# A STRENGTH AND STIFFNESS COMPARISON BETWEEN TIMBER FROM TIKITERE, KAINGAROA, AND A NEW ZEALAND WIDE STUDY

D. Gaunt, B. Penellum, K. McNab, J. Roper, J. Turner

Report No. 68 June 2000

FOREST & FARM PLANTATION MANAGEMENT COOPERATIVE

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# EXECUTIVE SUMMARY

## A STRENGTH AND STIFFNESS COMPARISON BETWEEN TIMBER FROM TIKITERE, KAINGAROA, AND A NEW ZEALAND WIDE STUDY

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This report compares the strength and stiffness performance of 190x45 timber cut from the second logs of the 400s/ha stocking using 26 year old trees from the Tikitere farm forestry site and nine stems from 27-year-old stands in Kaingaroa with timber from a 1999 nationwide study [2].

Timber from the three studies was visually graded, machine stress graded, E-graded, assessed for strength & stiffness and a range of wood properties determined.

The results show that:

- Simply ensuring timber is visually graded correctly is no guarantee that the characteristic grade stresses (traditionally associated with that grade) can be achieved.
- The Tikitere timber has a low recovery of MGP8 (~No 1Framing), our most common structural grade, whereas Kaingaroa compares well with the central NI site in the nation-wide study.
- There is a potential financial advantage to be made with the implementation of a performance grading system (using LMOEj as the grading parameter as in the E-Grader), over the old visual grading system in the majority of cases.
- Tikitere is characterised as having low strength and stiffness, which can be associated with having a low nominal density and high ring width.
- Comparing all the studies against a 'New Zealand wide old crop' study show a significant drop in density and increase in ring width. The Tikitere timber accentuates these differences.

## LUMBER SOURCING

### Six Site Study:

The timber was selected as follows:
150 pieces of dry gauged 190x45 timber 4.8m and longer from each of six locations (Figure 1) were purchased. This lumber represented the range of visual grades from No 1Framing to Box at each sawmill (site). The lumber was ordered as 1/3 No 1Framing, 1/3 No 2Framing and 1/3 Box grade. No information on log source, age, or cutting pattern is available for this lumber.

Note that the 6 site study included the 90x45mm framing size, and this size was in fact recovered in both the Kaingaroa and Tikitere trials. However, insufficient pieces were recovered from both these studies to enable in-grade performance to be calculated. Therefore, none of these comparisons extends to the 90x45mm size.

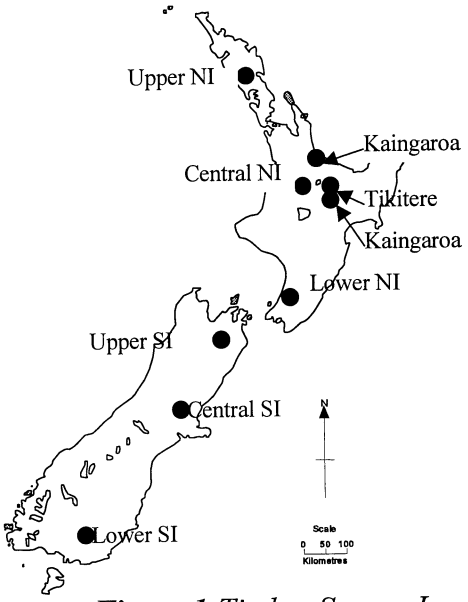


***Figure 1:****Timber Source Locations*

### Tikitere Study

The study timber was cut from selected 26-year-old *Pinus radiata* GF 14 trees grown on the ex-farmland Tikitere site. The stems selected were from within the 400 stems/ha treatment with the timber cut from 5.5m *second logs only* using a cant sawing pattern maximising 200x50 cross-section timber (with 100x50 being the fall down size). Mean BIX was 5.1cm and SED 403mm.

### Kaingaroa Study

The study timber was cut from 27-year-old *Pinus radiata* trees grown on two separate sites, a northern location at Matahina and from a southern location at Matea. Six of the buttlogs had been low pruned to 2.2m. Matahina provided four stems with Matea provided five stems and each stem when merchandised yielded 3 to 4 logs at 4.9m long making 34 logs in total. In order to get a reasonably sized data set the data from the two sites has been combined into one Kaingaroa site. Mean BIX was 5.6cm, and SED 341mm. (Mean IIX for all logs was 0.34 and this included the 2m pruned length on the six low pruned buttlogs).

The original intention for this timber was to study log scanning technologies and thus the logs were cut to a non-standard sawing pattern. A live-sawing pattern was used in conjunction with a "saw-dry-rip" (SDR) processing method to produce the structural lumber maximising 200x50 cross-section timber (with 100x50 being the fall down size).

## LUMBER TESTING

All the timber received was:

- Visually graded at ***Forest Research*** to the NZ visual grading rules (NZS 3631) with the knot area ratio (KAR) measured for the grade determining defect.
- Machine graded using the ***Forest Research*** Computermatic machine stress grader. All the grade points were data logged and the $MoE_{Paverage}$ and $MoE_{Pmin}$ calculated.
- Long span $MoE_j$ (LMoEj) tested using a laboratory test machine (span = 4.5m) in lieu of using the E-grader™.
- Mechanically tested for bending, tension, compression, shear strengths and bending stiffness in accordance with AS/NZS4063
- Ring width, presence of pith, basic and nominal test densities, moisture content and estimated distance from the pith to nearest face was recorded for all test pieces.

## VISUAL GRADING RESULTS

The following visual grading recoveries are based on (an accurate laboratory interpretation of) the New Zealand visual grading rules by ***Forest Research*** staff.

Table 1 shows for the New Zealand Six Sites, Tikitere and Kaingaroa studies the visual grade recoveries. Where possible the characteristic stiffness and strength properties have been derived for each visual grade. Table 2 lists the characteristic grade stress for the No. 1 Framing, No. 2 Framing visual grades.

Due to limited amount of timber, within grade for each of the six sites it was not possible to determine the characteristic stresses on a site by site basis and hence the characteristic stresses have been calculated on the combined New Zealand wide sample.

Figure 2 however show the visual grade outturn of each of the six sites, Tikitere and the combined Kaingaroa studies.

*Table 1: 190 x 45 Visual grade recoveries and characteristic strength properties.*

| Study | New Zealand Visual Grade | Grade Outturn % | Bending Stiffness GPa | Bending Strength MPa | Compression Strength MPa | Tension Strength. MPa |
|---|---|---|---|---|---|---|
| **Six sites** | No 1Framing | 8% | 9.12 | 18.18 | 28.11 | 12.44 |
| **Tikitere** | | 18% | 7.54 | 11.96 | 21.59 | 9.44 |
| **Kaingaroa** | | 22% | 9.61 | 11.00 | 29.92 | 7.17 |
| **Code values** | | | **8.00** | **17.70** | **20.90** | **10.60** |
| **Six sites** | No 2Framing | 28% | 8.20 | 13.48 | 25.18 | 8.10 |
| **Tikitere** | | 24% | 6.18 | 9.52 | 16.87 | 5.69 |
| **Kaingaroa** | | 35% | 7.85 | 15.11 | 18.99 | 4.89 |
| **Code values** | | | **6.10** | **13.00** | **9.70** | **7.70** |
| **Six sites** | Box | 64% | 6.95 | 9.69 | 21.25 | 6.02 |
| **Tikitere** | | 58% | 5.30 | 7.48 | 16.83 | 4.06 |
| **Kaingaroa** | | 43% | 6.51 | 6.52 | 12.81 | 3.84 |

***Table 2.** Characteristic Grade stresses for 45mm thickness ranked in order of bending stiffness*

| Grade | Bending Stiffness GPa | Bending Strength MPa | Tension Strength MPa | Compression Strength Mpa | Shear Strength MPa |
|---|---|---|---|---|---|
| **MGP 6*** | 6.0 | 10.0 | 4.0 | 19.0 | 2.5 |
| **F4** | 6.1 | 13.0 | 6.5 | 9.7 | 1.5 |
| **No 2Framing#** | 6.1 | 13.0 | 7.7 | 9.7 | 1.5 |
| **F5** | 6.9 | 16.2 | 8.2 | 12.1 | 1.8 |
| **F7** | 7.9 | 20.4 | 10.3 | 15.3 | 2.1 |
| **MGP 8*** | 8.0 | 14.0 | 6.3 | 20.0 | 4.0 |
| **No 1Framing** | 8.0 | 17.7 | 10.6 | 20.9 | 3.8 |
| **F8** | 9.1 | 25.4 | 13.05 | 19.5 | 2.5 |
| **MGP 10** | 10.0 | 19.0 | 8.9 | 24.0 | 5.0 |
| **Engineering** | 10.5 | 27.7 | 16.5 | 25.7 | 3.8 |
| **F11** | 10.5 | 32.5 | 16.6 | 24.8 | 3.1 |
| **F14** | 12.0 | 41.3 | 21.1 | 30.1 | 3.7 |
| **MGP 12** | 12.7 | 28.0 | 15.0 | 29.0 | 6.5 |
| **MGP 15** | 15.2 | 41.0 | 23.0 | 35.0 | 9.1 |

* Proposed new New Zealand MGP grades

\# Assumed equal to F4 as no grade stresses exist for No 2Framing.

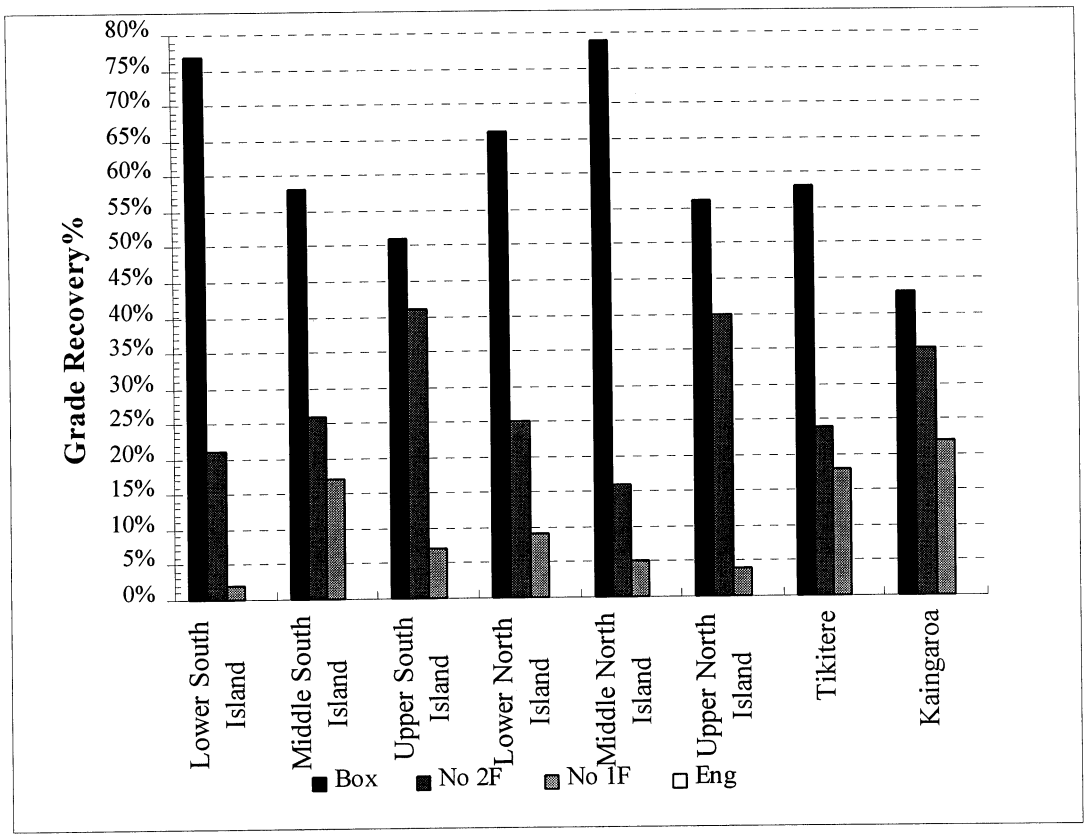


***Figure 2**: 190 x 45 Visual Grade Recovery*

From Table 1 in comparison with the characteristic values in Table 2:

- With the exception of the No 1F bending and tension strengths for both Kaingaroa and Tikitere, all the visual grade stresses were achieved for the 190x 45 sizes. Note No 2F has been assigned the grade stresses associated with F4.
- The Tikitere No 1Framing 190x45 timber failed to achieve the required bending stiffness, bending & tension strengths but achieved the compression strength.
- The Kaingaroa No 1Framing 190x45 timber failed to achieve the required bending and tension strengths, but achieved the bending stiffness and compression strength.
- The Tikitere No 2Framing 190x45 timber failed to achieve the required bending and tension strengths but achieved the bending stiffness and compression strength.
- The Kaingaroa No 2Framing 190x45 timber only failed to achieve the required tension strength but achieved the bending stiffness and bending & compression strengths.

The difference in grade recoveries is difficult to quantify in that:

- Kaingaroa has a non-standard saw pattern
- The fact that the six-site timber was purchased as (supposedly) one third mix of the three visual grades as opposed to being part of a sawing study ie. Tikitere or Kaingaroa.

The variation in grade stresses for timber within a visual grade again reinforces the need for a performance grading system, i.e. the MGP, Machine Graded Pine system which relies on some form of stiffness grading machine. Simply ensuring timber is visually graded correctly (from the younger trees now sawn) is no guarantee that the grade stresses can be achieved. After all when a timber element is asked to carry a load, it is it's performance under that load that matters, not it's appearance.

## MACHINE STIFFNESS GRADING (MSG) RESULTS

All the study lumber was machine stress graded using the ***Forest Research*** Plessey Computermatic stress grader. This grader, as do traditional machine stress graders, determines the $MoE_{Pmin}$ parameter, defined as the lowest stiffness section of the piece when graded as a plank over a 914mm span with a grading interval of 152mm. Recording all the MoEp data points allows calculation of the $MoE_{Paverage}$ parameter.

In contrast, long span MoEj (LMoEj), as measured by the new E-Grader™ is simply a single stiffness measurement over a long span testing the piece on edge i.e. as a joist.

The merits of using the different grading parameters are discussed in two papers [1];[2], the second paper was prepared using the data for the six site study. In summary

- A performance grading operation relies on known and reliable relationships between the grading parameter and the actual stiffness/strengths. The best relationships have been found with LMoEj, the next best with $MoE_{Paverage}$ and poorest relationships were found with $MoE_{Pmin}$.
- On a MGP grade recovery basis (grade stresses achieved) considerable variation is apparent when comparing the four grading methods of visual grading, stiffness grading using $MoE_{Pmin}$, $MoE_{Paverage}$ or LMoEj. The grading parameter that results in the best recovery of timber in the higher MGP grades is LMoEj, followed by $MoE_{Paverage}$ , and $MoE_{Pmin}$..

Thus using the best available grade parameter (LMoEj) the following Tables 3 and 4 have been calculated. These show the comparison between MGP (Machine Grade Pine) and 'F' grade recoveries for the three studies (data reworked to ensure all grade stresses are achieved for each grade). Figure 3 shows MGP recoveries of each of the six sites, Tikitere and the combined Kaingaroa studies

***Table 4**: 190 x 45 Machine Graded Pine MGP grade recoveries by the LMoEj parameter.*

| Machine Stress Grade | Six Sites Study | Tikitere | Kaingaroa |
|---|---|---|---|
| **Reject** | 11% | 44% | 20% |
| **MGP6** | 32% | 34% | 39% |
| **MGP8** | 38% | 19% | 31% |
| **MGP10** | 19% | 3% | 10% |

***Table 5**: 190 x 45 Machine Grade 'F' grade recoveries by the LMoEj parameter*

| Machine Stress Grade | Six Sites Study | Tikitere | Kaingaroa |
|---|---|---|---|
| **Reject** | 19% | 55% | 24% |
| **F4** | 26% | 26% | 39% |
| **F5** | 50% | 19% | 37% |
| **F8** | 5% | 0 | 0 |

From Tables 4 and 5:

- The timber from Tikitere produces results of 44% being assigned to the reject grade and only 22% falling into the MGP8&10 grade. MGP8 is commonly considered as a substitute* for No 1Framing timber in domestic housing construction with MGP6 a substitute* for No 2Framing. (* Not a direct substitute however.)

- The Kaingaroa timber is more typical on the New Zealand Study (six-site study) but however only 41% fell into the MGP8&10 grade.
- Comparing the MGP and 'F' grade recoveries shows a lower recovery in the higher stiffness 'F' grades. The reason behind this is that the MGP system has been developed specially for radiata pine whereas the 'F' grade system has been developed for Australian hardwoods.

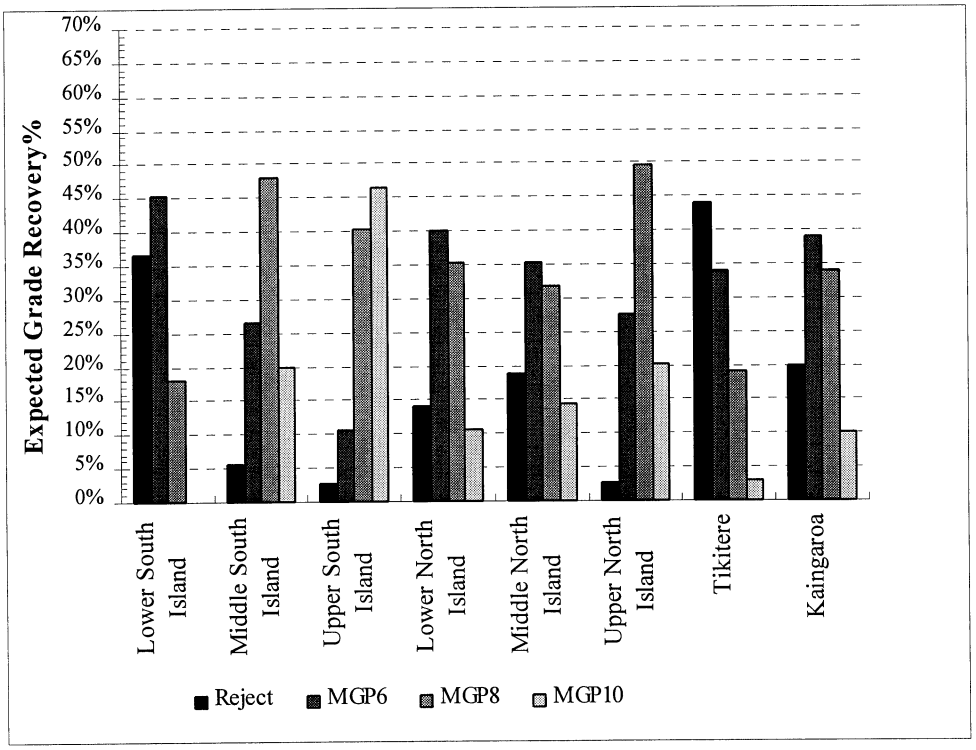


***Figure 3**: 190 x 45 Expected MGP Grade Recovery*

From Figure 3 the Tikitere grade outturn are similar to those from the southern South Island site, which traditionally is known to produce low-density timber with poor structural grade yields. The low recovery of MGP8 timber would appear to be a concern for the Tikitere site. The Kaingaroa timber in terms of grade outturn appears similar to the middle North Island site.

## THE FINANCIAL EFFECT OF DIFFERENT GRADING PARAMETERS ON GRADE RECOVERY

To put a dollar value comparison on the study timber the following Figure 4 has been prepared which aims to show the financial differences with visual and performance grading (MGP with the LMoEj parameter) grading between the sites. The basis of this comparison has been an assumption that:

| | |
|---|---|
| Box/Reject | is valued at \$150/$m^3$, green, off the saw. |
| No 2F/MGP6 | is valued at \$225/$m^3$, green, off the saw. |
| No 1F/MGP8 | is valued at \$300/$m^3$, green, off the saw. |
| MGP10 | is valued at \$330/$m^3$, green, off the saw. |

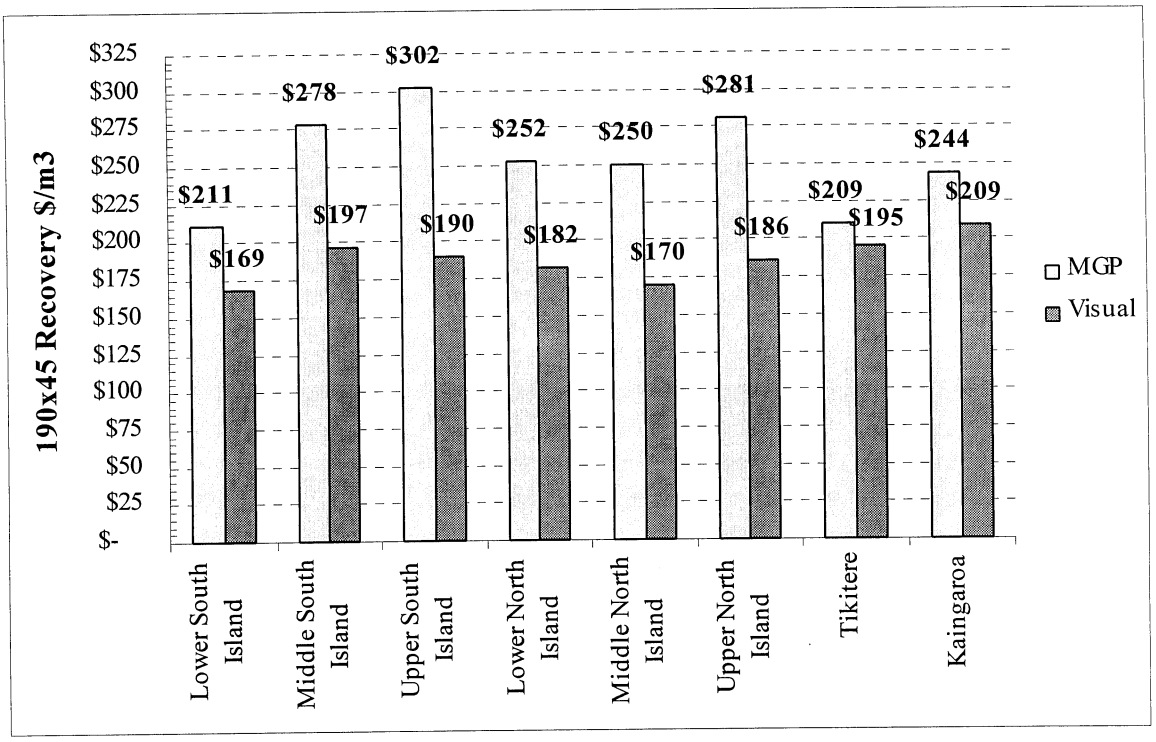


***Figure 4**: 190x45 Weighted Average Contributions and the Total $/m^3$ Financial Recoveries by region between Visual and MGP using LMoEj grading*

From Figure 4 it can be seen that performance grading does offer some financial gain over visual grading. The biggest gains are generally associated with the higher stiffness (density) locations, in this case the upper regions of both the North and South Islands. The Tikitere site shows the lowest Financial return with Kaingaroa being comparable to the middle North Island site at least on a MGP basis.

## CUMULATIVE FREQUENCY COMPARISONS

The following Figures 5 to 13 show comparisons between the six sites, Tikitere and Kaingaroa studies. Figures 5, 6, 7 & 8 compare the bending stiffness, bending, tension and compression strengths. Figures 9, 10, & 11, compare the failure knot area ratio nominal, and average, ring width.

In Figures 10 and 11 a comparison is shown with 'old crop' 190x45 from an earlier nationwide sample.

**Definitions**

1. Nominal density is defined as the oven dry weight over the volume before drying expressed in $kg/m^3$.

2. Ring width was the average ring width of the growth rings crossed by a line drawn through the centroid of the section in a radial direction.

3. The failure defect is the defect that failed during the strength tests. This is normally in the centre of the test spans and may or may not be the same as the grade determining defect.

4. The knot area ratio is defined as the cross sectional area of the knot over the total timber cross section expressed as a percentage.

5. The largest knot is the diameter of the largest knot in millimetres.

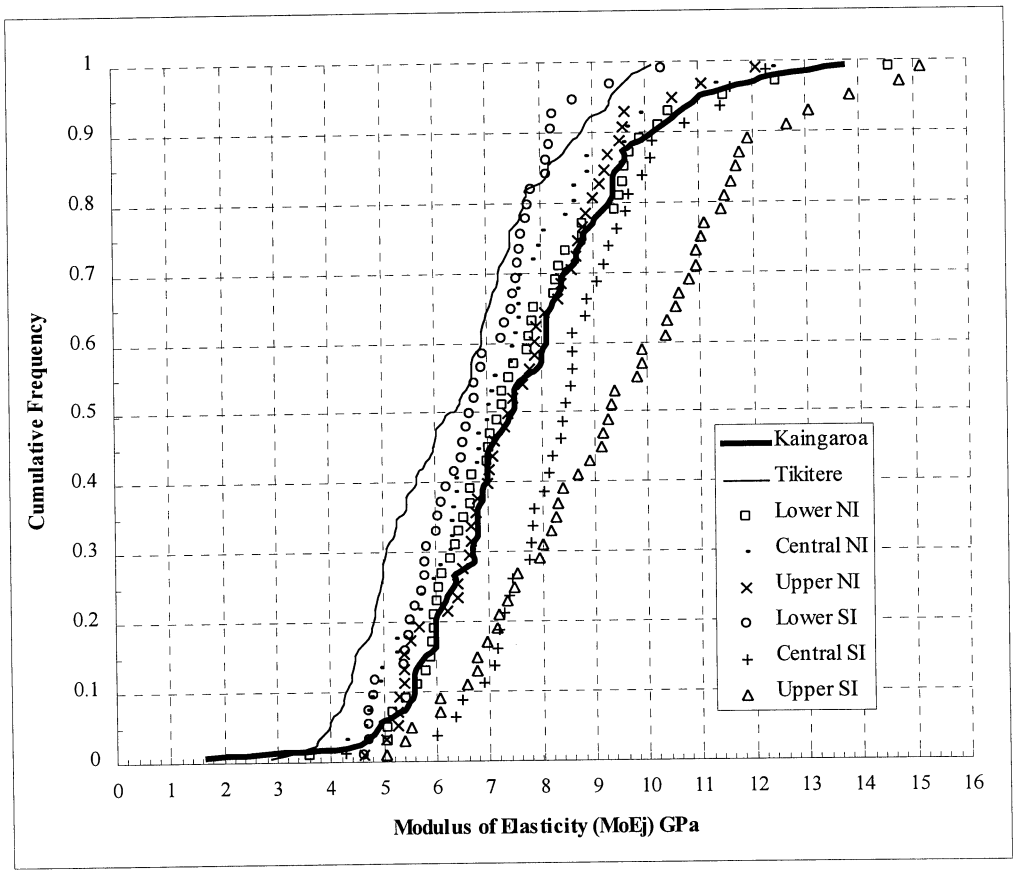


***Figure 5**: 190 x 45 Bending Stiffness Comparison*

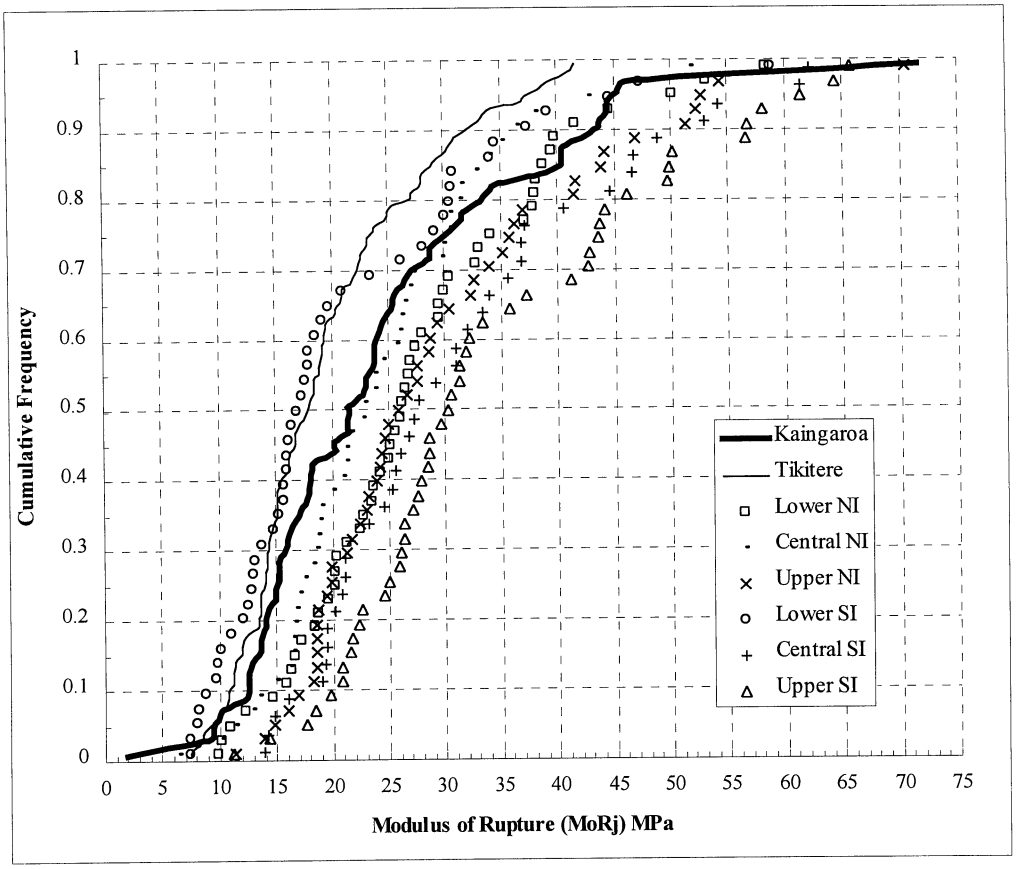


***Figure 6**: 190 x 45 Bending Strength Comparison*

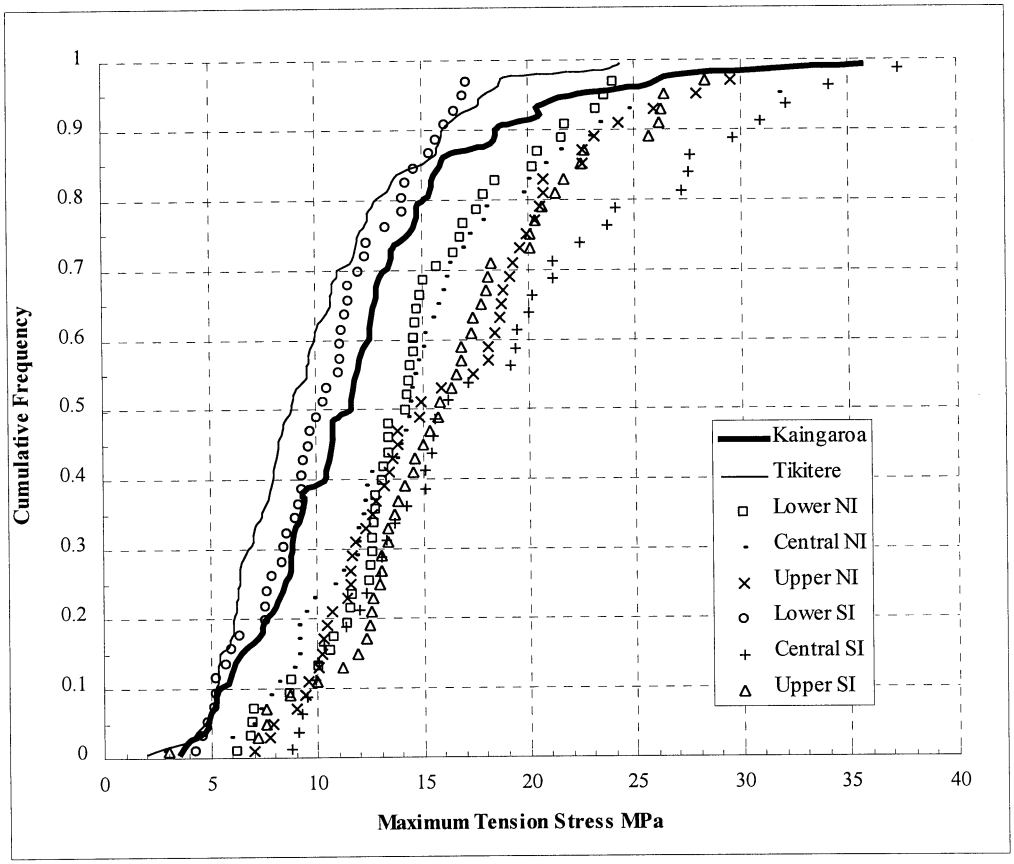


***Figure 7**: 190 x 45 Tension Strength Comparison*

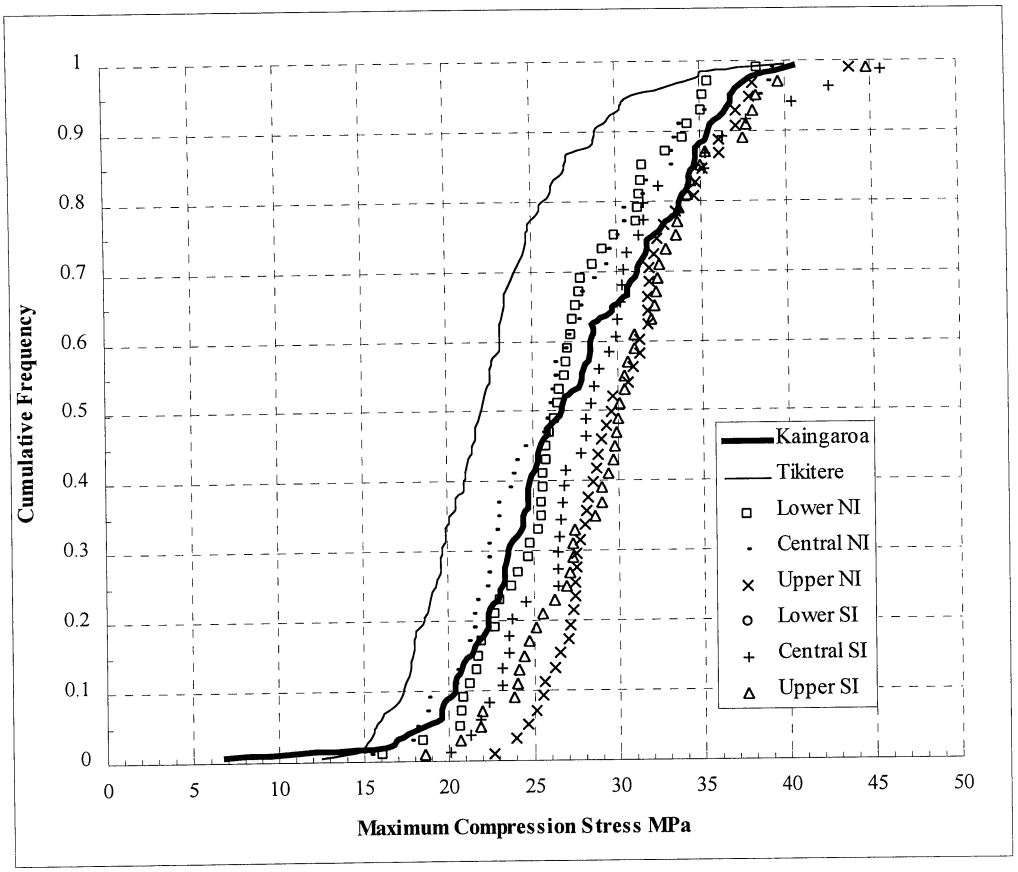


***Figure 8**: 190 x 45 Compression Strength Comparison*

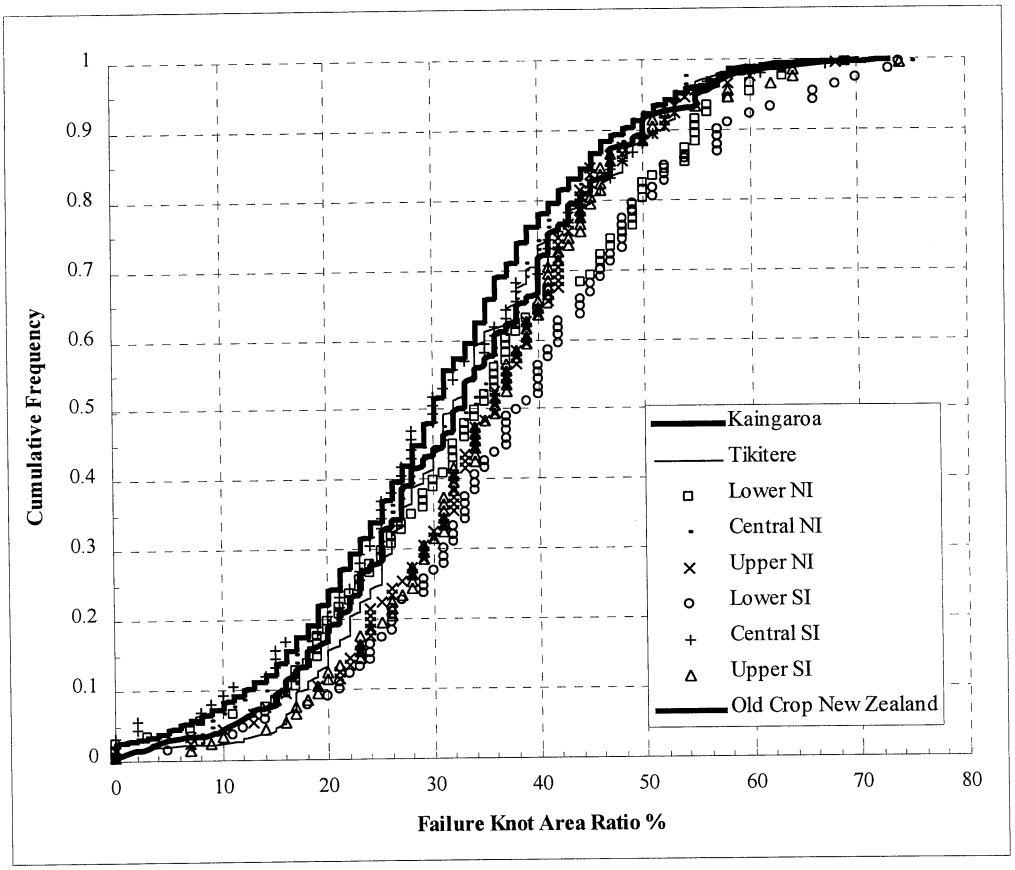


***Figure 9**: 190 x 45 Failure Knot Area Ratio Comparison*

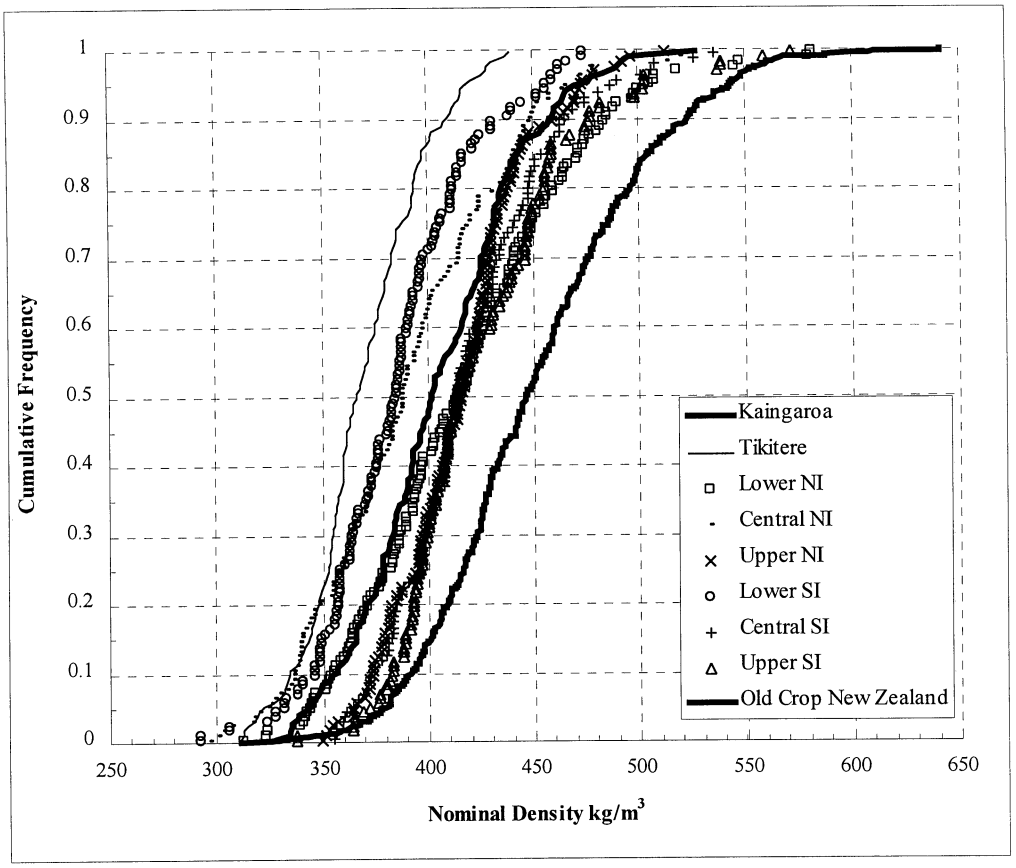


***Figure 10**: 190 x 45 Nominal Density Comparison*

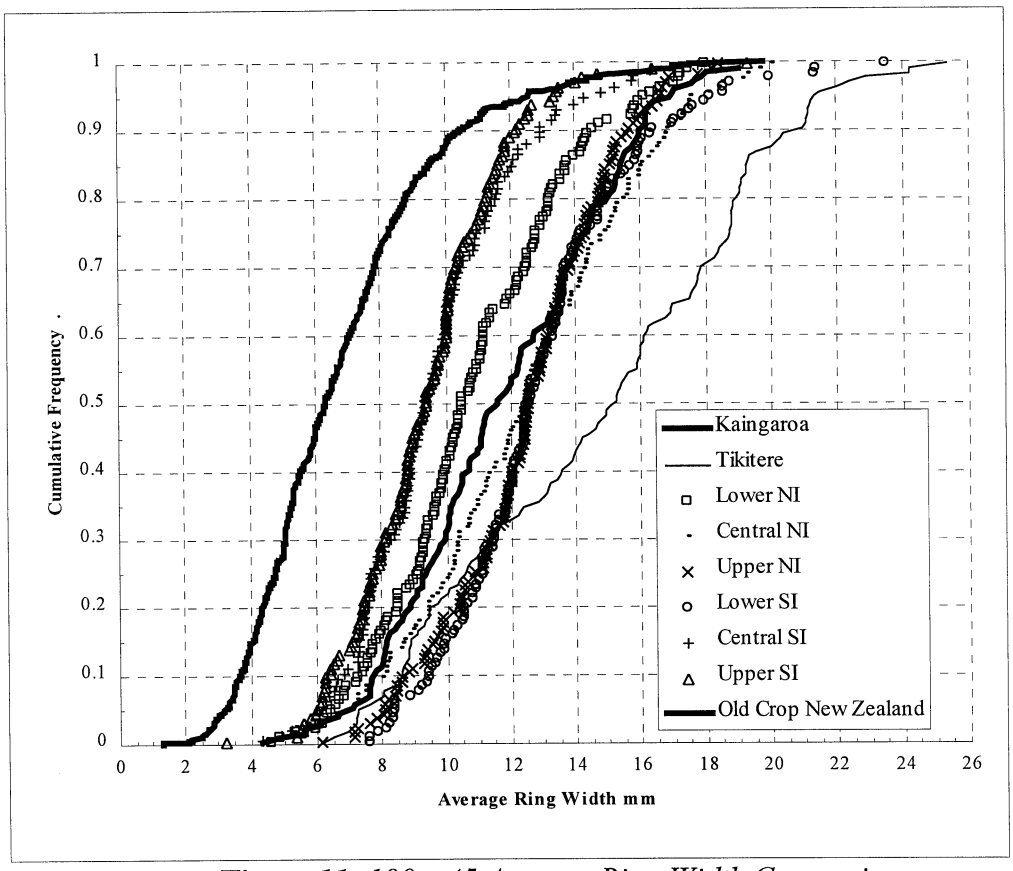


***Figure 11**: 190 x 45 Average Ring Width Comparison*

The following observations can be made from Figures 5, 6,7,8, 9,10 &11:

- In terms of strength and stiffness performance the Tikitere timber has lowest performance and is comparable to timber from the southern South Island.
- The Kaingaroa timber in terms of stiffness is in the middle of the range but in terms of strength is above Tikitere and the southern SI but lower than the other five sites in the six-site study. The live-sawing cutting pattern probably did not help the structural grade yield as it results in a lot of spike-knots, and quite often in pith along the edge of the piece of lumber in the saw-dry-rip process.
- Generally the best sites for strength and stiffness are the northern North and South island sites.
- Comparing the Knot area ratios shows little difference between Tikitere, Kaingaroa and any of the six sites.
- In terms of nominal density, Tikitere shows up as having the lower density with Kaingaroa ranked in the centre of the density ranges. Comparing the 'old crop NZ wide sample' with Tikitere shows on average a drop of 80kg/m$^3$ in nominal density. This difference is approximately 45kg/m$^3$ comparing Tikitere with the average nominal density from the six-site study. This lower density will help explain the Tikitere's lower strength and stiffness. It was noticeable that nearly all the Tikitere 200x50 lumber came from the first 10 growth rings (these were painted a different colour to the rest) and hence can be regarded as juvenile wood.
- In terms of ring width Tikitere show up as having the highest average ring width at 15mm, with Kaingaroa at 11.5mm, the average six site ring width at 11mm and the 'old crop NZ wide sample' at 6.5mm. Obviously the higher the ring width the lower the density and in turn the lower the strength and stiffness performance.

## CONCLUSIONS

1. The outturn of timber (from all recent studies) meeting the visual requirements of the No 1 Framing grade (NZS 3631) are low – ranging between 2 and 22% compared to sawmillers traditional expectations
2. Even for timber complying with the visual grades, the characteristic grade stresses are not always achieved - simply ensuring timber is visually graded correctly is no guarantee that the grade stresses can be achieved.
3. The Tikitere timber with E-grade graded into the MGP performance grades produces 44% reject, 34% MGP6 and 22% MGP8 (and better). This compares to 41 % for Kaingaroa and 57% for the NZ wide study for recovery of MGP8(and better) . MGP 8 can be related to No 1Framing -our most common traditional structural grade.
4. There is a potential financial advantage to be made with the implementation of a performance grading system, over the old visual grading system.
5. The Tikitere timber shows up as having the lowest financial return on a performance graded (MGP) structural timber basis compared to the Kaingaroa and six site studies. The Kaingaroa timber appears to be similar to the middle North Island site in terms of financial return.
6. Tikitere is characterised as having low strength and stiffness, which can be associated with having a low nominal density and high ring width, with most of the lumber produced from the juvenile core (first 10 rings).
7. Comparing all the studies against a 'New Zealand wide old crop' study show a significant drop in density and increase in ring width. The Tikitere timber accentuates these differences.

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