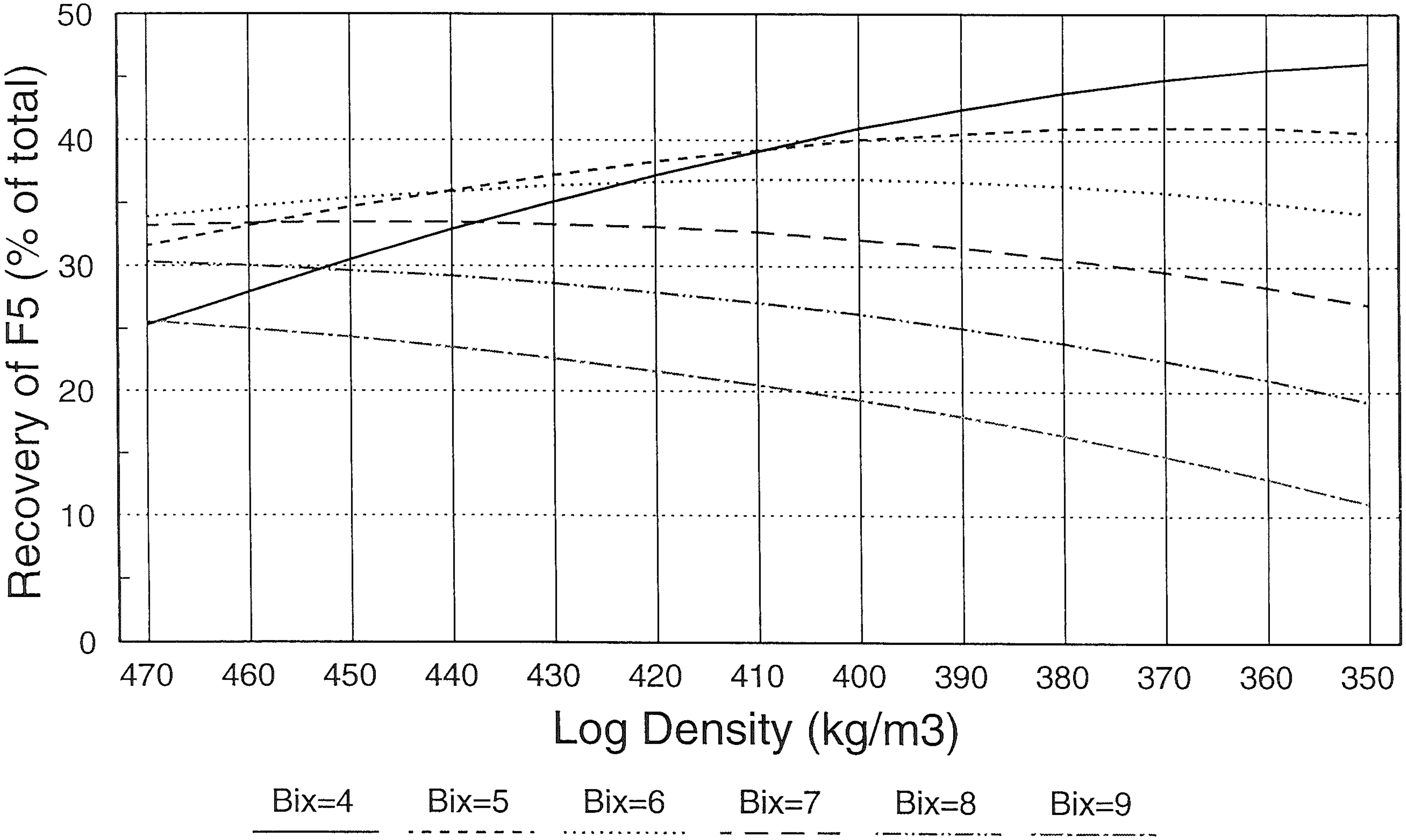
Recovery of F8+ Using Machine Stress Grading

Saw pattern 7 (100x40): SED 350



Recovery of F5 Using Machine Stress Grading

Saw pattern 7 (100x40) : SED 350



F5

SPIRAL GRAIN IN RADIATA PINE

VARIATION WITH HEIGHT