PINUS RADIATA WOOD RESIDUE QUALITIES AND SOME UTILISATION OPTIONS*

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ABSTRACT

Pinus radiata D. Don wood residues can be divided into two categories – top logs and whole trees <20 years old (predominantly of corewood quality), and the slabwood from sawn sawlogs (predominantly of outerwood quality). These two residue types are further defined by their wood basic density with top logs generally <400 kg/m³ and slabwood generally >400 kg/m³. The over-all basic density range for either residue category normally lies within 100 kg/m³. The actual density values of a given wood supply are dependent on tree age, and the growing site and silvicultural history of a forest stand. Moisture contents are higher and basic densities are lower for whole trees (<20 years old) than for top logs, which contain the same number of growth layers.

It is estimated that up to 60–70% of New Zealand's P. radiata resource could be utilised as residues rather than as solid wood. Residue utilisation options include the manufacture of chemicals, panel products, and a range of pulp and paper products. Pulp and paper products are considered to be the most sensitive to wood quality differences.

INTRODUCTION

Wood residues will constitute a significant proportion of the large increase in the volume of P radiata wood which will become available in the 1990s and beyond (Bunn 1981; Forestry Conference 1981). The qualities of these residues could well determine utilisation options in terms of the types of products which can best be manufactured from them.

WOOD RESIDUE QUALITIES

The stems of P. radiata trees contain a central core of low-density wood (corewood) with tracheids which are short and thin-walled compared with those in the outerwood (Cown 1980). Somewhat variable transition zones with indeterminate boundaries exist between corewood and outerwood. Within P. radiata stems, wood basic density and

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tracheid length increase with increasing numbers of growth layers from the pith (Cown & McConchie 1983). *Pinus radiata* stems are, therefore, divided into two categories (Fig. 1):

(1) Stemwood which consists of the first 10 to 15 growth layers from the pith and is predominantly corewood;

(2) Stemwood which consists of wood outside the fifteenth to twentieth growth layers from the pith and is predominantly outerwood.

Based on such a classification, corewood is of low basic density and contains short tracheids compared with outerwood which is of significantly higher basic density and contains longer tracheids (Cown 1980; Cown & McConchie 1983).
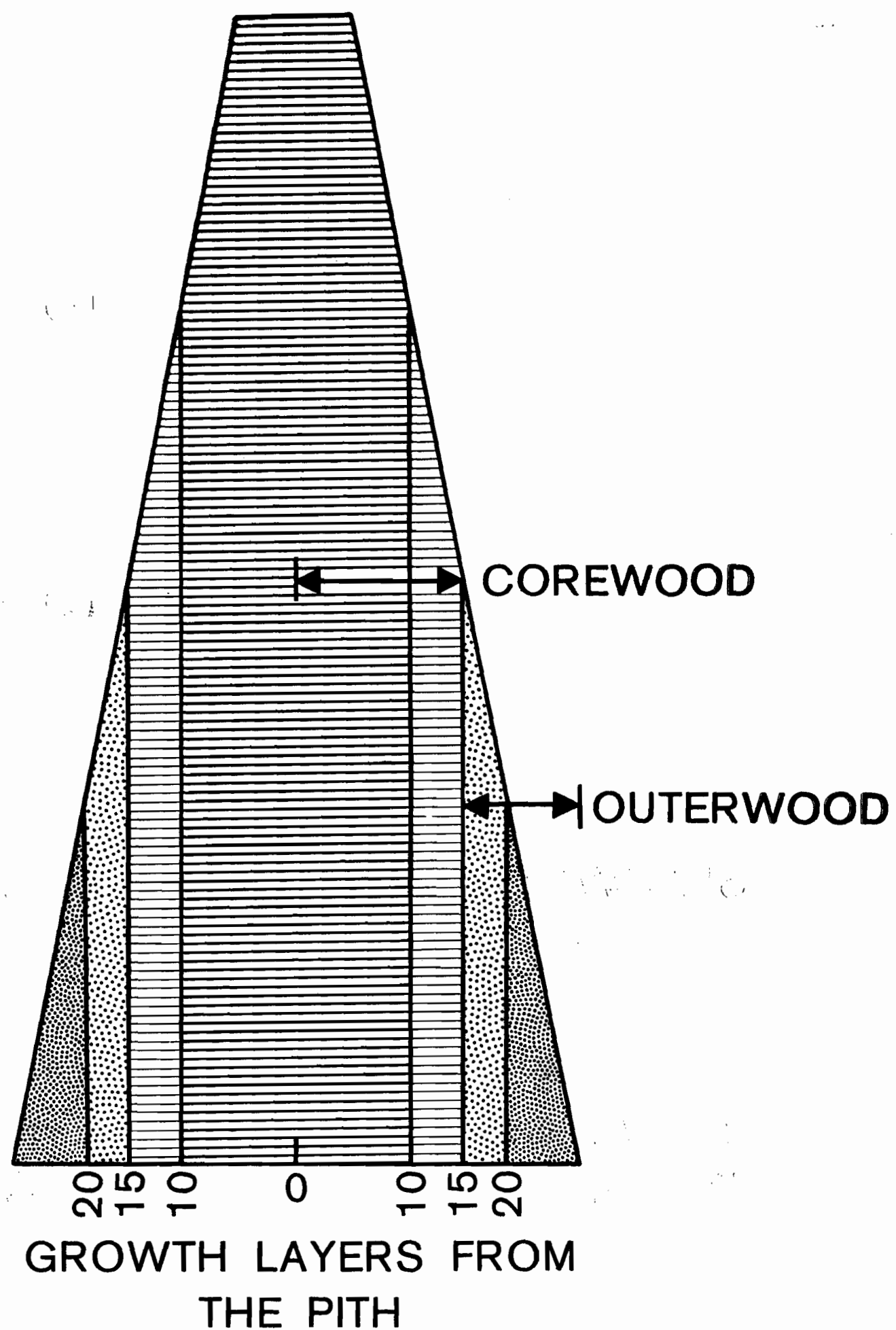

FIG. 1—Schematic diagram of the corewood and outerwood zones for a 30- to 35-year-old **P. radiata** stem.

Pinus radiata stems can also be divided into several sawlogs (>25 cm s.e.d.) and top logs (<25 cm s.e.d.) depending on tree size and age (Fig. 2) (Cown & McConchie 1982). Based on this classification, top logs generally consist of corewood and the sawmill residues (mainly from the outside of sawn sawlogs) consist predominantly of outerwood. It needs to be recognised that the size of the merchantable small-end diameter can range from <20 to >30 cm depending on the type of sawmill and its processing requirements (Forestry Conference 1981). The 25 cm used by Cown & McConchie (1982) represents a middle-of-the-road situation. Residues from the utilisation of *P. radiata* forests for solid wood can, therefore, also be divided into two categories.

(1) Top logs which are predominantly of corewood quality;

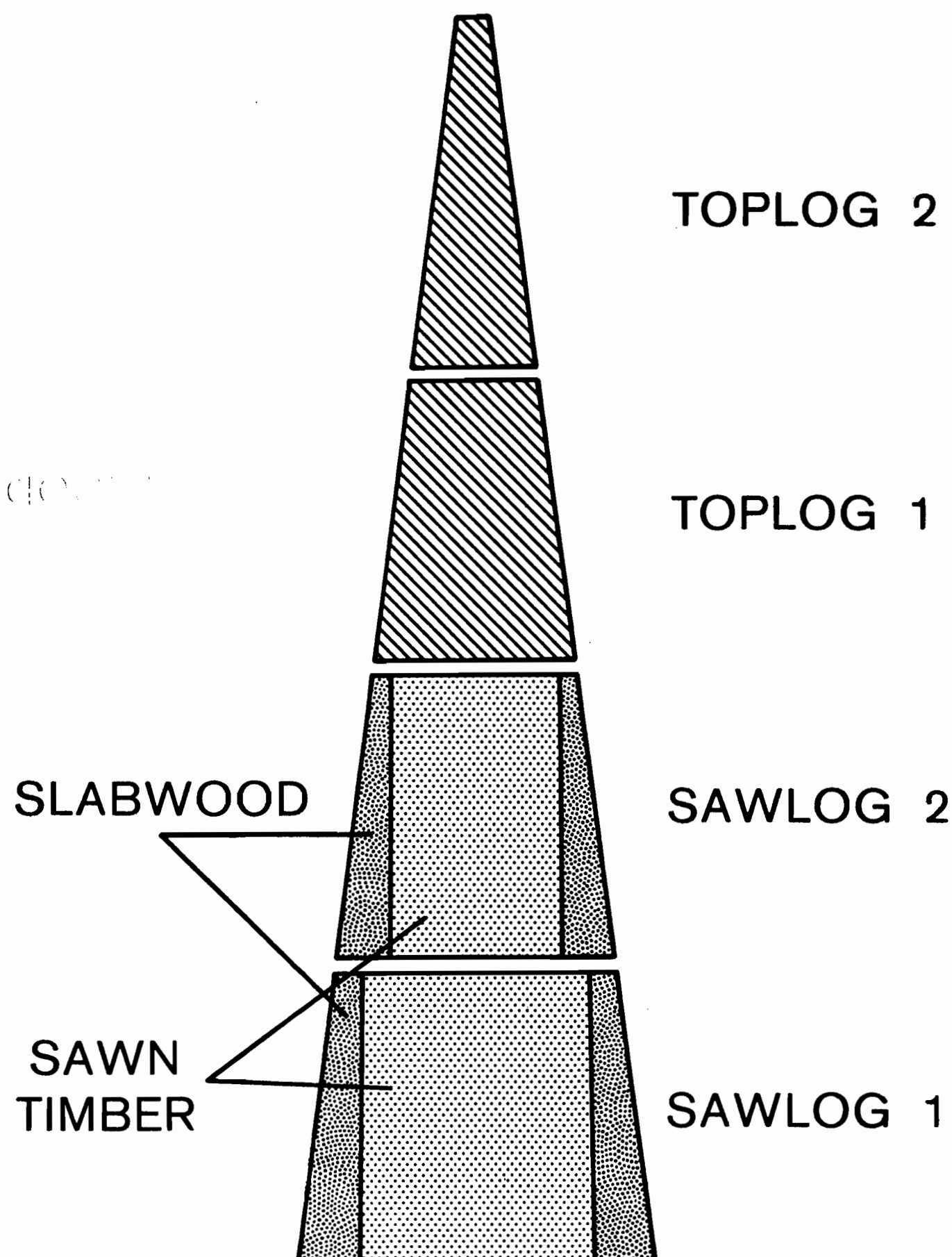(2) Sawmill residues which are predominantly from slabwood and of outerwood quality.

FIG. 2—Schematic diagram of tree components (after Cown & McConchie 1982).

The top-log category necessarily also includes whole-tree thinnings and whole trees <20 years old. Wood chips from this type of material are predominantly of corewood quality, with basic densities of 280 to 400 kg/m³ depending on tree age and the forest stand silvicultural history (Cown & McConchie 1982; Kibblewhite 1984a).

Finally, wood moisture content decreases with tree age and can be higher for top logs than for slabwood. Also, moisture content is higher and basic density is lower for whole trees (thinnings) than for top logs (from older trees) which contain roughly the same number of growth layers (Fig 3) (Cown & McConchie 1982; Cown *et al.* 1984).

Geographic locations of growing sites also influence wood basic density, moisture content, and tracheid length. As latitudes increase from north to south, and as altitudes
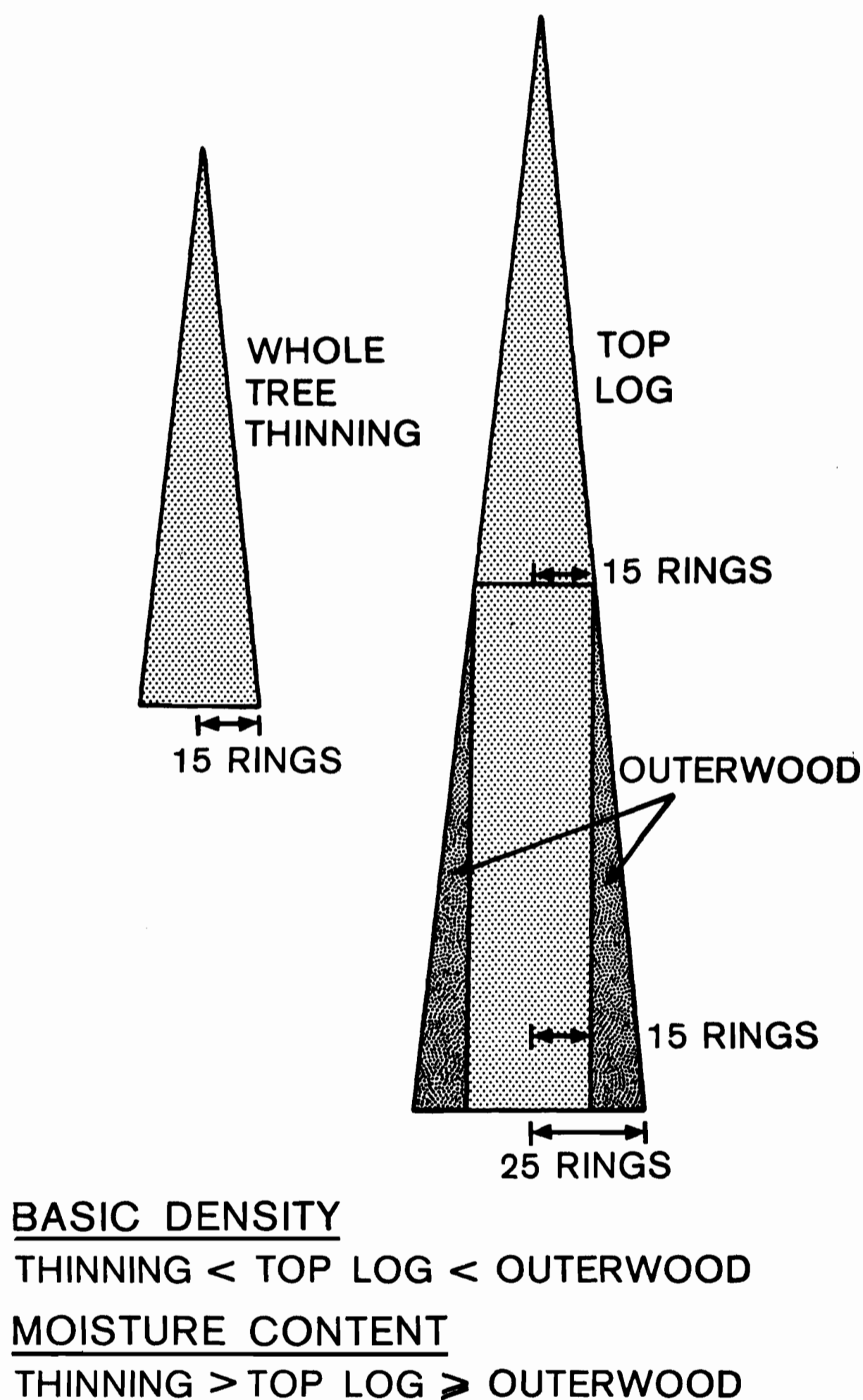

WHOLE TREE THINNING

TOP LOG

15 RINGS

OUTERWOOD

15 RINGS

15 RINGS

25 RINGS

BASIC DENSITY

THINNING < TOP LOG < OUTERWOOD

MOISTURE CONTENT

THINNING > TOP LOG ≳ OUTERWOOD

FIG. 3—**Pinus radiata** whole-tree thinnings and top logs of the same number of growth layers have different wood basic densities and moisture contents.

increase from sea level, wood moisture content generally increases and wood basic density and tracheid length generally decrease (Fig. 4) (Cown & McConchie 1983; Cown *et al.* 1984).

It is recognised that wood residues from *P. radiata* top logs and sawmill slabwood are of very different quality. Wood basic density, moisture content, and tracheid length values which can be expected from these two residue categories are listed in Table 1. The values presented vary with tree or crop age, the geographic location of tree growing sites, and sawmill processing constraints (i.e., sawlog small-end diameter). Because of this, the variation within each of the wood residue types can be expected to be high. Irrespective of such quality ranges, the two wood residue categories are clearly very different and are easily segregated during log harvesting and/or wood processing operations. In general, wood basic density for top logs is <400 kg/m^3 and for slabwood >400 kg/m^3, tracheid length for top logs is <3 mm and for slabwood >3 mm, and kraft pulp weighted average fibre length for top logs is <3 mm and for
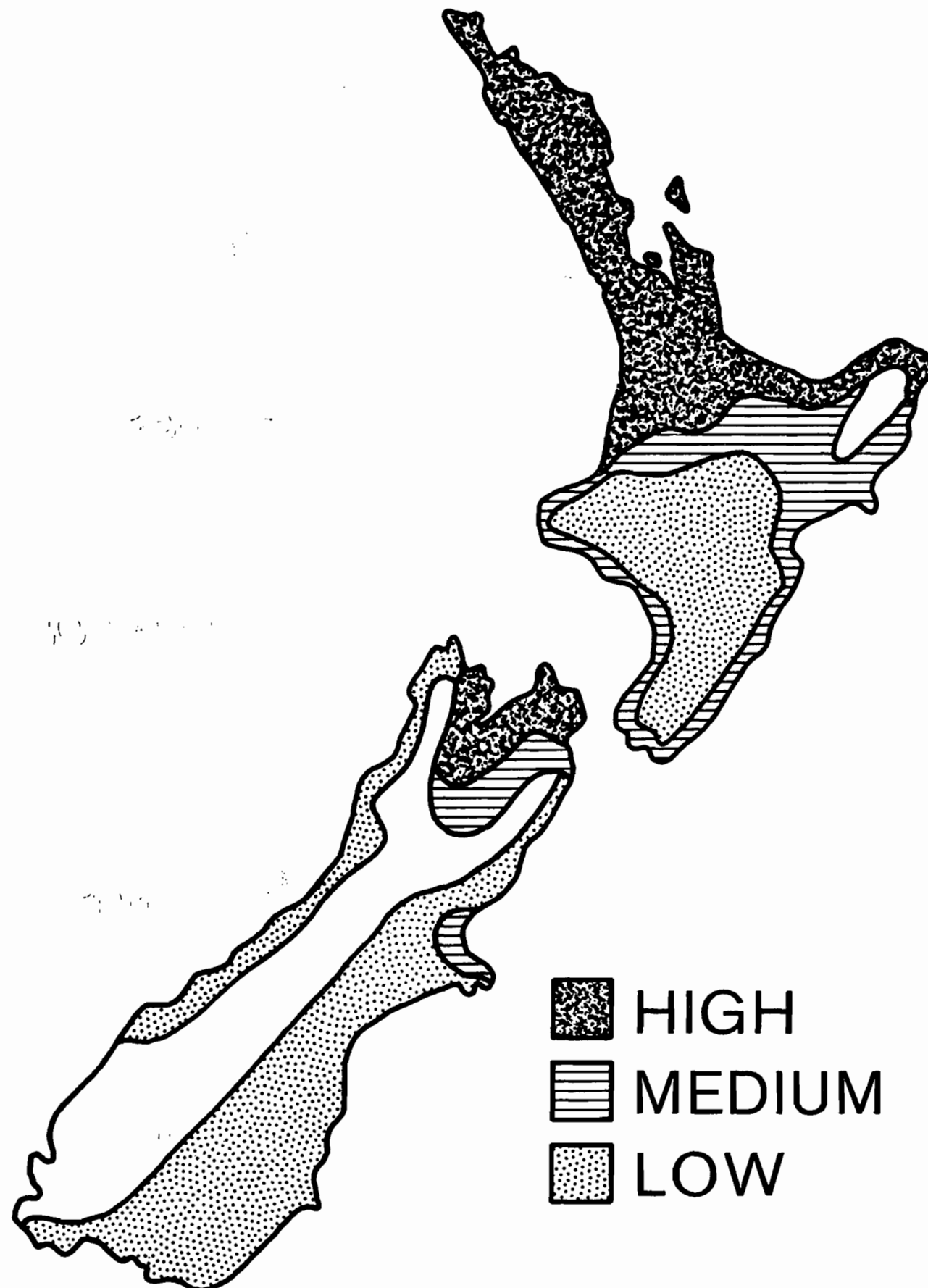

FIG. 4—Geographic distribution of **P. radiata** wood basic densities in New Zealand (**after** Cown & McConchie 1983).

TABLE 1—Wood properties of residue types

	Top logs* (<25 cm s.e.d.)	Sawmill slabwood residues
Selected trees from Kaingaroa Forest (Cown & McConchie (1982)		
Basic density (kg/m³)	325–410	420–475
Tracheid length (mm)	2.5–3.2	3.6–4.0
Moisture content (%)	215–125	160–130
Commercial wood chips from throughout New Zealand (Kibblewhite 1984a)		
Basic density (kg/m³)	320–407	399–500
Kraft pulp weighted average		
fibre length (mm)†	2.0–2.7	2.6–3.6

* Kibblewhite (1984a) refers to wood from top logs and thinnings as pulpwood.
† Refers to both the intact and shortened tracheids of wood chips (Kibblewhite 1984a). Tracheid length normally refers to intact wood tracheids only (Cown & McConchie 1983).

slabwood >3 mm. As far as wood moisture content is concerned, it is re-emphasised that for whole-tree thinnings from crops less than about 20 years old, moisture contents can be substantially higher than those of either the top logs or whole trees of older crops (Cown & McConchie 1982; Cown *et al.* 1984).

WOOD RESIDUE QUANTITIES

A forecast of the future yield from New Zealand's forest plantation was presented to the first session of the 1981 Forestry Conference by Elliot & Levack (1984). This supply projection was based on the current management intentions of all forest owners in terms of the rates of new planting, the application of management regimes, and the timing and magnitude of harvest. Resource projections refer to total exotic wood supplies rather than just P. *radiata*, but by 1986 P. *radiata* will account for 92% of the total exotic forest. This forecast was later modified by the Processing Options Working Party to take account of findings of the Radiata Pine Task Force (Forestry Conference 1981).

As shown in Fig. 5, there will be no significant increase in over-all annual log production until 1991, but by the year 2000 volumes will double, and then increase by a further 75% between 2000 and 2015 (Forestry Conference 1981). The estimated wood volume trends shown in Fig. 5 are considered to be generally valid for 1984 although present indications suggest that, for the period 1991 and beyond, the pre-dicted wood volume increases could be delayed by as much as 5 years. This has resulted from actual growth rates for some regions being slower than predicted, particularly for the Northland region (H. H. Levack, pers. comm.). The wood volume trends (Fig. 5) need to be interpreted with a degree of caution since a significant proportion of the resource is dispersed throughout New Zealand, often in relatively small forests and in areas which will result in high harvesting and transportation costs (Bunn 1981).
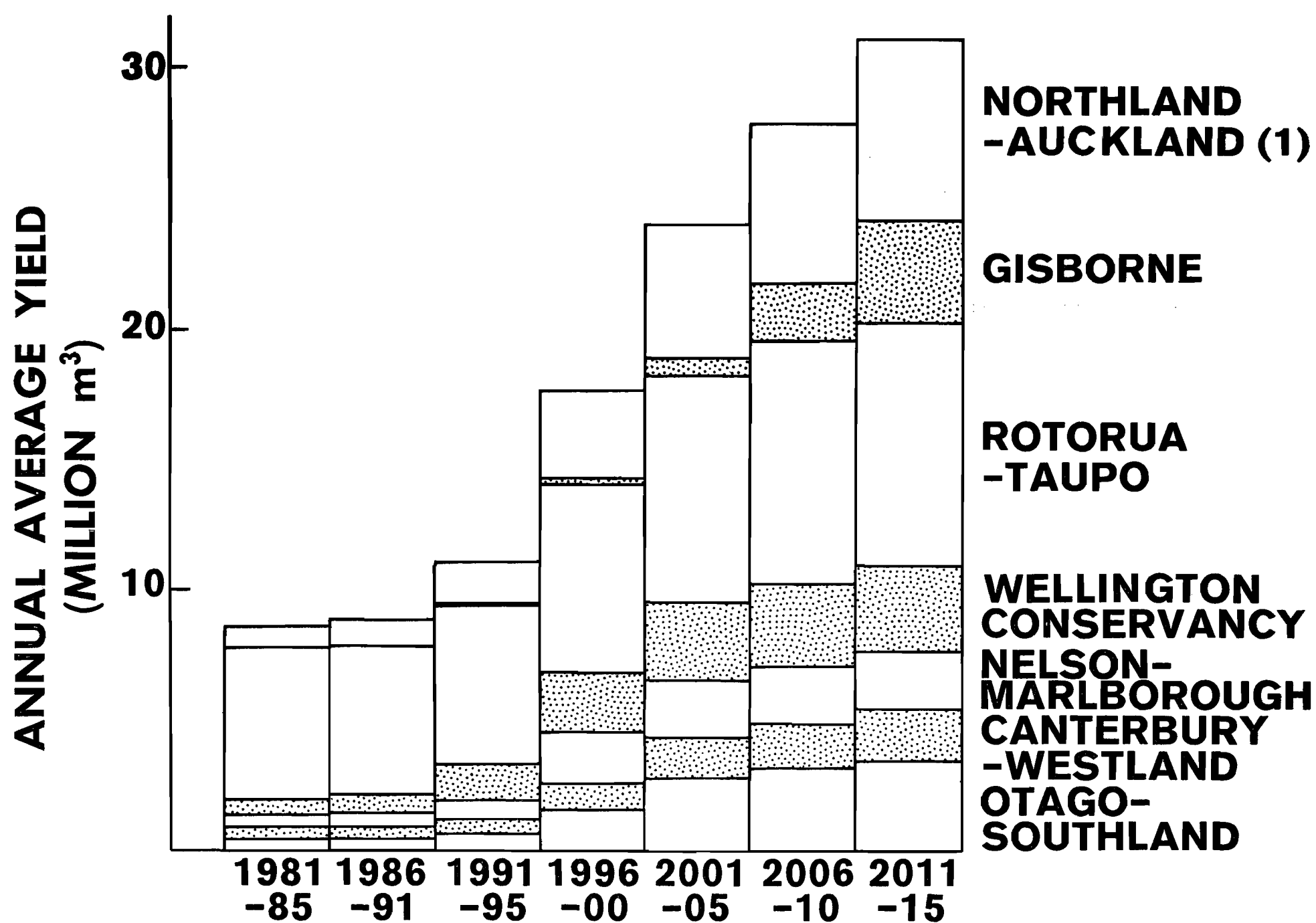
FIG. 5—New Zealand exotic supply forecasts by regions (after Forestry Conference 1981).

Classification of the forecast wood production into log types is presented in Fig. 6 (Forestry Conference 1981), but for this forecast small logs (top logs) were taken as having a small-end diameter of <20 cm rather than <25 cm as used in Table 1. If sawmill residues for this forecast (Fig. 6) are taken as 35% of all logs <20 cm s.e.d. (in accordance with the 1981 Processing Options Working Party (Forestry Conference 1981)), then volume forecasts for top logs (small logs), sawmill residues, and solid wood products (plus sawdust) are as shown in Fig. 7. On this basis, wood residue volumes (top logs plus the slabwood from sawn sawlogs) constitute about 50% of the forecast total resource. Such an estimate represents the minimum residue volumes which will be available since in practice the 20 cm s.e.d. for top logs is likely to be substantially higher, and significant quantities of the sawlogs could be found to be unsuitable for processing into solid wood products. For example, by increasing sawlog small-end diameter from 20 to 30 cm the proportion of wood residues is increased from about 50% to about 68% (Forestry Conference 1981). It is conceivable, therefore, that wood residue volumes will ultimately constitute some 60 to 70% of the total radiata pine wood resource.

SOME WOOD RESIDUE UTILISATION OPTIONS

Two *P. radiata* wood residue types are recognised – top logs and slabwood (Table 1). In dealing with wood residues, wood substance content rather than over-all residue volume is the criterion of importance for the processor. Thus, top logs contain less
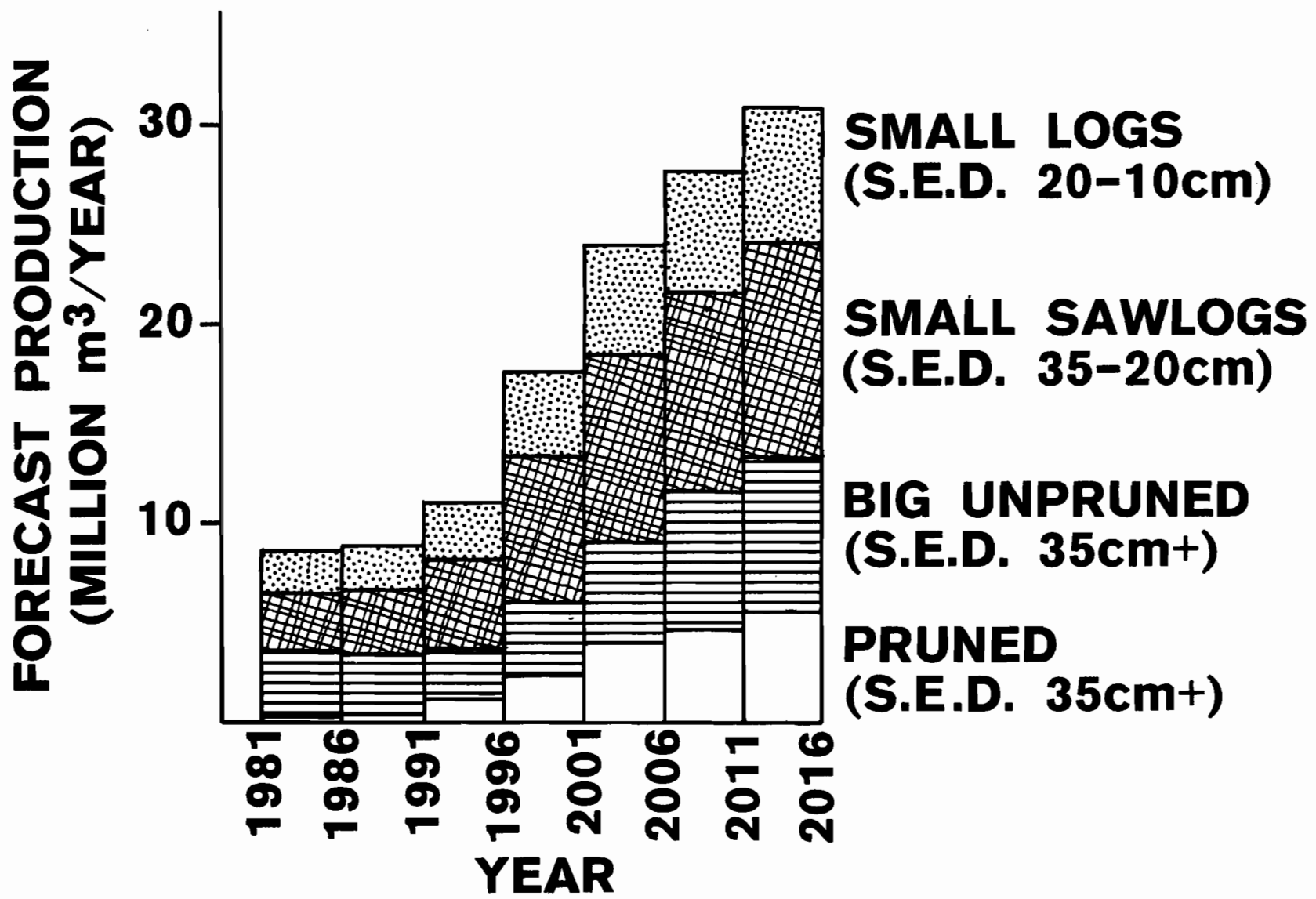
FIG. 6—Exotic log production by type (**after** Forestry Conference 1981).
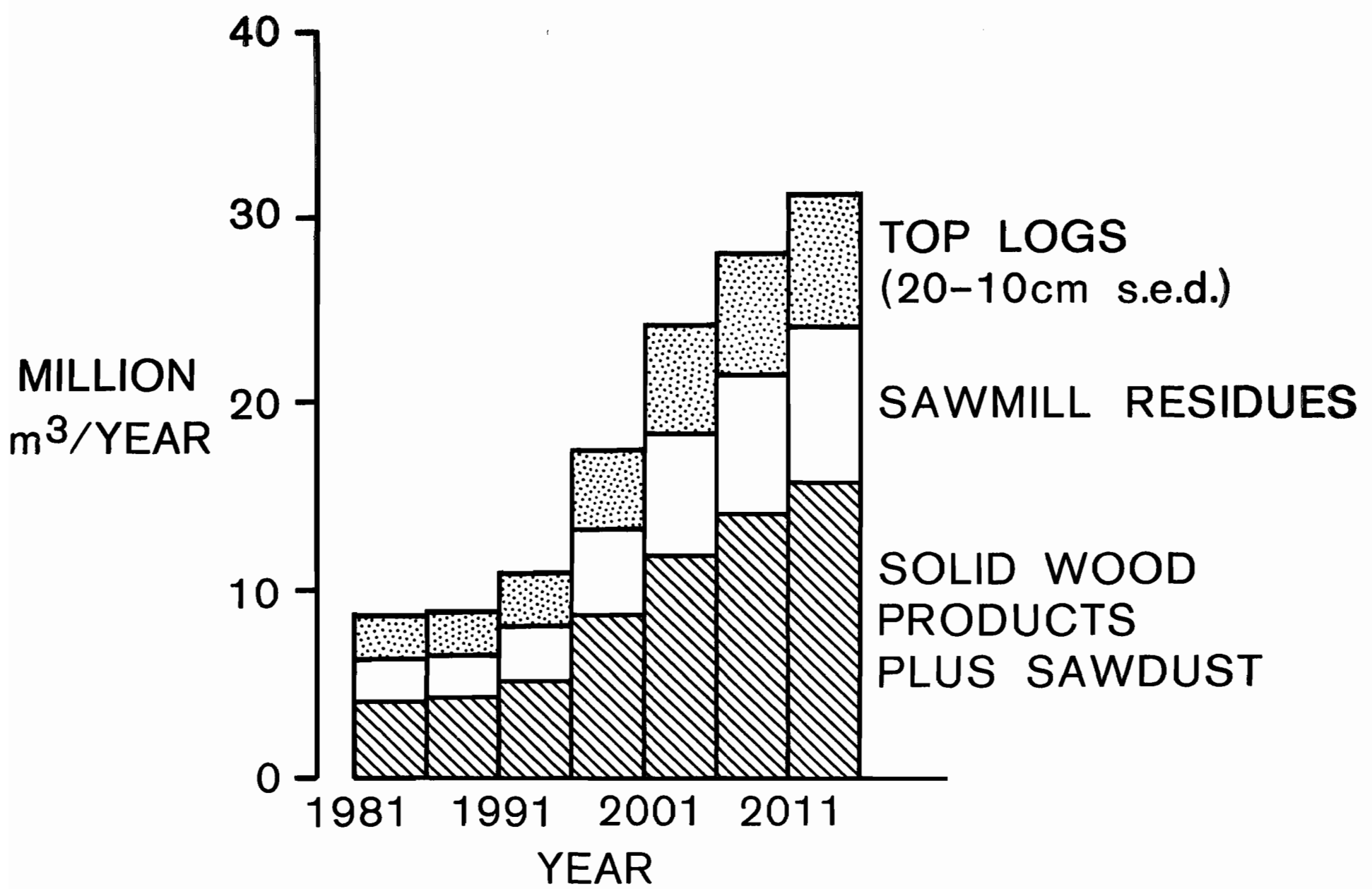

FIG. 7—Wood residue production based on top logs being <20 cm s.e.d.

wood substance for a given volume and weight than do slabwood residues (Table 1). For a given wood substance content, therefore, harvesting, transportation, and processing operation efficiencies and costs can vary widely depending on residue qualities and types.

Several options for the utilisation of wood residues are available:

(1) Top logs and thinnings can be left in the forest;

(2) Sawmill residues can be transported from a processing plant and dumped, or they can be burnt on-site as a source of energy;

(3) Sawmill residues can be chipped and used in on-shore or off-shore processing plants. Similarly, top logs and thinnings can be harvested from the forest and also used in on-shore or off-shore processing plants.

As far as the processing of wood residues is concerned, the following product options are available:

(1) The manufacture of chemicals, e.g., ethanol and methanol;

(2) The manufacture of reconstituted panel products, e.g., particleboard, fibre board, and medium-density fibre board;

(3) The manufacture of a wide range of pulp, paper, and paperboard products.

Although suitable technologies are available for converting wood into the above product categories, it is recognised that wood residue qualities can strongly influence processing operation throughputs since wood substance/wood volume ratios are very different for top log and slabwood material. For the manufacture of chemicals and reconstituted panels, it is expected that product qualities will be essentially unchanged by the different basic density and tracheid properties of top log and slabwood residues (Table 1). For pulp and paper products, on the other hand, product qualities are very much affected by wood and tracheid characteristics (Corson 1984; Kibblewhite 1982, 1984a, 1984b). The remainder of this paper is, therefore, concerned with the relationships between top log and slabwood residue qualities and kraft and thermo-mechanical pulp and paper properties.

WOOD RESIDUE AND KRAFT PULP QUALITIES

For kraft pulps prepared from top log (pulpwood) and slabwood residues from "old-crop" (52 years old) and "new-crop" (24 years old) trees, and from new-crop thinnings (12 years old), very definite wood, pulp, and handsheet interrelationships have been found (Kibblewhite 1984a). The mean basic density and mean fibre dimensions for each of these wood (or pulp) samples were very different and this was reflected in final handsheet properties (Table 2, Fig. 8). Furthermore, a wide range of top log and slabwood residues collected from commercial wood-processing plants throughout New Zealand gave almost identical trends and relationships to those of Fig. 8 (Kibblewhite 1984a). Wood property/handsheet property interrelationships were also found to be independent of the geographic location of sample sites (Fig. 9). The conclusions of this previously reported study were:

(1) *Pinus radiata* kraft pulp properties of handsheet tear, burst and tensile index, and apparent density can be predicted from chip basic density alone;

(2) Effects of including pulp fibre length in the handsheet-property/chip-basic-density predicting relationships are negligible.

(3) Chip-basic-density/handsheet-property relationships hold for whole trees (thinnings), parts of trees, and commercial pulpwood and sawmill residue chips.

TABLE 2—Sample chip basic densities and kraft pulp mean fibre dimensions

	Age of trees in sample (years)	Chip basic density (kg/m³)	Kraft pulp properties		
			Weighted average fibre length (mm)	Fibre wall thickness (μm)	Fibre diameter (μm)
Old-crop					
Slabwood	52	468	3.3	8.0	40.0
Pulpwood*	52	402	2.8	7.2	40.7
New-crop					
Slabwood	24	423	3.1	6.2	38.4
Pulpwood*	24	383	2.9	5.5	38.7
New-crop					
Thinnings	12	331	2.2	4.2	36.7

* From billet of wood containing 15 growth layers only.

WOOD RESIDUE AND THERMOMECHANICAL PULP QUALITIES

The wood, pulp, and handsheet properties of thermomechanical pulp (TMP) and refiner mechanical pulp (RMP) made from *P. radiata* slabwood and top logs have been described in a comprehensive treatise by Corson (1984). It was shown in this study that slabwood consumes more energy to a given freeness and produces pulps of higher strength than corewood. Both power consumption and sheet strength increase marginally with an increase in wood basic density. Conversely, pulps from top logs have excellent optical properties whereas those from slabwood are of a slightly lower quality.

Very definite fibre quality differences exist for TMP (or RMP) pulps made from slabwood and top log residues (Kibblewhite 1984b) and explain in part their different pulp and handsheet properties. For example, slabwood pulps consist of high proportions of fibres which are longer, stiffer (less collapsed), and less damaged than those of pulps made from top logs. Furthermore, the fines material (of the –100/+200 pulp fraction) of slabwood pulps consists predominantly of fine fibrillar elements whereas the fines in corresponding top log pulps are more heterogeneous in nature being made up of substantial quantities of both fibrillar material, and short and relatively long fibre
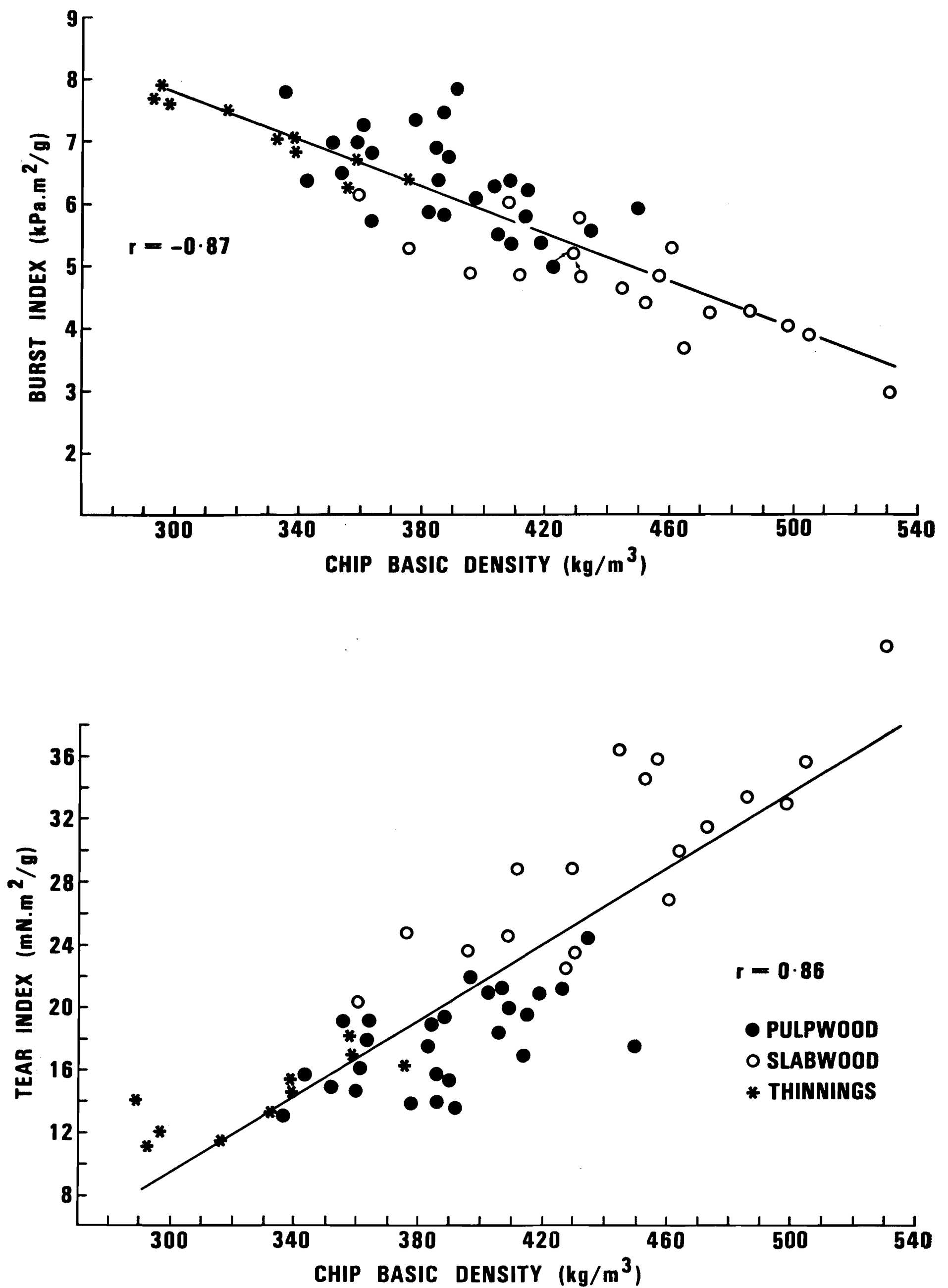
FIG. 8—Handsheet tear and burst indices, and chip basic density relationships -
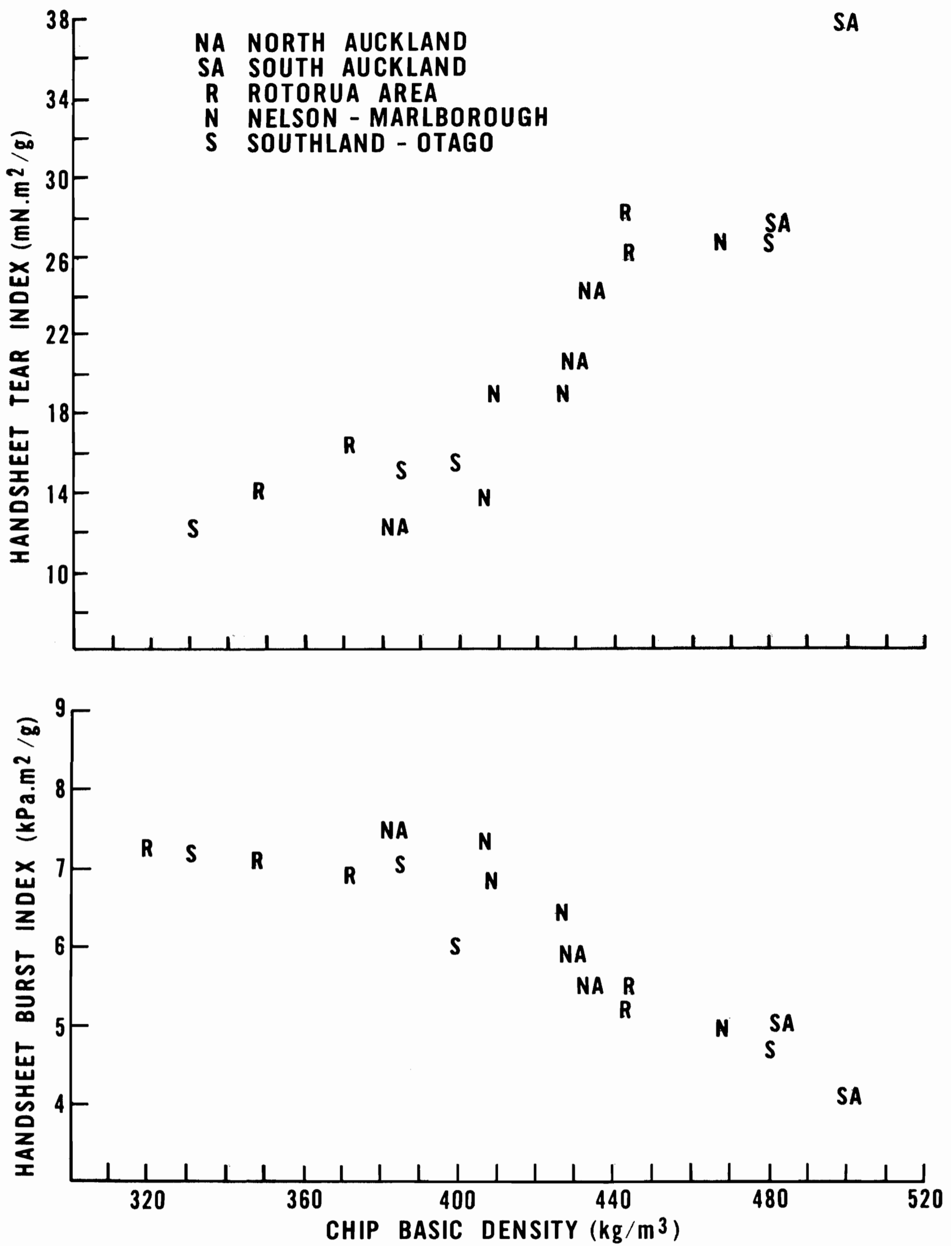influence of wood residue quality.

FIG. 9—Handsheet tear and burst indices, and chip basic density relationships – influence of wood residue geographic origin.

fragments with identifiable lumens. Based on these observations, the high handsheet densities and strengths obtained with the relatively long and stiff fibres of slabwood furnishes are explained in part by the consolidating influence of the fibrillar fines present in this pulp type. In contrast, the heterogeneous nature of the fines in corewood pulps can be used to explain their low handsheet densities (relative to the slabwood pulps), and their excellent handsheet optical properties.

CONCLUSIONS

Pinus radiata wood residue volumes available for utilisation in the period beyond the early 1990s could well constitute some 60 to 70% of the total wood resource.

The wood residue quality parameters of basic density and moisture content can influence processing operation throughputs since wood-substance/wood-volume ratios for top log and slabwood residues are very different. The basic density of top log residues is generally <400 kg/m³, and that of slabwood residues generally >400 kg/m³.

Wood residue basic densities and tracheid dimensions (length, wall thickness, and diameter) can also strongly influence the qualities of chemical and thermomechanical pulps, and of the papers made from them.

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