NZ SCHOOL OF FORESTRY

ABSTRACTS OF UNDERGRADUATE DISSERTATIONS

2006 ONWARDS

The abstracts presented here are from a range of outputs from the undergraduate students of the School. These outputs vary considerably in scope, length and quality.

All Faculties in the University of Canterbury give recognition to their top academic students by awarding their degree with Honours. In the School of Forestry these students are identified at the completion of their third year of study and an invitation to Honours is extended. If accepted, the students are required to complete a dissertation in addition to the regular 4th Year component of study towards the degree. The dissertation is an opportunity for students to gain experience in research methods and analysis. Students are able to select a topic of their own choice, but with a degree of supervision by an appropriate member of staff.

Topics vary widely and are frequently determined by the nature, location and conditions of summer employment and availability of time and appropriate research material. A project outline is developed and generally approved by a supervisor and some guidance given, though much is left to the student's initiative. The dissertations are not refereed or modified by editorial comments, and thus represent individual student effort. Consequently, they vary widely in quality, length and comprehensiveness and account should be taken of this.

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ADAMS, ISAAC (2011)
VALUE RECOVERY IN MARAMARUA FOREST

Accurate pre-harvest inventory data is essential for planning forest operations; optimising recovery at the skid is an important process in maximising profitability. This study looked at the accuracy of pre-harvest inventory estimates of value and volume and compared them with actual and optimal recovery at the skid site in Maramarua Forest, Waikato. Inventory data was collected on trees using two crusing methods, standard procedure (operational) and a thorough cruise (diligent). Trees were felled and sectionally measured to collect data to validate current volume, taper and breakage functions. The trees were then tracked to the skid site where actual and optimal recovery for each stem was recorded. Inventory estimates and actual recovery per stem was compared using the optimal recovery as a control.

The study found there was a significant difference in recoverable value between:

- The Operational Cruise and Actual Recovery
- The Operational Cruise and Diligent Cruise
- The Optimal Recovery and Actual Recovery

There was a significant difference in recoverable volume between Optimal Recovery and the Operational Cruise. Inaccuracy in the pre-harvest cruises was a result of conservative calls on marginal 4 cm branch size features. The majority of value loss during actual recovery was through cutting logs that were out of specification and subsequently downgraded. The current volume, taper and breakage functions adequately predict tree form and breakage in Maramarua Forest. Total value loss in this study was smaller than most losses found in other value recovery studies. This could be because of the level of experience and training that participants in this study had received. Bias because actual recovery was recorded could haVe influenced the results.

ALEKSANDROV, IVAN (2010)
NEW ZEALAND FOREST ROADS: PREDICTING AGGREGATE BEARING STRENGTH FROM ITS PHYSICAL PROPERTIES

A lot of the increased forest production is located in first-rotation forests with negligible amount of forest road networks in place. Therefore, road construction and maintenance comes at a high cost and is a significant task for New Zealand forestry industry.

Unbound granular aggregate is used as improvement layer on unsealed forest roads. Acquisition and application of aggregate makes up a large portion of forest road cost. To minimize costs, forest road engineers tend to use locally available aggregates. Forest road engineers have little knowledge about the suitability of a given aggregate for road construction. Aggregate bearing strength is an important engineering property as it describes how a given aggregate performs under load. In many cases, bearing strength is either over- or under-estimated, resulting in road failure or expensive over-engineering.

To avoid that, forest road engineers must be able to quickly determine aggregate bearing strength by looking at its physical properties. The bearing strength is represented by California Bearing Ratio (or CBR) values. With that data they can make informed decisions about aggregate suitability for road construction.

The aim of this dissertation was develop an equation correlating CBR to physical properties of an aggregate for bearing strength prediction.

Aggregate samples were collected in Canterbury, Otago and East Cape. Physical properties of these aggregates were tested in the geotechnical laboratory. Statistical analyses were used to find an equation that correlated these physical properties with bearing strength of an aggregate.

Following the analysis, aggregates with higher CBR values had stronger rocks (more crush resistant), needed less moisture to bind the mix at highest density (lower optimum moisture content), had short fat rocks (lower length to width ratio), were made up of light and porous rocks (lower density) and had more voids in the matrix (less compacted).

ANDREWS, SHAUN D (2015)
A COMPARATIVE STUDY OF THE INFLUENCE THAT MOTOR-MANUAL FELLING AND MECHANISED FELLING HAS ON STEM BREAKAGE

Motor-manual felling has been the predominate method of severing trees in the felling process of a forest harvesting operation. Yet this method has been coupled with numerous injuries and deaths, as trees can strike fallers during this task. An alternative felling method was developed in the form of mechanised tree felling, in an attempt to reduce the frequency of injuries. Subsequently, mechanised felling is poorly understood when compared to motor-manual felling upon the impact it has on stem breakage.

183 trees were assessed by measuring the frequency of breakage, height of the first break and the volume retention abilities of three felling treatments; motor-manual, mechanised felling out of the stand and mechanised felling into the stand. The effect that directional felling had upon the length to the first break was also investigated for motor-manual and mechanised felling out of the stand. The percentage of stems that broke once felled was 73%, 76% and 94% for motor-manual, mechanised out of the stand and mechanised into the stand felling respectively. The height at which the first break occurred for the aforementioned felling treatments was 71%, 71% and 69% of the total tree height. Mechanised felling out of the stand had the greatest volume retention ability with 94.5% of the trees total volume being below the first break. Followed by 93.7% for motor-manual and 91.9% for mechanised felling into the stand, however these differences were statistically insignificant ($p=0.14$). Lastly the length to the first break for motor-manual and mechanised felling out of the stand failed to statistically change when a tree was felled through a range of directions from downhill to uphill.

The influence that motor-manual felling and mechanised felling out of the stand had on stem breakage is similar, yet mechanised felling into the stand had a much greater impact on the percentage of stems that broke. With further improvements in technology, it could be seen that the number of mechanised tree-felling operations over take motor-manual felling, as their impact on stem breakage is comparable.

ARNOLD, THOMAS A H (2016)
NATIVE FOREST MONITORING: TRACKING CHANGES IN NATIVE FOREST REMNANTS

Native forest monitoring is undertaken by forest companies as a requirement for certification of their forests by groups such as the FSC. It is important for companies to be able to track changes that are occurring to native forest remnants that are often spread throughout their operational plantation forest estate.

Pan Pac tasked me with completing their 2016 native forest monitoring programme and review the results that have been collected since the programme was implemented in 2002. The objective of this was to both gain a better understanding of how the composition of the remnants in their5 estate is changing and to make recommendations on how the programme could be improved in the future.

The majority of the 11 Permanent Sample Plots (PSPs) measured were in good or stable condition, several of which showed strong regeneration of the understory over the past 14 years. Three of the sites have been affected by heavy ungulate browsing (deer and/or goats), which has resulted in the continued suppression of the understory vegetation. While all current canopy layers of the PSP have not changed significantly, current and future disturbance such as ungulate browse could result in a change in composition from the current forest makeup.

Ungulate browsing has been identified as the biggest driver of change in the native forest remnants within Pan Pac's estate. To further examine to magnitude of this, exclosure plots could be established in impacted remnants to assess the effect of removal of browsing pests as a basis for Pan Pac to make decisions about future ungulate control. Continued monitoring of native forests is key to be able to identify as well as understand what is happening with native forest remnants. Tracking composition change is important as it allows the forest manager to target management practices such as ungulate control to combat non-natural changes that are occurring.

ASHFORD, SHERIDAN M (2013)
VALIDATION OF A REDWOOD *SEQUOIA SEMPERVIRNS* (D. DON) ENDL. BUTT LOG SAWING SIMULATOR

Redwood (*Sequoia sempervirens* (D. Don) Endl.) has been identified as a species with considerable potential for plantation forestry in New Zealand. Investment decisions in high value alternate species must be based on accurate wood quality and value predictions. There is an opportunity to extend non-destructive evaluation tools available to redwood growers, and to present the outputs of the growth model by log products and sawn timber.

A redwood pruned buttlog sawing simulator has been developed however the simulator had not been tested with real data. Twelve redwood trees from Mangatu estate were selected for a sawing study; these logs were reconstructed and run through the sawing simulator. Computerised log processing was used to produce simulated pruned log sawing outturn from the redwood Buttlog Sawing Simulator, and results were compared to real results from a sawing study.

The objective of the study was therefore to determine how well the simulator matched volume and grade out-turn from twelve logs. This study found the many inconsistencies between simulated data and real data; particularly related to log size. While this study was unsuccessful in validation of the redwood sawing simulator, it provides initial insight into the simulators strengths and short comings.

BAYLEY, MARTIN (2006)
PREDICTING RURAL FIRE IN NEW ZEALAND USING THE FIRE WEATHER INDEX

Effective rural fire management requires the correct identification of spatial fire hazards to ensure limited fire prevention and suppression resources are effectively allocated to areas of high priority. This report was written to investigate the predictive strength of the Fire Weather Index in identifying fire hazard.

Using ArcView 3.2a, monthly severity rating grids were analysed both nationally and provincially to gain an appreciation of severity ratings throughout New Zealand. Data from 783 nationwide rural fires, from July 1995 to June 2005, was then imported into ArcView 3.2a for comparison to monthly severity ratings.

Linear regressions were performed between monthly severity ratings and rural fire occurrence, areas burnt, and fire suppression costs. All three regressions produced significant results but with varied in relationship strength. It was concluded that severity ratings are a strong indicator of rural fire occurrence with a coefficient of determination of 78%. Very weak correlations were found between areas burnt, and fire suppression costs, suggesting additional influences other than severity ratings are more important in predicting these elements of rural fire.

These results of this report suggest national resource allocation should be higher in the provinces of Wellington, Tasman, Northland, and in the eastern regions of both islands.

While these results provide insight into the current situation, there is a need to consider future conditions and their implications. Global warming and climate change will have large impacts on the fire risk in New Zealand increasing fire severity, intensity, and season length. Current and predicted land use changes are forecast to increase fuel loads nationwide.

BECKMAN-CROSS, TRENT (2012)
ARCHITECTS' PERCEPTIONS OF ENGINEERED WOOD FOR USE IN NON-RESIDENTIAL CONSTRUCTION IN NEW ZEALAND

An investigation into architects' perceptions of engineered wood for use in non-residential construction was conducted. Face-to-face structured interviews were conducted with 59 architects located in Auckland, Wellington, and Christchurch. Questions focused on the barriers to, and opportunities for, using engineered wood products for structural applications in non-residential construction.

The most significant barrier to increasing the use of wood was found to be architects lack of knowledge of engineered wood products compared with concrete and steel. As a result, architects perceive the durability of engineered wood to be inferior to concrete and steel. Respondents also believe the use of wood is limited to buildings four storeys or less and for buildings with short spans. Further, architects were found to be uninformed about the cost of engineered wood, which in turn appears to lower their confidence when specifying it as a structural material. The majority of respondents indicated that cost is the primary attribute that drives material selection in non-residential construction. Architects consider designing with wood risky because the products and systems are not what is normally used by the industry.

Architects were found to perceive engineered wood as a more environmentally friendly material. However, results show the influence this attribute has on the specification of materials is limited. It was also found that architects perceive engineered wood to be a more lightweight material with better acoustic and similar or better seismic properties than steel and concrete.

The Christchurch earthquakes were found to be a 'tipping point' for changing architects attitudes towards engineered wood, with architects in Christchurch and Wellington more likely to specify wood in the near future since as a result of the recent Christchurch earthquakes.

This research will be used by industry representatives, timber researchers and developers of new timber technology to gain a greater understanding of where to target their efforts to promote new building technologies that use wood.

BERRY, NICHOLAS (2019)
INVESTIGATING FACTORS THAT INFLUENCE PROCESSOR PRODUCTIVITY

In the last decade, there has been a transition from motor-manual processing to mechanised processing. This transition occurred rapidly over the past eight years due to increased awareness of health and safety, with some 33% mechanisation (ground-based) in 2009, increasing rapidly to 88% in 2017. Understanding factors that influence processor productivity is important to better estimate contractor rates and production targets.

A time study was completed on behalf of Hancock Forest Management at five crews in six locations within Kinleith forest estate over the summer of 2018/19. Data was collected from detailed video footage and STICKS woodflow management system.

Three factors were compared against processor productivity within this study, those being piece size, tree form, and skid size.

Cycle times analysing processor work tasks demonstrated that the majority of time was spent processing stems (59%). An overall utilisation rate of 91% for all crews was estimated; however, this only accounted for delays less than ten minutes. The average productivity for these six locations ranged between 34.8 m^3/hour and 79.1 m^3/hour, with average productivity of 62.7 m^3/hour. Statistically significant differences were identified between locations, suggesting that crew productivity cannot be assumed to be uniform.

A positive relationship could be observed between piece size and productivity for all crews in this study, suggesting that a larger piece size will yield a higher average productivity. Tree form categorised stems into one of three groups; 0 (Good), 1 (Poor) and 2 (Bad). A stem in category 1 took 54% longer and a stem in category 2 took 84% longer to process than a 'good' stem (0). A negative trend between tree form and productivity was observed. Larger skid size reduced the average delay per stem while also increasing the productivity of the processor, but with only 6 skids this result is not statistically significant.

BERKETT, HAMISH (2010)
BIOMASS DRYING TRIAL OF THE DRYING RATES OF ROUNDWOOD IN THE DUNEDIN AND CANTERBURY REGIONS: A COMPARISON OF SUMMER AND WINTER DRYING RATES

The purpose of this research is to investigate alternative methods of drying radiata pine roundwood, for use as fuel. Freshly harvested wood typically has a moisture content of 50% to 60%, but, to be an efficient fuel, wood should be at 20% to 30% moisture content (or lower) when burnt. Because wood is a low-value fuel, drying must be an inexpensive and simple operation so as to maintain profitability.

Two trials were established outside forests in Canterbury and Otago, to investigate the influence of log splitting and stack covering on drying rate and final moisture content. One trial looked at summer drying, the other, winter drying.

Results from the two trials suggested that there was:

- No benefit in covering stacks in summer time
- Increased drying rate with splitting
- Significantly more difficulty drying in winter than summer

Conclusions from this research included:

- It was not possible to produce suitable fuel using winter drying
- Splitting led to more effective drying in summer time, but is unlikely to be cost-effective
- The best result was 21% moisture content for small roundwood (uncovered), after 24 weeks of summer drying.

BOLITHO, CALLUM (2015)
FALCON FORESTRY CARRIAGE SERIES 2: A CASE STUDY OF PRODUCTIVITY AND OPERATION

The multiple drivers of workplace safety and increasing productivity are resulting in increased mechanisation within the forestry industry. The use of motorised grapples in cable harvesting is an applicable mechanisation method to the large proportion of steep terrain harvesting in New Zealand.

In this dissertation a time study of the Falcon Forestry Carriage Series 2 has been undertaken in order to access its productivity and operation. Mean values of productivity were found to be 54.9m3/PMH for wood extracted from the ground, 64.6m3/PMH for bunched wood and 75.6m3/PMH for excavator fed wood after adjustment for the cycle distance and accumulation type. Longer cycles were found to decrease productivity by 0.15m3/PMH for each meter of cycle distance.

Utilisation in the study was found to be 56% of total time which was similar to previous studies. 15% of total study time was accounted for by operational delays, 7% by personal delays and 23% by mechanical delays. Mechanical problems with the carriage occurred 6 times and accounted for 171 minutes or 13.4% of total delay time. Mechanical delay breakdown was similar to that found by McFadzean (2012) who recorded that 15% of total delay time was attributable to carriage mechanical delays.

During a study of Operator effect it was found that the inexperienced Operator 3 and Operator 4 had a productivity of 52.2% (not statistically significantly different) and 18.5% (p value <0.05) of that of the experienced Operator 1 on the same site. Large differences in productivity relating to experience were also found in a comparable Norwegian study. An 11.6% difference between experienced operators on different sites was found to be statistically significant (p value <0.05).

The effects of accumulation method and cycle distance upon productivity were found to be similar to the results of previous studies, as was the utilisation of time within the study.

BLACK, RHYS (2018)
AN ANALYSIS OF NEW ZEALAND'S IMPORT COMMODITIES AND POTENTIAL IMPLICATIONS FOR NEW ZEALAND'S LOG EXPORTERS

This report found that there is an increasing log vessel supply and a stagnate log vessel supply in New Zealand between 2012 – 2017 for the year ending 30th June. It was concluded that log vessel demand is likely to continue in the near future as China's domestic demand continues to grow as a consequence of the nation's ban for production harvesting of native forests, and the forests planted

in the 1990's planting boom nearing maturity. There was no signals of an increasing level of log vessel supply to New Zealand in the near future. Consequently, competition to attain contracts for the use of log vessels is anticipated to grow.

Palm Kernel Expeller, Aluminium Oxide and Phosphates commodities were found to have an average market share of 59.5% of New Zealand's log vessel supply over the observed period. Consequently it is recommended to develop relationships with companies that import these commodities into New Zealand, to acquire inside information about what is happening in terms of log vessel supply. It also allows log exporters to focus their time and resources on a few commodities that have consistently provided the majority market share.

Of the identified key commodities, Aluminium Oxide was found to be relatively constant due to there being one customer in New Zealand for this product. However the other key commodities were relatively more volatile in the log vessel supply in a monthly and quarterly basis. There was found to be no significant relationship between the milk solid price at farmgate and New Zealand's import quantity of Palm Kernel Expeller, despite speculation.

Overall it is recommended that log exporting companies the likes of Pacific Forest Products Ltd. develop long-term contracts with vessel owners as the log vessel competition appears to be continuing on the increasing trajectory. This report also provides some recommendations for further study to be completed in order to better understand New Zealand's log vessel supply.

BOWEN, GARETH A. (2007)

THE EFFECT OF THINNING AGE ON STIFFNESS OF *PINUS RADIATA*, IN OMATAROA FOREST

This dissertation investigates the difference in stiffness values obtained from stands thinned at different ages. Field measures were taken in Omataroa Forest, in the Bay of Plenty. The Director ST300, an acoustic time-of-flight tool was used to measure the acoustic velocity in standing trees.

Two different treatment levels were tested: trees thinned at age 7 and trees thinned at age 13. Two stands from each treatment group were sampled, with the average current age of each treatment being 15. Mean acoustic values for the treatments were 3.95km/s when thinned at 13, and 3.84km/s when thinned at 7. A significant ($p < 0.05$) difference was found between the two treatments.

Individual tree variables measured were regressed against acoustic velocity, with fatness (DBH/height), height and DBH all proving significant ($p < 0.05$). These factors were then modelled against acoustic velocity at a treatment level. The inputs into the model were: fatness, height and a dummy variable was created for the treatment. The dummy variable for the treatment was insignificant ($p > 0.05$). This means that once fatness and height have been accounted for, there is no significant difference between the treatments.

Hypothetical rotations were run through the radiata pine calculator (PradCalc_v2.1), to determine if age at which thinning is carried out influences recoverable volume at harvest. It was found for the study site that thinning at age 7 yields 6 m^3/ha more than thinning at age 13, assuming harvest at age 30.

The distance that the Director ST300 probes were placed apart was found to have a significant ($p < 0.05$) negative effect on the acoustic velocity readings obtained.

The main finding from this report is that a significant difference was found between treatments, this was expressed by differences in fatness and height.

BROWN, JESSICA (2012)

GROWING COVERAGE: THE COST OF MEETING EMISSIONS OBLIGATIONS USING RADIATA PINE PLANTATION FORESTRY IN NEW ZEALAND

Under the New Zealand Emissions Trading Scheme, businesses emitting greenhouse gases must surrender carbon credits of equal quantity to their emissions. These can be sourced through markets or intermediaries, or they can the government at a currently fixed cost of $\$25/tCO_2e$. For future emitting projects, the resulting variable carbon price is undesirable.

A spreadsheet based estate model was developed to assess the cost competitiveness of using *Pinus radiata* plantation forest establishment to cover the emissions of a business producing a total of $1.5MtCO_2e$ over 30 years.

Emissions can be covered by planting between 2,128 and 4,993 hectares on an average site, depending on the timing of establishment, whether a normal forest was developed and whether only the "safe" carbon was utilised. Estate scenarios that reached a steady state required less area to cover total emissions but this significantly reduced NPV compared with planting the entire area and harvesting 30 years later. Increasing the area planted increased NPV but also increased capital and annual overhead costs.

Regardless of the establishment strategy employed, exposure to the market price of carbon could be managed effectively by retaining excess credits as they occurred in order to cover future deficits. This resulted in a reduction in value but the forest could be sold once sufficient carbon had been sequestered. Depending on the area planted, the rate of establishment and how much of the sequestered carbon was utilised, sufficient carbon could be sequestered in as little as 10 years.

The project was cost competitive down to a carbon price of between \$0.63 and $\$5.91/tCO_2e$ depending on the previously mentioned assumptions and whether excess credits were retained to manage exposure to the market price of carbon. The specific establishment methodology employed would be dependent on a business's preference for capital investment and carbon price exposure management.

BUCHANAN, TODD (2009)

AN ANALYSIS OF TWO STAND EDGE SAMPLING METHODS

Pan Pac Forest Products Ltd approach to pre-harvest inventory sampling is for a plot centre that falls near a stand edge to be moved until the entire plot is within the forest stand boundary. An investigation was carried out to determine if this approach was significantly different from an alternative half plot method with the plot centre located on the boundary. The differences were analysed to gauge the effect on log output predictions. Plots were compared using a paired t-test which tested for differences in the means between each pair of plots. Significant differences were found for all stand variables tested except mean top height. Branching was significantly different between plots. Significant differences for log grade expectations were only seen for P1/P2 ($p= 0.03$) and L1/L2 ($p=<0.001$) grades, with a 40% increase in L1/L2. A stand level analysis also found that the location of edge plots had a significant impact of total recoverable volume estimated for the total stand with the impact generally increasing with the percentage of edge plots. Further investigation

is needed to determine if the use of an unbiased edge plot method, such as mirage plots, would also result in significant differences from current practice.

BURGESS, JACK H (2015)

GENETIC PARAMETER ESTIMATES FOR GROWTH TRAITS OF *EUCALYPTUS BOSISTOANA* – ASSESSMENT OF TWO PROGENY TRIALS IN MARLBOROUGH, NEW ZEALAND

This paper presents a follow up study to that was already completed by Luis et al. (2011). Luis et al (2011) investigated the survival of *E. bosistoana* half-sib families within two progeny trials in Marlborough, New Zealand. The study investigated genetic growth parameters of the same two progeny trials. Trees at Craven (progeny trial) were statistically taller and larger in diameter than Lawson (other progeny trial), which is likely to be a result of thinning occurring one year earlier at the Craven and Lawson North sites than at the Lawson East site.

The progeny trials were set up into randomized incomplete blocks which allowed effective calculations of fixed and random effects from a mixed-effect linear model. The family, incomplete block and residual variances from the mixed-effect model made heritabilities of growth traits possible to calculate. Narrow sense heritabilities for diameter at breast height ranged from 0.13 to 0.18, while tree height heritabilities ranged from 0.1 to 0.17.

The inter-site correlation of family performance was weak to moderate for both height;

- Craven : Lawson North = 0.28
- Craven : Lawson East = 0.44
- Lawson East : Lawson North = 0.27

and diameter at breast height (dbh);

- Craven : Lawson North = 0.32
- Craven : Lawson East = 0.39
- Lawson East : Lawson North = 0.36

Heritabilities were weak to moderate for growth traits but there was substantial variation so selection is still likely to provide sufficient gain. Further studies will need to consider researching the genetic parameters of wood qualities of *E. bosistoana*.

BURNETT, SHANNON (2007)

HISTORICAL DROUGHT OCCURRENCE AND DURATION, AND ITS POTENTIAL IMPLICATIONS ON FOREST FIRES IN NELSON, KAIKOURA AND CHRISTCHURCH

Wildfires in a forest can cause major economic, environmental and ecological damage to both production and native forest. With the prospect of global warming comes a series of changes that the world is likely to experience, including changes to temperature, rainfall and more extreme weather events.

Increased drought is a possible consequence of these changes in weather conditions, and from this the likely change in fire weather conditions. An increase in drought may lead to an increased fire risk. This study considered three regions Nelson, Kaikoura and Christchurch, at the top of the South Island

of New Zealand, and how drought conditions were affected; either by occurrence and duration, within and between these regions within the past 40 years.

One climatology indicator, Potential Evapotranspiration Deficit (PED), was used as a predictor of drought, and three fire weather indices (Buildup Index (BUI), Drought Code (DC) and the Duff Moisture Code (DMC)) were used as fire weather measures.

The first factor that was measured was the predictability of the fire weather indices, which are used by forest companies around New Zealand as a predictor of fire. It was found that BUI was the most strongly correlated Fire Weather Index (FWI) with PED. This meant the BUI was the best predictor of drought in the three regions considered.

When considering drought magnitude, it was found that BUI and PED indices for Kaikoura significantly increased during time. The weather variables temperature, rainfall and relative humidity were then analysed for trends.

- The results of this analysis is that the Nelson temperatures and relative humidity are increasing, these changes offset each other, which possibly explains the no change in BUI or PED.
- In Kaikoura, relative humidity and rainfall are decreasing, leading to drier weather and therefore an increase in droughts.
- Christchurch only had one significant change in weather, which was a slight decrease in temperature; this lead to no significant change in BUI or PED.

Drought duration was also looked at, by a count of months that reached a certain percentile in each region. The only significant result found was that Kaikoura has a significant increase in drought occurrence. Neither Nelson nor Christchurch had any evidence of an increase in drought occurrence.

Two natural phenomena in the climate system, the El Nino-Southern Oscillation (ENSO) and the Interdecadal Pacific Oscillation (IPO), have an impact of weather patterns. These weather patterns were considered and it was found that the El Nino weather pattern may have an impact on BUI and PED. These were not extensively investigated, and further research could provide more significant data.

CALLAGHAN, ANDREÉ (2013)

THE INFLUENCE OF WOOD CONTROL, CLONE AND STEM DIMENSIONS ON WOOD QUALITY OF 17 YEAR OLD STEMS OF *PINUS RADIATA* WHICH HAS BEEN GROWN ON THE CANTERBURY PLAINS

This study determined whether variation in clone, weed control treatment, or stem dimensions, could have an impact upon outerwood stiffness in 17 year old *Pinus radiata* stems. An experiment located south west of the Dunsandel township in Canterbury, New Zealand, was used to collect measures of acoustic velocity (windward and downward sides) from each of the 278 trees. Diameter at breast height, tree height, and height to live crown were also recorded for each tree. Findings from this research were compared with previous research carried out when the trees were ages eight and eleven.

Assuming a green density of 1,000 kg/m^3, Young's Modulus equation was used to convert acoustic velocity to wood stiffness, or, Modulus of Elasticity (MOE). The effect of wind direction upon mean wood stiffness was not significant (α = 0.05). Consequently, one measure of wood stiffness was calculated per tree.

Mean stem slenderness and mean wood stiffness values were calculated by block, weed control treatment, and clone. Weed control treatments had a significant impact upon mean wood stiffness in comparison to the control treatment (0.03 m^2 area of weed control). Significant differences did not exist between different levels of weed control, ie., 0.75 m^2, 3.14. m^2 and 9 m^2 chemical spot spray area.

Clonal variation and stem slenderness significantly affected mean wood stiffness measures. Stem slenderness appeared to be correlated with clonal variation (interaction between clone and slenderness was not significant), however, according to Dr Euan Mason, this finding is not corroborated by findings from other research on the wood quality of clones in Canterbury (personal communication, September 16, 2013). An analysis of covariance (ANCOVA) determined that mean height to the live crown was not a significant predictor of wood stiffness. Comparison with earlier research showed no change in the ranking of wood stiffness values by clone or treatment.

CAMPBELL, THORNTON (2014)

EDAPHIC ZONING AND SPECIES-SITE MATCHING TO ASSIST RE-VEGETATION OF INDIGENOUS SPECIES AT THE STYX MILL RESERVE

The Styx Mill Reserve is located in Belfast, Christchurch and is managed by the Christchurch City Council. Who aim to re-establish indigenous vegetation to large proportions of the area. These efforts have been successful in some sections of the Reserve; but large areas of the Reserve remain in grass and other weeds. The purpose of this investigation was to evaluate the presence of 5 hypothesised edaphic zones in a 10 ha study area, with a future aim of matching establishment practices to these edaphic sites. Findings indicated that all zones have significantly different vegetation and soil characteristics. Consequentially methods of native re-vegetation must be different in each zone if successful re-establishment of native species is to occur.

Based on confirmed edaphic zones and client input, a site matched management plan and species list for one zone was developed. This aimed to increase the health and survival rates of plantings. Site modification followed techniques used at sites with similar conditions that have had successes in establishing woody vegetation. The effect of hydrogel on heath and survival levels was also trialled. To assess species suitability, five species were selected based on their abilities to survive the site conditions. Due to a combination of frost damage and ungulate browse, only totara survived and demonstrated good health scores. The frost factor is difficult to mitigate, hence species affected severely by frost are not recommended. The browse issue is easier to mitigate and it is felt that the two species heavily browsed, but not frosted are likely to be suitable. This resulted in ribbonwood, totara and kohuhu being recommended. The time period did not allow assessment of the hydrogel treatment. Insufficient trial numbers exist to continue trials assessing future growth and survival rates over a longer time scale.

CARMAN, IAN (2011)

IMPROVING THE PRACTICABILITY OF LEAF AREA INDEX MEASUREMENTS FOR FOREST RESEARCHERS USING THE LAI-2000

Leaf area index (LAI) is an important ecophysiological factor which determines, in part, a plant's ability to intercept radiation. Hence it is an important predictor of growth and yield. LAI was measured using the LAI-2000 plant canopy analyser in experimental forest blocks of *Pinus radiata* on the Canterbury Plains, New Zealand. The LAI-2000 is reputedly subject to bias when used in direct full sunlight making it an impractical tool for large scale use.
LI-COR recommends deriving an adjustment factor to account for this bias, if waiting for cloudy

weather is impractical, but gives no indication of the likely nature or accuracy of such a factor. Measurements were taken in full sun and full cloud under a range of stocking, fertiliser and herbicide treatments to test: i) the effect of these treatments on LAI; ii) the nature and accuracy of the relationship between measurements taken in full sun and full cloud; iii) the effect of treatment on the accuracy of this relationship. High stocking and herbicide use caused a significant increase in LAI. There was a clear reduction in standard deviation of LAI at high stocking and with herbicide use, both of which had more uniform canopy. A linear relationship between sunny and cloudy LAI with an R-squared of 0.68 was found. The relationship was significant and showed little bias. Changes in stocking; time of measurement; location of measurement; fertiliser use and herbicide use had no statistical effect on the relationship. The data had some statistical outliers which reduced the accuracy of the relationship, but these outliers were not excluded from analysis. Further research should be done in mature forest to derive a more accurate relationship since it has been shown that treatment had no effect on the ability to adjust LAI measurements taken in full sun.

CHEN, ANSEN (2019)

WHAT ARE THE FACTORS THAT AFFECT LOG PORT CAPACITY IN NEW ZEALAND PORTS? (A CASE STUDY AT THE PORT OF TAURANGA)

61% of New Zealand's total harvest was exported as logs in 2018, highlighting the economic importance of ports to the New Zealand forestry sector. This proportion has doubled since 2008, and at the same time harvest has increased by 13 million m^3 (MPI, 2019). As a result, log ports in New Zealand have been experiencing problems with port congestion and port capacity. Identifying the factors that influence capacity and congestion is the purpose of this dissertation, as a first step in solving the problem.

Port operations experts at New Zealand's main log export ports were surveyed to identify factors that affect port capacity. The potential additional volume of future log exports was estimated for each port, using wood availability forecasts.

The survey identified that log storage area and vessel frequency were the two most important internal factors limiting port capacity, through their impact on log throughput at ports. The survey also identified that log price and forest harvest were the main external factors that affected log supply to ports. Finding solutions to the internal factors will overall increase the profitability of a port, while increasing the efficiency of port operations will increase the profitability of log exports.

The Port of Tauranga (PoT), which may experience an additional 1.85 million m^3 through the port in the future, is estimated to already be at capacity by Pacific Forest Products (PFP). Discussion with PFP staff yielded three options to increase capacity at PoT:

1. moving vessels to another berth for lashing,
2. re-location of methyl bromide fumigation operations from loading berths, and
3. the use of mobile harbour cranes

Analysis indicated that Options 1 and 2 together would increase port capacity by just under 1 million m^3 . Option 3 is expected to be able to provide all the potential capacity required.

CLEARY, DOMINIC (2022)

THE ECONOMICS OF CARBON ACCOUNTING IN THE ETS: COMPARING THE CANTERBURY/WEST COAST LOOK-UP TABLE TO MEASURED YIELDS FROM THE FIELD MEASUREMENT APPROACH IN NORTH CANTERBURY HILL COUNTRY FOR *PNUS RADIATA*

The New Zealand Emissions Trading Scheme (ETS) was introduced in 2008 to assist New Zealand in meeting requirements for international climate change agreements. Forest owners with land classified as post-1989 are eligible to apply for emission returns from carbon sequestration. Forest owners with less than 100 ha are required to use default look-up tables from the Ministry for Primary Industries (MPI) to account for carbon sequestration. Forest owners with 100 ha or more are required to measure forests through the field measurement approach (FMA).

Pinus radiata D.Don forests in North Canterbury Hill Country were measured in accordance with the FMA to create an average yield to compare with the Canterbury/West Coast look-up table. In North Canterbury Hill Country, fourteen forests were measured, and three in the Port Hills. A total of 149 plots were measured across 785.0 ha of forest. Economic analysis was then carried out to compare per hectare (ha) returns from measuring these forests to entering under the look-up table, and at what carbon price what size forest would provide higher returns in the FMA.

The results show that the Canterbury/West Coast look-up table is significantly lower than the average yield created for the North Canterbury Hill Country forests in FMA. Consequently, forest owners with less than 100 ha are not receiving the true value of their forests' carbon, and per ha, returns are lower than that of the FMA. In the current market, a forest size of 3 ha provides higher returns in the FMA than measuring, if it were allowed in.

The look-up tables need to be updated for a more accurate representation of forests' carbon yields, failing this forest owners in North Canterbury Hill Country should plant 100 ha or more to increase returns from carbon.

COLES, REBECCA (2008)

THE INITIAL STAGES OF NATIVE FOREST REGENERATION UNDER MATURE SERAL *KUNZEA ERICOIDES* STANDS

The aim of this study is to assess the initial stages of woody forest regeneration under mature seral *Kunzea ericoides* stands. Environmental elements such as aspect, slope, and distance from the gully centres were assessed to determine their influence on regeneration. This study was undertaken in Tiromoana Bush, Kate Valley, North Canterbury. Data for this study was collected from five gully systems, all dominated by *Kunzea ericoides* canopy cover. The entire area has an extensive history of stock grazing (sheep and cattle), which was removed in 2005, but some native forest remnants have persisted. Tiromoana Bush is now under active conservation management.

Regeneration within the gully systems were sampled with linear transects. 2x2 metre plots were established at 15 metre intervals along each transect, with multiple transects used to sample each gully system. Mahoe was found to be the dominant seedling across all plots sampled, and there was no evidence of kanuka regeneration. There was no association between canopy cover abundance and seedling density (R^2=0.001). Neither aspect or slope were considered key drivers of seedling distribution in this situation. Distance up the slope from the gully centre significantly influenced total seedling density for seedlings >20cm (P=0.001).

It is evident that regeneration is occurring under the seral *Kunzea ericoides* stands at Tiromoana Bush. Seedling abundance has been restricted by grazing in the past, and is now influenced by the distance

from the gully centre. Environmental factors other than aspect or slope are likely to be playing a key role in variation between gullies at Tiromoana Bush. Successional processes are evident within Tiromoana Bush, and it is likely that the forest cover will continue to increase with time. Regeneration at Tiromoana Bush is likely to be representative of other native remnants scattered throughout the New Zealand landscape.

COLES, SHAUN (2019)
AN INVESTIGATION OF PRE HARVEST INVENTORY METHODOLOGY AT VARYING INTENSITIES CONDUCTED IN OMIHI FOREST, CANTERBURY, NEW ZEALAND

New Zealand forestry has used current pre-harvest inventory (PHI) procedures for a very long time. With developing technology, such as LiDAR, management of forest estates should become more site-specific, hence the implementation of precision forestry (Dash, et al., 2016). Precision forestry requires higher spatial precision in estimates of productivity indices such as 300 index and site index. Both indices rely heavily on estimates of mean top height (MTH) at age 20 for a stand of Pinus radiata (D.Don).

Mason (2019) investigated the effects on estimates of MTH of fitting the height- diameter (H-D) relationship at a plot-level compared to the current standard, at stand- level. Stand-level fittings of the H-D relationships artificially reduced MTH standard deviations and violated the assumption of independent sampling units, when compared to plot-level fittings of H-D relationships.

The study reported here compared a range of height numbers measured (3, 6, 9, 12, and all) per plot, in order to fit H-D relationships at both a stand-level and plot-level, at a range of plot sizes (0.04, 0.06, 0.08, and 0.1 ha). Relevant costs (measured in time) associated with each different plot size and number of heights were balanced against increases in accuracy (compared with estimates obtained when all heights were measured) for those variables involving heights, and precision for all four key variables; stocking (N), basal area (G), volume, and MTH with increasing plot size and/or numbers of heights measured per plot.

Plot size did not significantly affect standard deviations of estimations of volume or MTH. However, increases in height measurements/plot did not add unjustifiably large costs, and mean absolute value of errors of MTH estimation was markedly reduced by measuring more than three height trees per plot. Analyses conducted by Mason (2019) were replicated yet produced larger absolute values of errors in MTH estimation were lower at plot-level fittings of H-D relationships.

COLLIE, ALAN G. (2011)
EVALUATION OF OPTIONS FOR THE UCSA FOREST AT MOUNT HUTT

The UCSA owns 237ha of land at Mt Hutt that has had a primary land use of a commercial forestry. Planted in 1975/6, the land is now a mix of harvested area and standing forest.

The UCSA has commissioned this report to ascertain what their obligations and opportunities are under Emission Trading Scheme (ETS) legislation and to obtain a financial evaluation for each of three categories of forest land present on the site:

- Land clearfelled prior to 1 January 2008;
- Land clearfelled after 1 January 2008;
- Land with standing crop

This analysis of forest included mapping of the estate, carrying out an inventory of the standing crop and investigation into the likelihood of natural forest regeneration.

Mapping of the estate found 65.1 ha of land is classified as pre 1990 forest land under the ETS and all other area is not deemed forest land, including the 90.8 ha of land harvested prior to 1 January 2008.

Of the 65.1 ha of pre 1990 forest 4 ha has been harvested since 1 January 2008. This land will be deemed to have been deforested unless a forest crop is established by the end of 2012. Should the UCSA fail to establish an ETS forest cop on this land they will be liable for a deforestation penalty of approximately $37,642. Establishing a forest on this land will cost between $11-13,000.

Of the 61.1 ha of standing forest 33.1 ha is economical to harvest now, and could give a stumpage return of $330,780. 22.4 ha of standing forest will be ready for harvest in 2014 comprising of the compartments north of Scott's Creek, potentially returning a stumpage of $276,444. Harvesting of the northern block is reliant on gaining access over the neighbouring property.

There is 5.5 ha of pre 1990 forested land that is not economical to harvest due to negative stumpage returns due to high roading and harvesting costs combined with poor tree form and small harvest areas.

All of the 65.1 ha of pre 1990 forest land is eligible for an allocation of NZUs to offset the effect on land value the ETS may have caused. The UCSA can claim up to 39 NZUs per hectare, resulting in a total NZU allocation of 2,383 NZUs with a value at current prices of $34554. The UCSA has until the 30th November 2012 to apply for this allocation. It is recommended that this application is carried out as soon as possible.

Financial analysis of establishing forest on land harvested prior to 1 January 2008 has shown that the best return results from establishing a Douglas fir forest and entering this land into the ETS to gain carbon sequestration revenues. The land that is eligible to be treated as post 1989 forest land has an internal rate of return (IRR) of 9%. The next best option is a Douglas fir forest not entered into the ETS and relying on timber revenue which has an IRR of 3%.

While establishing a Douglas fir forest entered into the ETS has the highest return the UCSA should keep in mind that any carbon revenue generated will have to be surrendered to AF should they choose to deforest the land in the future.

The cause of the low projected IRR values for non ETS forestry is the result of high forest establishment costs on the cutover sites due to the difficulty in clearing dense broom and gorse; and high harvest costs.

A survey of harvested areas measuring exotic species regeneration and native species abundance indicated that natural regeneration of forest species will not occur due to dense week species presence.

Alternative uses of the land should be considered before investing in forestry on the land harvested prior to 2008 as the return from developed or subdivision of the estate may yield a more favourable financial return to the UCSA. In making this decision the current users of the forest could be considered as the forest is used by local mountain bike clubs and businesses for its tracks and walkers accessing neighbouring DOC tracks.

COOPER, BLAIR R. (2008)
IMPACT OF THE "WORKPLACE SAFETY MANAGEMENT PRACTICES" PROGRAMME IN THE LOGGING INDUSTRY

An investigation to determine whether or not the ACC "Workplace Safety Management Practices" (WSMP) programme is encouraging and motivating workers to be more health and safety conscious was carried out within the harvesting sector of the New Zealand forest industry. Assessment was made using the results of a survey to compare workers' perceptions, attitudes and behaviours with management systems and procedures, and the "WSMP" audit standards.

Standardised questionnaires were used to survey 39 forest harvesting workers in a person-to-person survey. This was carried out in the greater Waikato region with the sample population coming from five tertiary accredited forestry crews.

Results of this research indicate that:

- Employer commitment to safety management systems was of a high standard, with the null being rejected at = 0.05;
- Workers were consistently identifying, isolating and eliminating hazards, with the null being rejected at = 0.05;
- Information, training and supervision was occurring yet the type of training being offered was narrow and there is room for improvement;
- Incident and injury reporting, recording and investigation is consistently occurring by the workers, with the null being rejected at = 0.05;
- Employee participation in health and safety management is of a high standard, with the null being rejected at = 0.05;
- Emergency planning and readiness occurs at the workers level with 90% of the population able to explain emergency procedures;

These results demonstrate that a thorough implementation of the WSMP (indicated by tertiary accreditation of the Olsen logging gangs surveyed) does encourage and motivate harvesting workers to become more health and safety conscious.

COULMANN, MALTE (2007)
VALIDATION AND REVISION OF CANSPBL_HILLS GROWTH AND YIELD MODEL

CanSPBL_HILLS is an empirical growth and yield model for the Selwyn Plantation Board Ltd (SPBL) foothill estate. Indications were that the model was not performing to a satisfactory standard, especially at low altitudes.

A new dataset was compiled containing measurement intervals from almost all permanent sample plots in SPBL foothill forests. It consisted of 2148 entries from 99 compartments and 603 plots.

Catastrophic morality was removed from the dataset using a mortality severity index (Pinjuv 2006). Validation of CanSPBL_HILLS was conducted using residual analysis. Applied Regression including Computing and graphics (ARC) software was used. The analysis found that the stand variables basal area, mean top height and stocking were all being under predicted, especially at low altitudes. In addition it was found that the basal area model did not have an upper asymptote and predicted negative growth at ages over 30 years. As a result the models needed to be revised.

A new set of equations (CanSPBL_HILLS1.2) were created. The mortality severity index was replaced with an arbitrary cut-off for catastrophic mortality which was set at 15 stems per hectare per year. The model for basal area was a Polymorphic Schumacher III equation with an adjustment to the asymptotic parameter to include altitude in the form of a scaled power transformation. Parameters for the mean top height model were simply recalibrated using the new dataset; the equation remained the same as in CanSPBL_HILLs. The same was planned for the stocking model but it was found that altitude was not a significant predictor. Therefore altitude was removed from the asymptotic parameter of the equation.

CanSPBL_HILLS1.2 showed improved residual distributions and variation compared to CanSPBL_HILLS. It is important that these models only be applied within the range of the data used to build them.

CRAIG, GEORGIA (2019)

LOG RESIDUES FROM STORAGE STACKS AND THE POSSIBLE EFFECT ON AIR QUALITY: A CASE STUDY AT THE PORT OF TAURANGA

Air quality has been a concern of the Mt. Maunganui Industrial Area mainly due to dust emissions. The Mt. Maunganui Industrial Area has breached rule 17 regarding PM10 in the NES-AQ bringing these environmental issues to the forefront. Residue from log storage is a known source of fugitive dust. However, the implications of log storage on air quality is unknown.

A line transect sampling method with $1m^2$ quadrants was used to measure residues less than 4mm x 4mm in log rows (g/ m^2). There were four treatments analysed separating bark-on and debarked log rows both before and after sweeping.

Bark-on rows have higher amounts of residue both before (447 g/ m^2) and after (119 g/ m^2) sweeping and scraping compared to debarked rows (119 g/ m^2 and 19 g/ m^2 respectively). On average the sweepers and scrapers removed 91% of fine residue from bark-on rows and 84% of fine residue from debarked rows. Debarked rows post cleaning on average had half the residue (19 g/ m^2) of bark-on rows (40 g/ m^2). This residue remaining in exposed rows could potentially become airborne fugitive or nuisance dust.

From the four samples tested, the particle size range analysis indicated that 1.3% of the samples were under PM10, and 13.7% was <60 µm which is the fraction which can become airborne for prolonged periods of time. Additionally, on average 72% of the dry weight was inorganic particulate matter.

Some considerations for improving dust management and suppression include reducing time periods where log rows are exposed, increasing the amount of debarked wood supplied, ensuring rows are cleaned before new logs are reloaded in and improving machine design.

This study showed that large volumes of residues are left immediately after logs are removed, however the current cleaning mechanisms remove large proportions, with only a fraction of what is remaining being < PM_{10}.

CRONE, TIM (2008)

THE EFFECTS OF AN AUTUMN APPLICATION OF HERBICIDES ON REDWOOD SEEDLINGS

One of the biggest obstacles to establishing redwoods (*Sequoia sempervirens*) is their susceptibility to weed suppression and their sensitivity to herbicide use. There are very few chemicals that can be applied successfully over young redwood seedlings without adverse effects.

A trial was conducted at the New Zealand Redwood Company's Hundalee forest to assess the effects of an autumn application of four herbicides on the health of redwood seedlings. The objectives of the trial were to assess how the different chemicals used, and the rate applied impacted on the health of redwood seedlings.

The chemicals assessed in the trial were Versatill, Gallant, Grazon and Atrazine, each applied at three different rates. A randomised complete block method was used, with a control treatment in each block. The seedlings were assessed eight weeks after application by being given a score of 1-5 based on the condition of the seedlings' health. Seedlings with curled tips and curved leaves were also recorded.

The analysis of the results showed that Grazon had a significant adverse effect on redwood health at all application rates. Gallant had a significant effect at a high rate, Versatill and Atrazine also may have had some impacts but they were not statistically significant. There was an apparent relationship between the rate applied and the impact on seedling health for all chemicals. However, this was stronger for Gallant and Versatill.

Based on the results of this trial, the use of a mixture of Gallant and Versatill at specified rates may be best to control grasses, broom and gorse, although the impacts of an actual mixture were not assessed. The application rate is critical as these are selective herbicides and applying too much will kill most plants. Atrazine is recommended to provide residual control of grasses and broad-leaved weeds. It is not recommended to apply Grazon to any redwood seedlings. To give an indication of the significance timing has on the impact of the chemicals, further trials should be conducted at a different time of year.

CURRY, MATHEW (2018)

FACTORS INFLUENCING SHELTER IN THE WOODHILL PROTECTION STRIP

Woodhill Forest, situated on the west coast of the Auckland region, is directly exposed to strong westerly winds coming from the Tasman Sea. To protect the 41km long *Pinus radiata* forest, a protective strip of trees has remained unharvested between the coast and the remaining forest. The protection strip plays a valuable role in sheltering the forest against strong, salt-laden winds. The aim of this research was to investigate the shelter provided to the production forest by the protection strip.

The protection strip was mapped using aerial imagery. A site was selected where measurement of the protection strip and the production stand immediately adjacent could be undertaken. Protection strip height, basal area, width, health, and crown length were measured at three plots along 24 transects. Production stand volume was measured at three plots at even intervals along the same transects. Regression analysis was used to assess the relationship between protection strip variables and production stand volume at 20m, 90m, and 170m from the protection strip.

The analysis showed that height (adjusted for the elevation difference between the protection strip and the stand) (r=0.56), and the health (r=0.41) of the inland edge of the protection strip were significantly correlated with volume within the first 20m of the stand. The two variables were multiplied together to create a shelter variable which had a significant correlation with stand volume at 20m (r=0.65), and at 90m (r=0.42) away from the strip. When confounding effects of site influence were controlled, the shelter was still deemed to have a significant relationship with stand volume, providing confidence that the relationships detected were not only the result of underlying site conditions. The shelter variable was significantly correlated with distance to the coast (r=0.50).

Despite the relationship between the shelter variable and distance to the coast, the protection strip width did not show a significant relationship with stand volume. It can be concluded that the protection strip can provide sufficient shelter when as narrow as 280m wide, the minimum width tested during this investigation.

These results provide an indication as to how to assess the quality of the protection strip and the key factors to consider when the protection strip is maintained or replaced in the future. They also provide some indication on how to improve the protection strip to achieve greater forest productivity.

D'ATH, RYAN (2006)

MODELLING THE EFFECTS OF STAND STRUCTURAL, EDAPHIC AND CLIMATIC VARIABLES ON TRACHEID LENGTH IN *PINUS RADIATA*

Data from a nationwide set of *Pinus radiata* site quality plots established at high stand densities and grown over a period of four years were analysed to (i) determine how site, age and fertiliser influence tracheid length, (ii) determine which structural variables were most strongly related to tracheid length, and (iii) develop a simple model to predict tracheid length for New Zealand grown *Pinus radiata*.

Site had a highly significant (P<0.001) influence on tracheid length, which ranged in value from 1.11 mm to 1.79 mm for unfertilised treatments, and 1.05 mm to 1.74 mm for fertilised treatments. Fertilisation did not significantly influence tracheid length, and values of tracheid length in fertilised plots were only on average 2% lower than those in unfertilised plots (1.42 vs 1.39 mm). Age was found to significantly influence tracheid length, with average tracheid length increasing from 1.10 mm for the first two rings to 1.62 mm for rings three to four.

Using ring level data, when fertilisation was included in a model with age and site, it was found to be insignificant, as was the age by fertilisation interaction. A correlation matrix assessing the correlation of stand variables with tracheid length at the ring level found that height was the main determinant of tracheid length. Ring width was tested in conjunction with site, age and height and found to be only marginally significant (P<005), while taper and stem diameter were found to be insignificant when included in a model with site age and height.

Using site level data, a forward stepping procedure selected annual average air temperature, tree height, soil exchangeable potassium and soil carbon to nitrogen ratio as significant variables in the final model. In this model, which explained 63% of the variance in the data, tracheid length was positively correlated with annual average air temperature, tree height and soil carbon to nitrogen ratio, and negatively correlated to soil exchangeable potassium.

DE GOUW, SARAH (2018)

THE UPTAKE AND BARRIERS OF GEOSPATIAL TECHNOLOGIES IN NEW ZEALAND'S FOREST MANAGEMENT SECTOR

Geospatial technologies have developed rapidly in recent decades and can provide detailed, accurate data to support forest management decisions. Commonly used technologies include Global Positioning System (GPS), Geographic Information Systems (GIS) and remote sensing technologies. Knowledge of the uptake and barriers of geospatial technologies in the forest management sector will be beneficial to the industry. This knowledge will provide a benchmark and can be used to overcome current barriers so that these technologies are fully utilised.

An online survey was sent out to 29 forest management companies within New Zealand. The survey was spilt into seven sections, composed of multi-choice and open-ended questions. These sections were demographic information, data portals and datasets, GPS receivers and remote sensing technologies. Four remote sensing technologies were included, aerial photography, multispectral imagery, hyperspectral imagery, and light detection and ranging (LiDAR). Each section included questions that asked about the acquisition, application and products created from each technology that companies used. Questions were also included that related to the barriers preventing the uptake of technologies. To determine the progression in the uptake of these technologies the results were compared to a study conducted five years earlier.

All 23 companies that responded to the survey used GPS receivers and acquired aerial photography. Multispectral imagery and hyperspectral imagery had an uptake of 48% and 9%, respectively. LiDAR had a 70% uptake. Common applications for the products derived from these technologies were, stand or forest mapping and assessment, harvest planning, cutover mapping, and site preparation or silvicultural mapping. The main barriers for companies not using geospatial technologies were the lack of staff knowledge and training, as well as the cost of acquiring the imagery. Some companies did not believe there were any benefits gained from acquiring multispectral or hyperspectral imagery.

The uptake of all four remote sensing technologies increased over the past five years. LiDAR had the largest progression in uptake, increasing from 17% in 2013 to 70% in 2018. In 2013, all aerial photographs were acquired using airplanes but the results from the survey have shown that unmanned aerial vehicles (UAV) were used by 83% of companies. UAVs were also used to acquire multispectral imagery.

This study showed that there had been a progression in the uptake of geospatial technologies in the New Zealand forest management sector. However, there are still barriers that are preventing the full utilisation of these technologies and the results suggest that the industry could benefit from investing in more training relating to geospatial technologies. It is recommended that a similar survey is completed in another five years as the developments of technology are still occurring rapidly.

DOWLING, LESLIE (2008)

THE EFFECT OF LOG PRICE DISTRIBUTIONS ON FOREST VALUE: A METHOD TO INCLUDE HARVEST OPTION VALUE IN FOREST VALUATIONS

Price distributions for nine log grades were approximated with Weibull distributions in statistical software (SAS Institute, 2002). The predicted log price distributions were used to calculate expected values (by summing log prices multiplied by their probability of occurrence). The expected values were not significantly different from long term average values; showing there is no advantage in calculating expected values for risk neutral forest valuations.

The distributions found for each log grade were then used to calculate a range of values for each log grade. Values were calculated to represent log values from the worst case to the best case scenarios; different percentile ranges of predicted possible log prices were used to find values ranging from risk averse to risk taking. Using risk taking log values in existing forest valuation methods show that with a 30 year rotation an increase in value of over 16% is possible for a range of silvicultural regimes. This extra value is referred to as option value.

The best chance of capturing option value is with an unpruned regime. The log grades produced by unpruned regimes are more volatile and the regime provides a long window where discounted values are close to optimum. Export grades are the most volatile grades and provide the best chance of providing high values inside the regimes optimum value window. Although, unpruned regimes optimum option values occur between 13 and 26 years. Rotation ages greater than 26 years are considered preferable for wood quality (Walker, 2006). Where rotation ages are required to be longer than 26 years pruned regimes provide the best opportunity for option value.

The valuation method used in this study can be used by forest investors to evaluate option value available to them. To capture option value investors will need to time harvesting to correspond with high log prices. A side effect of this is inconsistent wood flow. This needs careful consideration before a commitment to inconsistent harvesting is made.

DOYLE, MATTHEW J.A. (2011)

IMPACT OF STOCKING, WEED CONTROL, FERTILIZER, GENETICS AND WIND SWAY ON ESTIMATION OF MICROFIBRIL ANGLE

192 stems in 48 plots located in Rolleston, Canterbury, New Zealand were measured for sonic velocity in four directions as an estimate of corewood microfibril angle. The plots allowed estimations of variations in stocking, weed competition, fertiliser application and wind sway on wood properties of two clones. Sonic velocity was measured in metres per second using an Ultra Sonic Velocity scanner, with high sonic velocity correlating with desirable low microfibril angle.

Stocking, weed control and stem height were the most significant factors investigated (at 95% confidence interval). There was a positive linear relationship with sonic velocity and increasing stocking rate and disk height, suggesting corewood microfibril angle improved with increased stocking and stem height. Weed competition improved sonic velocity significantly suggesting competition also improved corewood quality.

However, a weak relationship was found between sonic velocity and radial distance across the pith, despite previous research suggesting a strong relationship. In addition, tying stems as a means of controlling wind sway did not significantly affect sonic velocity. Effects of fertiliser application and genetics on corewood sonic velocity were also insignificant.

These results promote the presence of weed competition and high initial stocking for improved corewood quality. Therefore, forest managers who seek ti improve corewood microfibril angle may seek to decrease weed control while increasing initial stocking rates.

Further research is required into the economic impacts of these applications. The addition of values of the overall stem of increased corewood quality needs to be quantified to justify drastic changes to forest management strategies.

DOYLE, RYAN (2023)

NON-DESTRUCTIVE WOOD EVALUATION: OPERATIONALISING A RESISTOGRAPH IN THE SOUTH ISLAND OF NEW ZEALAND

In New Zealand, some sawmills are requesting logs above a stiffness grade, prompting forest managers to integrate stiffness-related data into their resource inventories. The IML PD400 resistograph provides a rapid and non-destructive means of sampling trees for density with studies demonstrating a high correlation between site-average estimates of basic density and site-average stiffness of board outturn at a sawmill.

OneFortyOne New Zealand has purchased a resistograph with the intention of using the estimates of basic density that it provides to segregate their stands for stiffness. This study investigated the sampling intensity necessary to achieve a probable limit of error (PLE) of 10- 15 % for stand-level basic density estimates to help OneFortyOne operationalise the tool. High- intensity sampling was carried out across 15 stands that covered a range of environmental conditions. Simulations of the PLE equation were run in R with the sampling intensity systematically reduced to assess the influence on PLE.

Results suggested that sampling programs for stand-level estimates of basic density can be carried out at a very low sampling intensity. With only 10 total measurements across two sample plots, a PLE of less than 12.5% was achieved across the range of stands assessed. Increasing the sampling intensity to 30 total measurements across 15 plots returned a PLE of 2.5-5%. However, beyond this point, further increases to sampling intensity yielded diminishing returns.

Decisions relating to sampling intensity should be an operational call that takes into account the findings of this study alongside manager experience and knowledge of wood variability across a forest estate. Further research should be conducted to confirm the relationship between site-average estimates of basic density and site-average stiffness of board outturn. The IML PD400 and the processing software is a rapidly evolving space that will likely continue to be adopted as wood product customers demand higher quality logs.

DRUMMOND, RYAN (2015)

UNDERSTANDING DEMAND FOR WOOD PRODUCTS IN NEW ZEALANDS MAJOR LOG MARKETS

New Zealand's forestry sector is largely reliant on the presence of a strong export market with 57% of the volume harvested being exported of which 99% goes to Japan, the Republic of Korea, China and India. This identifies the need to analyse demand in these countries to better understand their needs in the future. Consumption of wood products per capita is a commonly used metric for estimating demand and was used in this research. Volumes of imports, exports and production were collected from the Food and Agricultural Organisation of the United Nations (FAO) and data for a range of explanatory variables was collected from a variety of official sources. Historical trends in consumption identified that as countries develop socially and economically their consumption shifts from largely solid wood products such as sawn timber to more processed products such as wood-based panels and paper and paperboard. Consumption was modelled using linear regression techniques to develop models which could be used to forecast consumption in the future. A wide variety of potential explanatory variables were considered and the models presented represent the most effective of these. GDP per capita was found to be the single most effective explanatory variable being highly significant ($p<0.01$) in all models. Price was also found to be a strong determinant of consumption, understandable as price is a major component of supply and demand dynamics. Measures of construction activity were found to be related to consumption of sawn timber in all

studied countries and for wood-based panels in Japan. Forecasts produced for consumption in Japan should be used as only an example of the capability of the models presented herein. More work is required to develop these equations into a form where they can be used to more accurately estimate future consumption.

DU, ZHIBIN (2017)
RATES OF RETURN ON FORESTRY INVESTMENT IN NEW ZEALAND

Financial information in the public domain is important for investors and landowners to understand the profitability of forestry investments. Interest from institutional investors in purchasing New Zealand forests has increased, and information on returns may also encourage new investment. This study calculates a single-period rate of return (IRR) on existing forest investment in New Zealand using date from financial statements. The rate of return is calculated as the sum of the productive return (net cash return on assets) and the change in asset value. Results show the high variability of financial performance in companies included in this study, ranging from -1% to 14.9%. Returns may be affected by forest age class structure, forest productivity, exchange rate, log prices, forest management and company strategies.

Two methods to calculate productive return were examined. The cashflow statement method is recommended as it includes both operating and investing cashflow, and the data is easy to extract. It is also possible to use income statement when cashflow statement is not available. In this case, the accuracy of the estimate depends on the amount of detail provided by financial statement. This study provided an industrial estimate based on the revenue-weighted average. Overall, New Zealand forestry companies studied had an average rate of return of 8.3% during the period 2009-2015. An increasing trend of profitability on forestry investment is expected, although it is likely to fluctuate from year to year. The was a small impact of carbon markets on return in studied companies. This was caused by the proportion of their forest asset that is “pre-1990” forests which does not qualify for earnings under the NZ Emissions Trading Scheme, and generally low carbon price during the study period.

The main limitation of this study is the availability of data. The result can be improved by using cashflow statement, covering more forest companies and more extended series. Therefore, more work is required to provide more accurate estimates, develop an industrial measure, such as index, for the forest industry in New Zealand, and compare with other land businesses to further explain land use changes.

DUVAL, ALFRED W (2016)
AN ANALYSIS OF VESSEL LOADING OF EXPORT LOGS AT FOUR NEW ZEALAND PORTS

Over half of New Zealand’s annual harvest was exported as logs in 2015 (MPI, 2016). The large scale and economic importance of log exports highlights the importance of efficient port operations.

Productive cycle elements for the log loading operation were defined. The vessel loading cycle was split into six elements: three ‘action elements’ (loading, tallying, and slinging), and three ‘carting elements’ between the ‘action elements’. Time study measurements were carried out at four New Zealand ports (Tauranga, Marsden Point, Gisborne, and Port Chalmers) to identify differences in productive time to load log export vessels. Port Chalmers wasn’t compared to the other ports as it was too different operationally.

Loading had the longest productive element time, followed by slinging and tallying, and lastly the 'carting elements'.

Loading was uninfluenced by port but affected by log grade, length, operator skill, and the time of day. Tallying was significantly different between the three ports with Marsden Point fastest and Tauranga slowest. Slinging was quickest in Gisborne and faster whilst loading below-deck and during the daytime.

Carting elements were heavily influenced by distance to or from log stack for all four ports.

Tauranga displayed the fastest historic gross load rate (JASm^3/hour) yet the slowest productive cycle time. Gross load rate is influenced by delays, volume per cycle, and productive cycle time. The difference in productive time and gross load rate could therefore be assumed to be from increased volume per cycle and/or reduced delays in Tauranga.

Exporters are fined for loading slower than scheduled. This cost is greater when shipping rates are high as fines are based on shipping rates. A 5% increase in loading efficiency can save the exporter US$11,000 per vessel at historic maximum shipping rates.

EVISON, KIMBERLEY (2012)
THE PERFORMANCE OF THE 300 INDEX GROWTH MODEL IN TIAKI ESTATE

An investigation was undertaken for Hancock Forest Management into the performance of the 300 Index growth model in Tiaki Estate. The growth of the estate is currently forecasted using the PPM88 growth model. Hancock are interested in examining how the 300 Index model performs within the estate and how its performance compares to that of the PPM88 growth model. Analysis of how well 300 index and site index are predicted by the Palmer Productivity Surface was also required.

Data from 165 plots across five different PSP trials were used to evaluate the performance of the two models in Tiaki Estate. Measurement data from the PSPs was put into Atlas Forecaster and grown forward using both the 300 Index and the PPM88 growth models. The outputs were then compared to the measurements of the PSPs at the same age for basal area, mean top height and final stocking.

Five plots from each trial were run through Forecaster from a measurement age of 20 years to gain estimates for site index and 300 index. The locations of the same plots were also put into the Palmer Productivity Surface to gain a second series of site index and 300 Index estimates. The estimates from the Palmer Productivity Surface were then compared to the PSP estimates.

Some significant over-prediction in basal area growth was found in both models in two of the trials analysed. In both cases, the 300 Index growth model predicted less extreme estimates than the PPM88 growth model. Both models predicted mortality quite accurately in all cases. The models performed similarly in most scenarios but the PPM88 growth model was marginally more accurate the majority of the time.

It is recommended to Hancock that more investigation into the reason for the large over-predictions in basal area is necessary before making any changes to their current practices. The results of this analysis indicate that Hancock would be best to continue to use the PPM88 growth model for growth forecasting in Tiaki Estate.

The Palmer Productivity Surface was found to generate site index estimations that were, on average, 1.5m higher than the estimates in the PSP data. The Palmer Productivity Surface tended to estimate

300 index above and below the PSP estimates which resulted in it over-predicting 300 index by 0.18m^3/ha/yr on average. The Palmer surface was deemed to generate plausible and appropriate estimations in both measures of site productivity.

FARMERY, ACACIA (2015)
THE PERFORMANCE OF BLOCKS OF CLONES IN A RADIATA PINE PRODUCTION FOREST

Problem: Genetically identical clones of *Pinus radiata* are being planted in New Zealand plantation forests. There have been many clonal trials carried out; however there is a weakness in published literature surrounding the performance of clones in production blocks.

Method: Five comparisons in four of Pan Pac Forests Products production forests were measured. Three comparisons were measured at age 4.5 years old and two were measured at 7.5 years old. There were six Forest Genetics clones and three different control-pollinated seedlots measured in these comparisons. Each comparison had a different number and selection of seedlots. There were six different traits measured for the trees; diameter at breast height over bark, height, acoustic velocity, straightness, branching habit, and malformation.

The different traits were compared between the seedlots within each comparison. The differences in variation for diameter at breast height and modulus of elasticity were compared between clones and control-pollinated seedlots. Finally, the results by clone for the traits, excluding height, were compared to the expected performance supplied by Forest Genetics.

Results: There were differences in performance between seedlots. Four clones performed well across a range of traits. One clone performed well in the 7.5 year old blocks but not in the 4.5 year old blocks. One clone did not perform well in size and stiffness. Clones were significantly less variable than control-pollinated seedlots for diameter at breast height but not for modulus of elasticity. The performance of each clone in Pan Pac Forest Products forests was very similar to the expected performance provided by Forest Genetics.

Implications: There are clones that can produce desired yield, stiffness and form. Clones will provide a more uniform crop in diameter than control-pollinated seedlots. Pan Pac Forest Products can rely on Forest Genetics prediction of clonal performance as a guide to performance in their forests.

FARRELL, AMANDA (2009)
A COMPARISON OF REALISED GAIN BETWEEN COMMERCIALLY AVAILABLE GENETIC MATERIAL

Background
This trial was set up by Hancock Forest Managers in 1995 in order to compare the realised gain between 10 different seedlots which were planted on a site in Woodhill Forest, located North of Auckland. These seedlots had growth and form (GF) factors ranging from 19 to 30. The traits looked at were diameter at breast height (DBH), straightness, branch thickness and angle; the number of whorls present to a height of 6m; forks, number of ramicorns and cluster frequency; any malformations which were present, and also the height, density and velocity of selected individuals, which were representative of each plot.

Results
When data analysis was carried out on the measurements, it was found that only seven out of the total 17 traits (more traits, e.g. basal area, were calculated from the measured results) showed significant differences between seedlots at a 0.05 ANOVA level. When Tukey tests were carried out

on these significant variables it was found that the DBH and number of ramicorns were not significant, and so only the ANOVA results were taken into account for these variables. No single seedlot was found to be outperforming the others for all traits, and so tradeoffs had to be made in order to discover the best seedlot to be planted on the site.

Conclusions

Tradeoffs were made in order to find the seedlot best suited to being planted on the trial site. This was found to be seedlot 342, which has a GF rating of 27 – one of the higher ratings planted in the trial. There were, however, several limitations found with this trial, the main being that not every plot contained 66 trees, and there could be possible issues with the velocity data. These are discussed in more depth in the report.

FERGUSON, GEORGE (2014)

CALCULATING THE POTENTIAL INCREASE IN *PINUS RADIATA* STEM VALUE THROUGH SELECTION FOR HIGHER STIFFNESS

New Zealand grown *Pinus radiata* is limited in its application for structural purposes by its stiffness deficiencies. This dissertation aims to estimate potential improvements in stem value through selection for improved stiffness. A new method to model and value volumes of structural wood grades within a stem was used to calculate these value improvements. Data for each stem from a stand in Kaingaroa Forest bred for improved wood quality was used to perform this analysis. This data was from a stand bred for improved wood quality and included information on the stiffness, density and width of each growth ring for each stem. The data was in the form of cores. Height and volume data was not recorded and therefore needed to be modelled. The volumes of MSG8, MSG11 and MSG13 wood were estimated by modelling the stem volume at the age when wood is produced that is stiff enough to qualify for each grade.

The majority of stems had merchantable volumes between 1-2.5m^3 with the largest stems containing 3.6m^3. Average stiffness ranged between 5.2GPa and 11.3GPa with the stand average being 8.4GPa. There was no relationship between average stiffness and merchantable volume. Stem values were found to range between \$60-\$131/m^3 with the stand average being \$91/m^3. The 10 most valuable stems had a total stem value \$318) twice that of the stand average (\$157). The most valuable stem (\$411) showed at 160% increase in stem value from the average. The increases in value/m^3 were caused by large increases in the proportion of MSG11 and MSG13 wood held within the merchantable volume. These potential gains in stem value could help tree breeders assign an accurate economic weighting to stiffness improvements. Forest managers wanting to justify using a more expensive, improved stiffness seedlot may also find these results valuable.

FISHER, REIHANA (2019)

EVALUATING THE INVESTMENT IN PRUNING IN THE LAKE TAUPO AND LAKE ROTOAIRA FOREST ESTATES

Pruning has been a major part of forest management since the early 1950s carried out to produce clearwood in the butt section of the stem. Pruning regimes are more intensive and require additional management compared to no pruning, this in turn generates additional costs during the rotation. The economics of pruning has become a controversial topic in recent times, as many large scale owners (Timberlands) have stopped pruning completely. The Timberland's estate is adjacent to the Lake Taupo and Lake Rotoaira Forest estates and trustees have begun to question their silvicultural investment in light of Timberland's recent decision. This dissertation aims to analyse the economics of pruning within the Lake Taupo and Lake Rotoaira Forest estates.

As of 2018, 98% of the pruned log supply was sold domestically while the remaining 2% was exported. In the same year, 44% of the unpruned log supply was sold domestically while the remaining 54% was exported. This suggests that the main outlet for pruned logs is the domestic market, while the main outlet for unpruned logs is currently split between the domestic and export markets. All pulp logs are currently being sold to the domestic market.

Domestic customers are vital in terms of selling the log grade mix produced from the trusts estate. Currently there are three main pruned log customers, two main unpruned log customers and two main pulp log customers located in and around the Central North Island.

Based on land expectation value the two lift pruning regime is the most profitable regime on all four sites analysed (low, medium, high and very high productivity). The difference in land expectation value between the two lift pruning and unpruned regime is minimal on low to medium productivity sites. This difference increases as site productivity increases (high and very high), which suggests that pruning should be confined to the high productivity sites as this generates a better financial return for pruning regimes. The investment in pruning is extremely sensitive to changes in prune log price and tending costs, with minor changes in each variable having a significant influence on the overall profitability. The three lift regime is the least profitable regime which supports the trusts decision to shift to a more profitable regime in 2014 (2 lift prune). The analysis has artificially favored the two lift regime, as log prices do not account for the better pruned log index that is achieved under the three lift pruning regime.

FLANNERY, BRAYDEN (2009)

INFLUENCES OF SILVICULTURE AND GENOTYPE ON COREWOOD ACOUSTIC VELOCITY OF RADIATA PINE

The joint influences of stocking, grass control, fertilisation, genotype and wind sway on the corewood acoustic velocity of 4-year-old *P. radiata* D. Don were investigated in an experimental plot at Rolleston, Canterbury, New Zealand. Acoustic velocity was determined on standing trees using both the Fakopp Ultrasonic Timer and the TreeTap time of flight tools.

Stocking significantly ($P = 0.0098$) influenced TreeTap acoustic velocity measurements, with an increase of 1.44 to 1.51 km/s as stocking increased from 625 to 2500 stems/ha. Genotype had a significant ($P < 0.0001$) effect on TreeTap acoustic velocity measurements, ranging from 1.41 to 1.52 km/s between the 2 extreme clones.

Stocking significantly ($P < 0.0001$) influenced acoustic velocity measurements from the Fakopp Ultrasonic Timer. Acoustic velocity increased from 1.58 to 1.67 km/s with an increase in stocking of 625 to 2500 stems/ha. There was a significant ($P < 0.0001$) interaction between genotype and Fakopp acoustic velocity measurements, ranging from 1.56 to 1.69 km/s between the 2 extreme clones. A significant ($P < 0.0110$) relationship was found between Fakopp acoustic velocity and grass control treatment, where trees that had no grass control had higher velocity than trees with treatment. Fertiliser and restraining trees from wind sway had no significant ($P > 0.05$) interaction with acoustic velocity measurements.

A comparison of tools found that the Fakopp measurements explained a relatively weak proportion ($R^2 = 0.3648$) of the TreeTap measurements. Reconciliation of measurements found the Fakopp measurements to be highly variable ($R^2 = 0.3409$), compared to TreeTap measurements which were more consistent with an R^2 of 0.9847. Therefore, it is recommended that only the TreeTap tool be employed for reliable acoustic measurements of trees of similar age and size to this study.

The influence of stocking and genotype on acoustic velocity corroborates other research and indicates the potential for the incorporation of these factors into silvicultural regimes and models to help improve the corewood stiffness of radiata pine.

FLUITSMA, HANNAH M. (2011)

PERCEPTIONS OF AND BARRIERS TO THE USE OF LAMINATED VENEER LUMBER FOR STRUCTURAL APPLICATIONS IN SINGLE-STOREY INDUSTRIAL BUILDINGS

Laminated veneer lumber (LVL) is not currently a preferred material for structural applications in non-residential construction in New Zealand. This study explores the perceptions and attitudes of engineers and quantity surveyors with respect to the structural use of wood in single-storey industrial buildings.

Separate nationwide surveys were conducted to identify perceptions about wood as a structural material, and barriers to the greater use of wood.

For engineers, the required sizes of structural members, the availability of prefabricators, and the availability of experienced contractors were barriers to the greater use of LVL in construction. For quantity surveyors the main barriers were the lack of historical cost data, and the lack of information about LVL suppliers. The availability, uniformity and cost of LVL compared with steel were also considered important.

Client perceptions were a significant barrier identified by both parties as was the need for improved design guides and tools. Overall, the need for more projects using LVL is required if both parties are to become more confident in working with it, and the majority of engineers believed that there would be increased specification of LVL in the future.

Information obtained from this research will be delivered back to engineering professionals and research organisations who are working to increase the use of LVL in structural applications.

FOWLER, THEODORE (2022)

THE INFLUENCE OF THE TIMING OF THINNING ON FACTORS AFFECTING VALUE WITHIN *PINUS RADIATA* FOREST IN THE HAWKES BAY

Thinning is a key silvicultural practice, applied widely throughout New Zealand's Pinus radiata plantation forests. The timing of thinning has often been a topic for debate, with selection ages varying depending on factors such as site, regime, and managers' preference. A paper by Piers Maclaren (1995) analysed the effect of selection age on final crop acceptability. He concluded that there is "... insufficient information present at young ages to make informed decisions around the most valuable trees at harvest."

In 1998, forest managers at Carter Holt Harvey Ltd established a trial within Hamptons Forest in the Hawkes Bay. They were interested in taking Maclaren's research a step further. The treatments in the trial were variations in the timing of thinning, at ages 3, 6, 9, 11, and an unthinned control. In 2021, the trial was decommissioned and clear-felled. A total of 15 measurements took place over the life of the trial, from ages 3 – 26. Using the data from this trial, this study investigated how the timing of thinning influences tree and stand characteristics that affect value.

The results indicated that by age 26, later thinning had significantly improved: the number of acceptable crop trees at harvest age; the proportion of trees that met the maximum branch diameter requirement for small-branch sawlogs (S grade) in New Zealand of 7 cm; and stand uniformity. Analysis of Rieneke's (1933) stand density index (SDI), revealed that thinning at age 6 did the best job optimizing stand dynamics. Despite differences in these factors, the timing of thinning had no significant impact on LEV.

Forest managers may also wish to consider site, thinning intensity, safety, carbon sequestration, and log quality when determining the optimal timing of thinning. Growth rate variability across New Zealand makes it difficult for managers to optimize thinning schedules on different sites. Theoretically, a better alternative to standardized selection ages may be to use SDI as an indicator of competition between trees. This can act as a tool to inform the timing of thinning.

HABERKORN, MITCHELL (2012)
EVALUATION OF CURRENT BARK AND TAPER EQUATIONS FOR *EUCALYPTUS GLOBOIDEA* IN NEW ZEALAND

Eucalyptus globoidea has been trialled for naturally durable vineyard post production in New Zealand drylands. No accurate taper and volume equations have been validated in New Zealand for this species. Interim bark and taper equations (Gordon et al., 1999) have been evaluated as these are the only equations for *Eucalyptus globoidea* available in New Zealand.

Based on recently measured New Zealand data from permanent sample plots it is apparent that current bark and taper equations both over-predict bark thicknesses and over-bark diameters along the stem respectively. The dataset collected over the summer 2011/12 is large enough to support this argument, however the sample size is not large enough to develop new bark and taper equations due to lack of upper-stem diameter and bark thickness measurements.

It is of interest to continue collecting data in order to create accurate bark, taper and growth & yield models as these provide insight into *Eucalyptus globoidea* stand dynamics and management alternatives.

HADDON, SALLY (2008)
HABITAT UTILISATION BY GPS-COLLARED SHEEP, OTEMATATA STATION, NEW ZEALAND

Habitat use by sheep *Ovis aries* will impact upon natural ecosystem functions. Building a better understanding of the relationship between habitat use and environmental patterns will aid in applying sustainable land management practices. This dissertation quantifies the summer habitat use of four merino wethers on Otematata Station, Waitaki Valley.

Four merino wethers were fitted with Televilt GPS collars and left to graze on a 5332 ha alpine grassland block from December 2005 to April 2006. The collars were programmed to record the animal location every 20 minutes, with 34 000 locations logged.

Using ArcMap 9.2, each sheep's home range was determined from the GPS locations and was summarised in terms of landcover, aspect, altitude and slope. The distribution of each of habitat parameter class was represented as a proportion of each home range, representing the expected utilisation of each habitat parameter. The incidence of sheep locations falling on each habitat parameter class was then summarised. The proportion of locations that fell on each class was represented as the actual observed utilization of each habitat parameter.

Landcover was not utilised differently to its proportion in the landscape. The sheep did show a preference for higher altitude (>1500 m.a.s.l.) and flat slopes, however these two parameters may be spatially correlated. Northerly aspects were also preferentially selected for, with a distinct avoidance of southerly aspects. Northerly aspects are warmer than southerly, thus possess higher vegetation growth and better forage.

It is likely that the detrimental effects of grazing sheep within high country ecosystems will be disproportionately concentrated in preferred areas. Sheep can impact on native biodiversity, accelerate erosion, and contribute to nutrient concentration. Land managers may be able to mitigate these impacts through practical measures, and encourage sustainable land use.

HENDERSON, THEO J A (2016)
COMPARING PERFORMANCE OF SEEDLOT TYPES IN THE KAINGAROA FOREST USING GROUND PLOTS AND AERIAL LIDAR

Problem:
As more improved planting stock such as clones and genetically improved seedlings are introduced to the market it is important to properly understand the benefits of each production type. Various breeding programmes make claims around performance of their seedlots but there is a shortage of literature around the performance of these production types in a plantation setting for most production species.

Approach:
One seedling, two cuttings, and 7 clonal varieties were compared in a plantation setting on a single site. The stand was measured via five permanent sample plots (PSPs) per seedlot. The seedlots were categorised by material production type and compared using pair-wise analysis to find statistically significant differences. The seedlots were then compared individually to find any intra-material differences. Available aerial LIDAR was then used to estimate tree height for the total seedlot area and establish whether this was an accurate estimate. Average LIDAR height was then used to estimate tree height for each of the five PSPs to establish whether this would improve the prediction of heights and permit its use for large-scale evaluation of genetic material.

Results:
Categorising seedlots by material type there was no statistical difference for height performance but there was for DBH and basal area. Clones and open-pollinated seedlots showed superior performance over controlled-pollinated material, but not different from each other. Clones showed reduced height variability over non-clones. DBH and basal area variability was also reduced but the difference was only statistically significant versus open-pollinated seedlots. Comparing seedlots individually there was large variation in performance and variability within material types, with clones showing some superiority and non-clones inconsistent improvements.

The LIDAR tree height model for whole seedlot area showed to be a significant predictor average PSP height but poorly predicted CV. Predicting PSP area provided with LIDAR improved correlations over whole stand predictions for both values.

Implications:
The performance superiority for clones over other production types in this trial is not as pronounced as previously suspected. Clones do, however, provide a more uniform crop. The LIDAR tree height model could be used for further analysis but not for height variability without further improvement.

Result validity was, however, reduced by the lack of trial replication and randomisation. This is the key limitation and makes guaranteeing improvements are due to improved genetics (not environment) problematic.

JACKSON, AMY L. (2011)
INVESTIGATION INTO THE LOWER RECOVERY OF S30S IN NORTHLAND, NEW ZEALAND

This research explores the contributing factors to the lower recovery of S30S volume compared to inventory estimates. The S30S log is a high quality *Pinus radiata* domestic sawlog with tight diameter specifications from Northland, New Zealand. A review of pre-harvest inventory methods, yield analysis (taper, volume and breakage functions) and log making was commenced. Comparisons were made to an optimal cutting solution produced by Timbertech calliper system, across four forest sites, totalling 155 stems.

The pre-harvest inventory predicted volumes were not significantly different ($P > 0.05$) at the regional level, compared to the optimal solution. Actual volumes of S30S produced on the skid were significantly lower ($p << 0.01$) from both the optimal and pre-harvest inventory methods. The S30S log was being downgraded into A grade resulting from a lack in log maker awareness and issues associated with cutting strategies. The implications of this study highlight the need to better understand log making and improving quality control methods for higher specification log grades.

JONES, BLAKE (2013)
THE EFFECT OF LANDING SIZE ON OPERATIONAL DELAYS FOR NEW ZEALAND HARVEST OPERATIONS

Landings are an integral part of New Zealand Harvest operations where extracted trees are processed into logs and loaded out onto trucks. Forest owners need to balance the cost and environmental considerations when designing and constructing landings, with the productivity and safety of the harvesting crew that will use the landing.

The objective of this study is to gain a greater understanding of landing size and how they affect forest harvest operations. This study investigates the relationship between landing size and processing delays. A time study was carried out for ten harvest operations predominantly in the lower North Island. The time study recorded all delays on the processing task of measuring and cutting stems into logs. The delays were then categorised so that only processing delays that are influenced by the size of the landing remained. These processing delays were then expressed per m^3 and used as the response variable in regression analysis to test their correlation against landing size and a range of other predictor variables.

A very strong, linear relationship between processing delays per m^3 and actual landing size was found. This indicates that harvest operations on smaller landings exhibited higher delays per m^3 than those on larger landings. Loading of the deck was the most significant processing delay; this is a direct result of not having enough room for surge piles as delimbing was not able to be carried out during loader downtime. The significance of the relationships developed in this study can help forest owners realise the implications of building landings that are too small for the intended purpose. Not only will small landings affect productivity, but have the potential to financially affect the forest owner also.

JONES, CHARLOTTE (2010)
ESTIMATING THE INFLUENCE OF THINNING ON THE RISK OF WIND DAMAGE

Matariki forests are evaluating the option of production thinning in Eyrewell forest, Canterbury, New Zealand. The forest is situated on flat terrain and is close to the market. However, Eyrewell forest has a history of being damaged by wind and so there is concern that thinning the stands in question will result in increased risk of wind damage. Stand data was collected and a total of 81 plots were measured in January 2010. Data using both the Slenderness (Cremer, Borough, McKinnell, & Carter, 1982) and ForestGALES (Gardiner, Suarez, Achim, Hale, & Nicoll, 2004) models have been used to assess the risk of wind damage. Both models concluded that as stand age increased, so did the risk of wind damage; being consistent with many publications that state wind damage is minimised by thinning at earlier ages. No considerable differences were identified for risk of wind damage between a production thinning operation and a waste thinning operation. The economic analysis showed that when using specialised equipment and thinning down to 350 s/ha, the cost of production thinning was less than the cost of waste thinning, and in some cases a profit can be made. A trade-off analysis emphasised the need to separate the financial potential of production thinning for the health and future of the residual stand. The analysis showed that while the older stands may be production thinned at a profit, the risk of wind damage is higher than that of the younger stands.

JONES, GRACE (2016)
FACTORS WHICH INFLUENCE COREWOOD STIFFNESS IN RADIATA PINE

Increasing stocking and competition with weeds significantly increased Hitman estimates of stiffness at the significance level α=0.05. Accuracy of models predicting Hitman from TreeTap measurements can be improved by customizing them for particular silvicultural regimes and diameter at 1.4m (DBH). Controlled factors: genetics, wind sway and fertilizer use, did not significantly influence Hitman estimates of stiffness. Tree height did not significantly influence stiffness estimates, but including DBH in prediction models improved models of stiffness estimates.
Stiffness in 10 year old *Pinus radiata* stems was studied in an experiment with the following factors: genetics, herbicide/fertilizer use, stocking and wind sway. Acoustic velocity was used as an estimate of modulus of elasticity (MOE) and was estimated using 2 different tools: Hitman, a resonance based tool used on 2m log sections, and TreeTap, a time-of-flight based tool used on 1.2m outer-wood sections of standing trees. DBH and tree height were also recorded for each tree. Green density was measured using submersion in order to use the formula:

$$\text{MOE} = \text{green density} * \text{acoustic velocity}^2$$

Stiffness estimates from TreeTap were strongly correlated with Hitman estimates, but were about 30% higher on average. The relationship between stiffness estimates from these tools changed with weed competition and with stocking. No significant difference in stiffness was found between the northwest and the southeast sides of the stems when using the TreeTap tool, and an average value for each tree was used for subsequent analyses.

These findings are similar to those from other studies carried out on different sites, and to a previous destructive sample at the same site. There were a few major outliers, but despite these the final model relating TreeTap and Hitman estimates was significant (P<0.0001). Weed competition and stocking significantly affected the intercept (P=5.71e-05 and P=1.08e-05 respectively) of a model predicting Hitman values from TreeTap estimates of stiffness.

KUWABARA, SATORU (2017)

PREDICTION OF EXTRACTIVE CONTENT OF *EUCALYPTUS GLOBOIDEA* HEARTWOOD USING NEAR INFRARED SPECTROSCOPY

Natural durability of wood is highly sought for a number of wood products due to the emerging concern over and tightening regulations on the use of toxic preservatives. In New Zealand, various wood properties of several naturally durable Eucalyptus species have been investigated in order to provide potential alternatives to CCA (Copper Chromium Arsenic) treated timber of radiate pine, the widely planted commodity species. Extractive content (EC) in wood plays an important role in determining the natural durability. In this study, near infrared (NIR) spectroscopy was used to predict the extractive content of *E. globoidea* heartwood. The EC of the wood powder samples ranged between 0.54 and 13.51%. A number of Partial Least Squares (PLS) regression models were developed to predict EC from the NIR spectra of the samples. Several spectra pre-processing techniques were applied. The significance Multivariate Correction (sMC) variable selection was also applied to improve the model accuracy. Of all models, 1st derivative NIR spectra with sMC variable selection gave the best results (R2v – 097; RMSEv – 0.52%). Spectral bans around 4,700 cm-1 (2112 nm), a spectral region assigned to the bond vibration of chemical components characteristic of lignin and extractives, explained much of the variance of the EC. Calibration of NIR for the EC of *E. globoidea* heartwood was successful. The model can potentially be used in the future to accurately and rapidly predict the EC for a breeding programme which aims to improve the natural durability of this species.

LILBURNE, MICHAEL (2021)

MEASURING THE EFFECT OF DIFFERENT SILVICULTURAL TREATMENTS ON RADIAL STIFFNESS DISTRIBUTION WITHIN 15-YEAR-OLD RADIATA PINE

Pinus radiata (radiata pine) is a common plantation species grown extensively across New Zealand (Cown, 2005). It has good form and fast growth making it a good species for timber production (Cown, 2005). However, the timber produced from radiata pine tends to be of relatively low quality for structural purposes. It has poor strength qualities, particularly in the corewood region, due to low stiffness and high microfibril angle (MFA) within this region (Jakawickrama, 2001).

This study has investigated how different silvicultural treatments have affected the radial stiffness distribution within the stem of 15-year-old radiata pine. Silvicultural treatments observed include herbicide and fertiliser application, stocking, and clone type.

Acoustic velocity measurements were recorded using time of flight and radial disc scan tools. The time of flight measurements were taken at approximately 1.2 m and the disc scans were taken at approximately 2.2 m height. Two linear mixed-effects models were developed for each of the datasets. Modulus of elasticity and microfibril angle were inferred using formulas developed in Mason et al. (2017).

Herbicide: Herbicide had a significant effect on stiffness ($P<0.01$). The application of herbicide treatment reduced average stem surface MoE by 4% regardless of stocking level or clone type. Herbicide application increased DBH by 3.5%. Herbicide treatment had the greatest effect on MoE close to the pith. Effects were greatest and longest lived at 625 stems ha^{-1}. Effects of herbicide were minimal at the stem surface.

Stocking: A planting density of 625 stems ha^{-1} achieved the lowest surface MoE. On average, surface MoE was 10.6% lower at 625 stems ha^{-1} than that achieved at 1250 stems ha^{-1} and 2500 stems ha^{-1}.

Stocking of 2500 stems ha^{-1} achieved the highest MoE throughout the stem but also had the highest gradient change in MFA and MoE with distance from the pith. The high stocking also had the smallest DBH. On average, DBH was 23.2% and 41.9% lower at 2500 stems $^{-1}$than 1250 stem ha^{-1} and 625 stems ha^{-1} respectively.

Clone: Clone 3, a clone bred for low MFA and high basic density, had the highest MoE. On average Clone 3 had a MoE that was 13.0% higher than the other clone types. Clone 3 had the lowest radial gradient change of MFA and MoE. There was greatest variation in MoE between clone types at 625 stems ha^{-1}. The difference between clones was less at 2500 stems ha^{-1}. This suggests that genetics had a greater effect when environmental pressure was minimised.

LOO, ADRIAN (2015)
WORKING HOURS IN THE FORESTRY SECTOR

Problem: There are concerns that the current working hour patterns are having a negative impact on the rate of accidents and fatalities in the New Zealand forestry sector. However, the is a lack of up to date information on the current working hour patterns. This study quantifies the current onsite and total working hours, travel time and rest breaks patterns. This information is used to describe the current working hour patterns in the New Zealand forestry sector.

Method: A total of 920 forestry workers were surveyed for the purposes of this study. Surveys were completed throughout New Zealand via face to face interviews.

Results: Long working hours were found to be common for employees in the forestry sector. This study reports that the total length of the work day was on average 11-12 hours, this was comprised of an average length of the on-site work day of 9-10 hours and an average daily travel time of 1-2 hours. This study identified that the preferred break structure was to take two rest breaks of 20-4 0 minutes. This study suggests that a 9 to 10 hour work day would be considered acceptable working hours for all job categories except trucking. Those in Trucking suggested that a long 11 to 12 hour work day would be acceptable.

Discussion: The results of this study are consistent with previous workforce surveys. These results provide an insight into current work patterns and further supports the suggestion that working hours have been increasing over time. The interactions of these differences have allowed the working hour patterns to be further explored. Finally a suggestion of acceptable working hours has been made; this suggestion is consistent with the ILO Decent Working Hour's concept and the expected industry aims.

MCCALLUM, DANIEL (2007)
THE INFLUENCE OF WIND EXPOSURE ON *PINUS RADIATA* WOOD QUALITY, TREE FORM, AND VALUE IN NELSON AND MARLBOROUGH, NEW ZEALAND

The aim of this study was to test whether exposure to wind (topographic exposure, and altitude) is correlated to a number of *Pinus radiata* tree form, wood quality and value, measures in complex topography. These relationships were assessed as topographic exposure (topex) or altitude may be used as a variable for estimating wood quality and value gradients within a stand (or within a harvesting setting). Furthermore, topex or altitude may be useful in determining the best regime for a particular site.

Two sites were studied, one in the Nelson region and the other in the Marlborough region, New Zealand, both sites were located within Weyerhaeuser New Zealand Inc forest estate. Standing tree stiffness measurements were recorded in 30 plots within each study site capturing a range of different topex scores and altitudes. 2006 pre-harvest inventory data was analysed within each site to test tree form and value relationships.

Significant ($p<0.001$) relationships were found between altitude and wood quality (stiffness), tree form and value variables in both sites. However these relationships differed markedly between sites. Significant relationships ($p<0.001$) were found between variations of topex and stiffness, in both sites, again relationships differed markedly between sites. These relationships were generally weak ($R^2<0.10$). However, stronger relationships (r^2 0.23-0.32) were found between variations of topex and tree form variables in the Nelson site, suggesting a influence of wind exposure variables on ranch size, sweep severity and taper.

MCEWAN, MARIA (2007)

EXPLORING THE RELATIONSHIP BETWEEN FIRE DANGER AND FIRE OCCURRENCE

The New Zealand Fire Danger Rating System (NZFDRS) is used by rural fire managers as an effective tool for preventing and controlling forest, grass and scrub fires. The five fire danger classes display the potential for a fire to develop and spread over a given time. This report was written to provide fire managers with a useful evaluation of the NZFDRS and its ability to determine fire conditions by comparing fire occurrence and the annual area burned with the fire danger class at the time.

Department of Conservation's electronic database of fires for the Canterbury region from 1997 to 2007 and their fire reporting form were used to create two databases that contained the raw weather values and Fire Weather Index System's indices obtained from the National Rural Fire Authority.

Significant analysis of variance and contingency tables showed that within forest and grassland fuels, more frequent and larger fires are occurring when the fire danger is Moderate or Low. Within scrubland fuels, fires were more frequent and larger when fire danger was Extreme. While the NZFDRS only appears to be functioning as expected for scrubland fuels, there are many factors not considered in this research that may explain the discrepancies for grassland and forest fuels. The causes of fires over the ten-year period were also analysed and showed that fires of unknown causes made up 30% and landowners burning off land accounted for 24% of all fires. The results indicated that fire managers may be less prepared in Low conditions and fire danger awareness among the public may be an issue.

Further analysis into the location of fires in regards to access difficulties and response is required to better understand the NZDFRS.

This report has emphasised the issue of data quality affecting analyses. Improved methods of reporting and recording data are necessary for better future analyses.

MCGREGOR, ROB (2009)

DEVELOPMENT OF A CORRELATION EQUATION FOR CLEGG IMPACT SOIL TESTER CBR EQUIVALENT VALUES ON EAST CAPE FOREST ROADS

Forestry road construction in New Zealand varies widely across regions, where each region faces their own unique set of issues, problems and benefits. The East Cape of New Zealand is an area where road building is problematic, with the transport cost of aggregate being the major issue. The cost of aggregate can be reduced by improving the subgrade, so that less aggregate is required. Improvement can be achieved through many methods, such as chemical stabilisation, compaction and water content management; however, subgrade improvement requires an effective method of testing subgrade strength in the field. A test method widely used for low volume roads is the Clegg Hammer (CIST) – a rapid infield subgrade soil tester.

The purpose of this dissertation was to develop a correlation equation for Clegg Impact Soil Tester - CBR equivalent values on East Cape forest roads. The study was carried out in two phases where 1) a correlation equation was developed between CIV and CBR for subgrades from the East Cape, and 2) the soil type and soil moisture content were assessed to determine whether they had a significant impact on the relationship. Seventeen soil samples were collected from six different forests in the East Cape region. These samples were analysed using the following tests: particle size distribution, dry density/water content relationship, liquid limit, plastic limit, plastic index, CBR test and the CIST test.

The analysis has shown that CBR and CIV correlate well for Gisborne soils. Soil types lean clay and silty clay as well as moisture content type WET had a significant ($P<0.05$) impact on the CBR/ CIV equation. The practicality of the equation is essential for a forestry situation where time and technical expertise in road construction are limited, which is why only the WET variable was included in the equation to predict CBR:

$$\mathbf{CBR = 0.92\ CIV - 3.26\ WET + 0.31}$$

The CIST is not a highly accurate device, but the speed at which you can gain results and the level of simplicity of the tool makes it a great entry level tool to promote a higher understanding of subgrade bearing strength. Through averaging multiple readings, greater accuracy can be achieved.

MCQUILLAN, SHANE (2013)

ABOVE AND BELOW GROUND ASSESSMENT OF *PINUS RADIATA*

A comparison of above ground forest metrics with below ground soil CO_2 respiration was carried out in an attempt to reveal if any correlations exist. Above ground measurements of 2720 clonally propagated trees were taken assessing the silvicultural treatments of stocking, herbicide and fertiliser. These were compared to 480 below ground soil CO_2 respiration measurements. Using measurements of mean height, mean dbh and basal area the data was analysed and returned significant results for mean dbh and the interactions of herbicide and clones, and stocking and herbicide. Mean height returned a significant result for the interaction of stocking and herbicide. Below ground measurements showed an interaction between ripping and stocking; however these results were not ratified by the above ground results. Overall the results were encouraging and should aid in future experiments that seek to understand what effect above ground treatments have on below ground CO_2 activity.

MA, YUHUI (DAVID) (2019)

THE ECONOMIC VALUE OF *EUCALYPTUS BOSISTOANA* FOR VENEER PEELING WITH NATURALLY DURABLE POSTS AS A BY-PRODUCT

Eucalyptus bosistoana is one of the breeding objectives of NZDFI (New Zealand Dryland Forest Initiatives). Currently, most of the material peeled in the New Zealand veneer market is *Pinus radiata* of which the low stiffness is an important deficiency in producing structural veneers. So, it is interesting to know the value of peeling *E. bosistoana* as it can produce much stiffer veneers with the peeler core produced into naturally durable posts as a product.

A tree data was acquired from NZDFI on a trial site by Craven Road North of Blenheim, New Zealand. A veneer price data was acquired by surveying JNL (Juken New Zealand Ltd.). Together with a table derived from literature covering the value range of the important variables the study looked into and a model on R Studio, the value of a *E. bosistoana* tree was simulated, the sensitivity analysis of the variables were conducted and a comparison of *E. bosistoana* and *P. radiata* were done.

It is concluded that the out of the variables tested in the study: stiffness profile, conversion ratio, volumetric shrinkage, veneer price, peeler core size and post regimes, the conversion ratio is the most important variable. Under base scenario in which a conversion ratio of 0.7 was applied, the value of one *E. bosistoana* tree of 29.6cm DBH is NZ$102 while a tree only worth NZ$41 at 0.25 conversion ratio. MoE profile is insignificant under the current price data as no or less price premium was assumed for stiffer veneers. Also, it is concluded that by processing a small peeler core of 30mm, by producing the peeler core into posts or by applying a price premium to stiffer veneers, the value of *E. bosistoana* exceeds *P. radiata* regardless of DBH. The result of the study can support the growers, peelers and tree breeders in making decisions about how much the tree is worth and what to breed for.

MACE-COCHRANE, WILLIAM (2022)

AN EVALUATION OF LANDSAT 9, LANDSAT 8, AND SENTINEL-2 ON FOREST CLASSIFICATION IN THE EAST COAST, NEW ZEALAND

The Landsat programme recently launched Landsat 9 (L9). This sensor has not been widely evaluated for forest classification accuracies within New Zealand. This study evaluated L9 with two commonly used sensors, Landsat 8 (L8) and Sentinel-2 (S2). The creation of classifiers, imagery, and analysis was carried out using the cloud-based processing capabilities of Google Earth Engine (GEE), a cloud-based GIS software.

The need for national small-scale forest classification system is of great importance. Improving the understanding of new sensors and their respective capabilities will improve their uptake within new systems and applications that may fulfil this need.

The study was carried out in the southern part of the East Coast Region, below Gisborne City. Summer imagery was collected and processed for all three sensors. Imagery was integrated into a random forest classifier system, which was tested with ground truth data to attain different accuracy metrics for each sensor.

S2 provided greater accuracy for forest classification with 95.0% accuracy when compared to L9 (93.7%) and L8 (93.7%). The Kappa co-efficient supported this with S2 (0.899), L8 (0.875), and L9 (0.875). McNemar's test showed that S2 was performing significantly differently from L8 and L9 on

the test dataset. From these three measures of accuracy and performance, it was concluded that L9 is not more accurate than S2 or L8 for forest classification in the East Coast of New Zealand.

The key issue for L9 in this study was the classification of forest sizes less than 30 ha. Compared with S2, L9 struggled to accurately detect these areas and should not be implemented into systems that quantify resources with polygon sizes below this threshold (30 ha) if S2 is available. This was due to L9's lower spatial resolution compared with S2, which likely caused more mixed value pixels, therefore increasing error.

MARSHALL, GRACE (2020)

EFFECT OF ARTIFICIAL CANOPY GAPS ON NATIVE REGENERATION IN MATURE *PINUS RADIATA* FOREST IN NEW ZEALAND

Gap creation is what drives succession in natural forests. This research explored the effect of artificial canopy gaps in a mature single-aged *Pinus radiata* forest on understorey native regeneration, and what potential role artificial canopy gaps could have in transitioning a pine forest to a native forest. Species and abundance by cover class was recorded at 22 plots beneath a 22-year-old *P. radiata* forest, in the Marlborough Sounds. The plots included three treatments comprising (1) a closed canopy control, (2) a small gap with trees within a 2.3 m radius felled, and (3) a large gap with trees within a 5.6 m radius felled. The gaps were established in 2014, allowing six years for species to regenerate before they were measured.

The effect of treatment and gap ratio on native species importance value was found to be highly significant ($p<0.01$). Whereas only the effect of gap ratio, and not treatment, was found to be significant on native species richness ($p<0.05$). Native species importance value was found to be significantly different between the small gap and the control, and the large gap and the control. However, there was no significant difference between the small and large gap treatments. The composition of understorey species was also found to be significantly different between treatments ($p<0.05$).

The growth and abundance of regenerating understorey species was strongly influenced by the creation of canopy gaps. Gap creation also caused an increase in species richness; however, this effect was not as strong as the effect on growth and abundance. The presence of gaps was found to be more important than the size of the individual gap as there were only minor differences in understorey regeneration between small and large canopy gaps. This suggests that artificial canopy gap creation can be used to facilitate native regeneration beneath a mature pine canopy.

There was a distinct lack of later successional species in the forest understorey. This is likely due to both a lack of nearby mature forest to act as a seed source and effective seed dispersal mechanisms. Enrichment planting is likely to be necessary in many restorations to bring later successional species into ecosystems from which they have been lost. Herbivore exclusion and control of other mammalian pests is also likely to be necessary to allow for species to regenerate freely in the understorey without browsing pressure. Artificial canopy gap creation in single-aged plantation monocultures creates light environments and structural heterogeneity which can accelerate succession to a natural indigenous forest. However, long- term management and monitoring will be essential for successful ecosystem restoration.

MARSHALL, WILLIAM (2008)

ENSURING A STEM ACOUSTIC VELOCITY READING CAN BE USED AS A CUT OFF TO ENSURE STRUCTURAL LOGS WILL MEET MILL REQUIREMENTS

This dissertation project explores the relationship between stem and log sonic measures in *Pinus radiata* stems for forests managed by New Zealand Forest Managers (NZFM). The stands studied were in both the Lake Taupo and the Tongariro Prison Farm Forests within the Central North Island in which after statistical analysis, were pooled together. Acoustic velocities were determined to determine structural logs within a stem for three variables. The three variables being (a) 2nd logs, (b) 3rd logs and (c) 2nd and 3rd logs combined.

For this study the hypothesis was: it is possible to use a stem acoustic velocity reading as a cut off to ensure that 80% of NZFM's 2nd and 3rd logs that are delivered to mill customers achieve a 3.0km/sec threshold.

Data collection from both forests required gathering sonic readings for stem and logs. The pattern of sonic velocity up the stem was explored. The focus was on the 2nd and 3rd logs which are typically structural logs. Statistical analysis was conducted to determine if there were relationships between stem and log velocities and whether there were differences between (a) LTAU and TPF forest and (b) 2nd and 3rd logs.

Analysing both forests' pooled 2nd and 3rd logs highlights that when using a stem velocity of 2.96km/sec as a velocity cut off, greater than 80% of the 2nd and 3rd logs will meet a 3.0km/sec threshold.

This dissertation project provided the necessary information to highlight that a stem velocity reading can in fact be used to determine the probability of structural logs within a stem meeting structural specifications. Choosing a practical stem cut off reading will result in a trade off with the major focus being on the percent of logs incorrectly allocated. To meet NZFM's mill customer's requirements, there is currently a leeway of 80% correct allocation for structural logs. It is important to note that being able to cut a structural log, the cut off applies to the 2nd and 3rd logs only.

MILNE, JAMILA (2022)

UNDERSTANDING THE VEGETATION PATTERNS AND PROCESSES OF A REGENERATING SWAMP KAHIKATEA (*DACRYCARPUS DACRYDIOIDES*) FOREST IN WESTLAND, NEW ZEALAND

Widespread forest clearance in New Zealand has resulted in changes to forest composition and biodiversity through the modification and subsequent fragmentation of stands. Mixed-podocarp kahikatea stands which historically dominated the alluvial floodplains have now been both significantly reduced in size and the species composition drastically altered. This research explored the vegetation patterns, processes and trends for a regenerating swamp forest fragment in Westland and the consequent implications for aiding restoration. Species and abundance by cover class were recorded for26 different plots at the Taminelli creek restoration site and 2 comparative plots were recorded at Lake Kaniere.

Hierarchical cluster analysis suggested that there were 3 key vegetation clusters at the site: Forested plots with the presence of key sub-canopy species such as *Griselinia littoralis, Melicytus ramiflorus* and *Pterophylla racemosa;* regenerating shrub with species such as *Veronica salicifolia, Leptospermum scoparium*, *Coprosma tenuicaulis* and *Coprosma propinqua*; and plots with a high

number of weeds species present such as *Holcus lanatus* and *Lotus pedunculatus. Dacrycarpus dacrydioides* was a key species for all plots at Taminelli in clusters 1 and 2 but had a markedly lower presence (if any) in cluster 1 plots.

All three clusters were distinctly separated along NMDS 1 in the ordination space with environmental vectors such as weed importance, canopy height and species diversity all being significantly correlated with the ordination while plot distance from the edge was not significantly correlated.

When observing regeneration trends for key species in the understory it was found that the mean percent canopy cover for each height tier was what would be expected for a kahikatea dominant forest early in early succession whereby percentage canopy cover generally increased incrementally for each height tier. Deer-palatable species such as *Griselinia littoralis and Melicytus ramiflorus* were found to have comparatively lower mean percent canopy cover in tiers less than two metres in height compared with the considerably less palatable *Pseudowintera colorata.* This indicates that deer may be a threat to regeneration of more palatable species in the understory and subsequent species composition for the stand in future. Lastly, a restoration plan for the Taminelli creek site based on these findings is also included.

MILNE, PHOEBE (2021)

THE POTENTIAL FOR USING FORESTRY OFFSETS TO MEET UNIVERSITY OF CANTEBURY'S NET-ZERO CARBON EMISSIONS TARGETS: A CASE STUDY

The University of Canterbury (UC) has a strategic objective of being net carbon neutral by 2030. This case study has analysed the ability to meet this using forestry on UC's high country properties and the framework of the NZ ETS to offset an estimated 6,525 tonnes CO_2e annually from 2030.

Variations of three scenarios which facilitate carbon neutrality were investigated. The potential contribution from Mt Barker, UC's only existing forest, was analysed under the assumption it was 1) retained and 2) cleared and replanted. In both cases complementary afforestation on UC Pastoral Lease properties was needed. A third scenario of new afforestation on UC pastoral land was also evaluated.

The results show that UC can achieve carbon neutrality. This can be facilitated at least cost using the forest at Mt Barker if the Corsican pine forest is retained and the additional eligible area entered into the ETS. However, for UC to maintain its status as net carbon neutral using forestry offsets, additional planting will be required. There are numerous programmes that UC could consider implementing to achieve this. If action is taken urgently, the estimated offset requirement of 6,525 tonnes annually can be met from 2030.

MOLLOY, MAC (2017)

EVALUATING THE TRUE COST OF METHYL BROMIDE FUMIGATION AND DEBARKING FOR LOG EXPORTS OUT OF MARSDEN POINT

Over half of New Zealand's annual harvest was exported as logs to four markets in 2015: China (68%), Korea (17%), India (11%) and Japan (3%). All of the deck cargo currently exported out of Marsden Point to India, as well as the majority of Chinese cargo, is fumigated with methyl bromide in order to meet phytosanitary requirements. The remaining proportion of Chinese deck cargo is debarked.

Exports to Korea and Japan are treated on arrival. If the 2020 deadline set by the Environmental Protection Authority (which requires that all methyl bromide must be recaptured or destroyed following fumigation) cannot be met, then alternative methods will be needed to meet phytosanitary requirements. Debarking is an alternative method that could be used instead of methyl bromide for Chinese exports, whilst Indian exports would have to cease due to a lack of approved alternative treatment methods.

Several factors were identified that influence the cost of debarking operations, including: debarker specifications, resource availability, production mix, shipping load improvements, bark disposal, land lease, additional handling and transport, power, maintenance, and staffing costs.

When all suitable log grades were included in the production mix (Pruned, Small-Pruned, A-Grade, A- Oversize, and K-Grade logs), it was found that the entire volume of wood in Northland that is forecasted to be exported as deck cargo (960,400m^3), from 2020 onwards, could be debarker using a Nicholoson A5C 27" ring debarker. The average cost expected for debarking this volume was calculated at \$2.52/JAS m^3. When broken down by log grade it was found that A-Oversize and Pruned logs were the cheapest to debark, at a cost of \$1.09/JAS m^3; followed by A-Grade and Small-Pruned logs at \$1.84/JAS m^3 ; and K-Grade logs at \$3.86/JAS m^3 . Despite the high cost of debarking K-Grade logs it was found to be \$0.46/JAS m^3 cheaper to include them in the production mix due to increased economies of scale. As China is the only country that currently approves debarking as a phytosanitary treatment it would be logical to only debark Chinese bound cargo. If this was to occur, it is expected the average debarking rate would increase to \$2.88/JAS m^3 due to reduced economies of scale.

Additional handling and transport costs were the most significant factor influencing debarking costs, accounting for 71% of the overall cost. Capital cost was the next most important factor, accounting for 16% of overall costs, followed by maintenance (11%), shipping load improvements (-10%), staff (6%), power (5%), and land lease costs (1%). The base case model assumed that there would be no cost or revenue resulting from bark disposal. However, if a price, or a revenue, of \$20/m^3 was imposed for disposal, then a 37% change in the average debarking cost would be expected.

When compared to the true cost of methyl bromide fumigation at Marsden Point, which was calculated at \$5.25/JAS m^3 (in June 2017 dollars), debarking appears to be an economically favourable method for meeting phytosanitary requirements.

MOOYMAN, JOSHUA (2011)

ANALYSIS OF THE EFFECTS OF SHORT TUSSOCK PATTERNING ON PASTORAL PRODUCTIVITY, MACKENZIE BASIN, NEW ZEALAND

Pastoral productivity in the Mackenzie Basin has been declining for a number of years (Ledgard 2001; Sage *et al.* 2009). Tussock pedestals are the only areas unaffected by wind erosion (Basher *et al.* 1997) and make up the majority of biomass available for pastoral grazing (Norton *et al.* 2006).

This study aims to assess the effect of small-scale short tussock patterning (pedestals) on the reported decline in pastoral productivity in the Mackenzie Basin. This was achieved by: sampling soil; sampling vegetation; and quantifying vegetation cover at 5 sites. At each site a total of 12 plots, consisting of 6 plots of 'inside tussock pedestal' treatments occurring on observed 'tussock pedestals' and 6 plots of 'outside tussock pedestal' treatments occurring in between tussock pedestals, were established. Samples were taken at monthly intervals over the 2010/11 summer. It was hypothesized that pedestal quality (soil depth and water content) will affect tussock cover.

Homogeneity of plots of the same treatment has been proved through visual observations and ANOVA analysis, with a few minor outliers. Heterogeneity of variables, when comparing different treatments, has shown that the studied areas indeed display tussock pedestals, and that these pedestals have dramatically different soil and vegetation properties than surrounding areas. This leads to differences in pastoral productivity contribution between treatments. A linear model proves that tussock cover and total soil water content are related (Adj. R^2 = 0.531) which allows the assumption: higher soil depth and/or total soil water content will result in better tussock cover and therefore better pastoral productivity.

In summary, tussock cover has a major effect on pastoral productivity and the 'tussock pedestals' should be the focus of future management interventions, as inter-tussock pedestal areas seem to have declined beyond the ecological threshold for tussock success.

MORROW, BEN (2012)
A PILOT SCREENING STUDY INTO THE WOOD PROPERTIES AND QUALITY OF *EUCALYPTUS BOSISTOANA* IN THE MARLBOROUGH DRYLANDS

International scrutiny and poor strength of CCA treated vineyard poles had created a demand for naturally durable timber species. The NZDFI has sourced an unimproved seed source from Australia to grow here in the Marlborough drylands, where *Eucalyptus bosistoana* is showing promising growth and a natural durability rating of 1.

Twenty 7-year-old *E.bosistoana* trees were selected and felled on 3 different sites (Millen, Cuddon, and Pukaka) in Marlborough. Taking a total of 20 trees from three sites is not ideal, but no landowner was willing to provide a more robust sample. Cross-sections were extracted up the stem and then taken back to the School of Forestry where they were cut up and measured for stiffness, density, MC, shrinkage, and growth strain.

There is evidence of a linear correlation between the velocity data of the thick and thin discs, and green and dry samples, though the best relationship was found between the green and dry thick disc samples.

The data for both the green and dry samples was found to be normally distributed, more so for the green dataset as the dry exhibited some skew. Measures for basic density and stiffness were very promising at roughly twice that expected of radiata at age 15.

Shrinkage and growth stresses also proved to be much less pronounced that initially hypothesised, as they were both very small in the tangential direction, and even less so in the radial direction.

More research is needed before any actions should be carried based on the results as this is merely a scoping study. Based on what has been done here, I would recommend that an improved *E.bosistoana* seed source should be developed here in New Zealand, and that further research and testing needs to be done on this species at a later age when mature.

MUIR, KATE R. (2014)
FOREST INDUSTRY EMPLOYEES: TRAINING, SAFETY AND RETENTION

Forestry employees are the most valuable asset to forest operations. An analysis was completed to determine employee training status, how safe employees feel within their roles and identify major reasons of dissatisfaction.

Through the development of job descriptions and person specifications, it was possible to identify the job requirements along with the personal attributes and qualifications required by employers, to ensure employees were capable of undertaking their role.

There is an identifiable gap within the level of formal education among employees. Over half (55%) of the employees have lower qualifications than those required to have undertaken further forestry on-job training.

A majority of employees', particularly those in machine operator roles feel safe in their forestry operational roles. A small proportion of employees in breaker out, thin to waste and pruning roles feel unsafe. All employees surveyed except loader operators, felt only moderately safe in their role.

The difficult environment associated with forestry was determined to be the major reason for dissatisfaction (52%) among employees, along pay and length of day. Paradoxically, the environment was also a major reason for satisfaction among those surveyed. By identifying the major reasons of dissatisfaction among forestry employees it is possible to improve job satisfaction and employee retention.

Training forestry employees needs to be from a more practical aspect. This will lead to increase the number of employees that are trained for the roles they are undertaking, by ensuring they are equipped with adequate knowledge, and have the skill to work safely and to a high quality standard.

MUNRO, HANNAH (2022)
THE NEW RECOMMENDED FORESTRY MANAGEMENT PLAN FOR PORT MARLBOROUGH'S SHAKESPEARE BAY FOREST

After the harvest of the existing Shakespeare Bay Forestry block owned by Port Marlborough, there is an opportunity to replant with alternative species. Port Marlborough does not wish to see a replanting of *Pinus radiata.* This will better align with the Port's long term strategy to deliver balanced outcomes for people, the planet, and prosperity and to achieve these outcomes through partnerships.

This final recommended management plan outlines the agreed alternative species replanting plan which consists of the following timber species. There will also be some permanent native forest areas including a Māori heritage forest area:

- White Stringy Bark (*Eucalyptus globoidea*)
- Coastal Redwood (*Sequoiadendron sempervirens*)
- Totara (*Podocarpus totara*)
- Black Beech (*Nothofagus solandri*)

The total NPV was analysed by comparing the alternative species planting plan to a normal *Pinus radiata* replanting. This was extended out to 80 years ensuring each species had been harvested at least once, considering the entire forest. As expected, Pinus radiata had better financial returns resulting in a total NPV of $928,114 versus $776,082 for the alternative species. This was not a large enough economic difference to counterbalance Port Marlborough's wider sustainability objectives.

The recommended replanting plan is dependent on the success of risk mitigation plans for animal and plant pest management. Fencing is the recommended control for the large ungulate population before replanting. Compared to strategic hunting this was the more cost effective option and better

fitting Port Marlborough's long term restoration goals. The western side of the forest was assessed to be especially problematic, with Oldman's Beard receiving urgent priority ratings. This area will need to be dealt, first with hand releasing, spray approaches, and biocontrol agents in the long run.

NAYLOR, SARAH (2013)
THE IMPACTS OF SPECIES, PHYSIOLOGICAL AGE AND SPACING ON TREE FORM AND BRANCHING

This dissertation examined the impact of species, physiological age and spacing on tree form and branching at a Nelder experiment located near Rolleston, Canterbury. Two species were compared, *Pinus radiata* and *Eucalyptus nitens*, at a range of stockings from 271 stems/ha to 40,466 stems/ha. Within the *P. radiata*, two different physiological ages were compared.

Stocking and species significantly affected the (p-value <0.05) tree height, diameter at breast height (DBH), crown depth, branch mortality, branch angle, branch size and internode length. Only stocking was statistically significant for crown width, and height from the ground was also statistically significant for branch angle and branch mortality.

DBH, crown width, crown depth, branch size and branch survival decreased with increased stocking for both species. Branch angle and average internode length increased as stocking increased for both species, and branch angle and average internode length also increased as you moved away from the base of the tree. DBH, average internode length and branch size were significantly larger for *P. radiata* across all stockings, however branch mortality and branch angle were significantly larger for *E. nitens*.

Physiological age was not statistically significant for any aspects of tree form or branching examined in this study.

NGUYEN, LISA (2019)
ASSESSING THE WOOD PROPERTIES OF 2-YEAR OLD *EUCALYPTUS TRICARPA*

This dissertation is focussed on the wood properties of *Eucalyptus tricarpa* at age 2 and their associated genetic parameters. The results of this report are intended to aid the New Zealand Dryland Forests Initiative (NZDFI) project with *E. tricarpa* tree improvement work, with the focus being on the reduction of growth strain.

Six traits for *E. tricarpa* were assessed using 32 families from a breeding trial established in November 2016. The traits were diameter, acoustic velocity (AV), dry density, Modulus of Elasticity (MOE), growth strain and volumetric shrinkage. The genetic parameters analysed were the narrow-sense heritability, genetic correlation and the coefficient of additive genetic variation.

The mean growth strain of *E. tricarpa* was 1735.00 με, which was less than that of three other species of interest in the NZDFI project. The growth strain had a moderate narrow-sense heritability of 0.32, which means that reducing the growth strain via breeding may be a challenge, however, the CV_a for growth strain was 12.32%, meaning that there is scope to manipulate the growth strain.

The genetic correlation between growth strain and MOE was high (0.65), implying a trade-off but this may be offset by the high stiffness wood present in *E. tricarpa*, which had a mean MOE of 11.35 GPa at age 2. The estimated genetic gain showed that the growth strain in *E. tricarpa* could be halved (-52%) if the top family was selected but this would be impractical in a breeding programme. Selection

for further tree improvement work should consider selecting multiple families based on their breeding value rankings for growth strain, diameter and MOE.

The main limitation of this study was that the environmental effects on the traits could not be assessed and therefore further studies on *E. tricarpa* wood properties should include multiple sites to analyse these effects.

NISH, FALLON (2022)

ASSESSING INTERATCTIONS BETWEEN SILVICULTURAL TREATMENT AND SITE EFFECTS ON CARBON SEQUESTRATION IN *PINUS RADIATA* D. DON PLANTATIONS

This study explored the interactions between silvicultural treatment and site effects on carbon sequestration in *Pinus radiata* plantations. Rates of CO_2 sequestration using data from long-term silvicultural experiments and models of individual tree carbon were assessed and compared in different regions of New Zealand. Models of individual tree carbon content applied to plots of trees in experiments with different silvicultural treatments were compared to the Emissions Trading Scheme (ETS) carbon look-up tables to assess whether there were any differences. Given the increasing economic and environmental incentives of carbon sequestration it makes carbon forestry an appealing investment. Therefore, it is beneficial to understand the silvicultural treatments that will optimise carbon sequestration. Given the climate crisis and the need to reduce emissions it is important carbon sequestration is accurately accounted for.

A literature review was conducted and explained that the carbon sequestration function of forests is intimately related to the production function of forests. Therefore, an increase in forest biomass leads to an increase in forest carbon storage.

Comparisons of carbon sequestration rates across different silvicultural treatments of radiata pine stands found that silvicultural treatments influence carbon sequestration. The New Zealand regions analysed within this study were Northland, Bay of Plenty and Canterbury and these regions all contained experiments showing the influence of silviculture treatments on carbon sequestration.

The silvicultural treatments found to significantly influence carbon sequestration ($p<0.05$) included weed control, stocking, genotype, and cultivation. Previous biomass studies have found similar results; that silvicultural treatments that aim to increase biomass such as high stockings and weed control results in an increase forest carbon storage. There were three types of interaction effects. Firstly, interaction effect between stocking and weed control and secondly between stocking and genotype and lastly between weed control and fertiliser.

Comparisons of observations of carbon sequestered in radiata pine stands compared to the ETS carbon look-up tables showed that generally the look-up tables incorrectly estimated carbon sequestration at older ages when significant silviculture treatments are applied. Six out of the nine analyzed experiments in this study showed higher carbon sequestration rates than the look-up tables when significantly influential silvicultural treatments were applied. Two out of the nine experiments had no significant difference between observed carbon and the carbon look-up tables and one experiment the observed carbon was below the look-up table.

NUSKE, SAM R. (2014)

A COMPARATIVE STUDY OF MECHANISED CABLE HARVESTING SYSTEMS IN NEW ZEALAND

Productivity and safety concerns of traditional cable harvesting systems have been the key drivers for increasing levels of mechanisation in New Zealand. The use of grapples in cable yarding could eliminate the need for motor-manual tree fallers and breaker-outs in most situations.

A comparative time study was carried out on two mechanised cable harvesting systems utilising grapple carriages in an attempt to better understand the benefits and limitations of each system in different harvest settings. These systems include the Mechanical system which involved a swing yarder operating a mechanical grapple carriage and the Motorised system, which used a tower yarder with a motorised grapple carriage.

The Mechanical system took less time to accumulate felled trees but took longer to unhook trees on the landing than the Motorised system. The Mechanical system had a shorter cycle time (2.07 minutes) than the Motorised system (2.32 minutes) and extracted 1.3 tonnes more than the Motorised system per cycle. The Motorised system had shorter cycle times when in horizontal haul distances of less than 90 metres, but had the longest times when the distance exceeded this. Utilisation rates were similar between the two systems, although the main difference in delays between the two systems was the use of surgepiles on the landing by the Motorised system.

Both systems were effective, although on average the Mechanical system was more productive, with a productivity of 45 t/SMH, compared to 40 t/SMH for the Motorised system. The Mechanical system was the most productive when extracting mechanically felled and pre-bunched or trees while the Motorised system was the most productive when extracting motor-manually felled trees. Pre-bunching with an excavator was a more cost effective method than handing stems directly to the grapple carriage. Further research of the Mechanical system under more adverse conditions would allow a better overall comparison.

ORTON, SARAH (2008)

NEEDLE RETENTION AND TREE TRANSPARENCY MEASUREMENT METHODS AND THEIR RELATIONSHIPS WITH TREE GROWTH, TREE HEALTH AND ENVIRONMENTAL VARIABLES FOR USE IN CONDITION MONITORING PLOTS IN TIMBERLANDS LIMITED'S ESTATE, ROTORUA, NEW ZEALAND

This paper explores the significance and strengths of relationships between new measurement variables of needle retention and tree transparency with forest growth (height and diameter), forest health (*Dothistroma* Health Scores) and environmental (site index and LENZ) variables in permanent sample plots in Timberlands Limited's estate in Rotorua, New Zealand. Needle retention is the number of years worth of needles present in the bottom third of the green crown and is measured using a four value scoring system. Tree transparency is measured as the percentage of needles remaining on a tree out of a possible 100%. Two readings are made per tree (whole tree and top half) to minimise the effect of suppression. Scoring is in 5% increments for both readings.

This report found few significant (p-value >0.05) relationships between the variables tested. Of those relationships that were significant, all of them produced weak relationships ($R^2 > 0.56$). Due to the weak nature of the relationships, no attempt was made to model needle retention or tree transparency. The tree transparency measurement methods were found to be subjective and hard to measure in overcast conditions. Also the two readings produced very similar results, which did not fully counter the effect of suppression created by high stocking. Unless a less subjective way (not

using an assessor) can be found to measure tree transparency, it is recommended that this measurement method be used.

PARK, DA WOON (2009)
DOCUMENTATION AND ANALYSIS OF CATASTROPHIC WIND DAMAGE IN NEW ZEALAND RADIATA PINE PLANTATIONS

This study had two purposes. The first was to provide an update of historical wind damage records of all regions in New Zealand, and the second was to describe any spatial and chronological patterns of the damage. Over 60 000 ha of damage on large owners' radiata pine forests was collected through a literature review along with a survey.

Average annual % damage was estimated for each region. Four regions had over 40 years of records. Canterbury has the highest average annual % damage followed by Nelson and CNI with Otago at a lower level. The ranking is the same as that found by Somerville (1995) except that Nelson and CNI are reversed although still at similar levels.

There has been a decrease in wind damage in the CNI and Canterbury regions where there have been no wind events causing over 1000 ha of damage during the last 20 years. The reduction in damage in CNI and Canterbury corresponds with a reduction in extreme winds at weather stations at both Rotorua Aero and Christchurch Aero. A more extensive analysis of weather station data is required before wind speed trends can be generalised for the CNI and Canterbury regions.

The majority (50 out of 59) of the recorded events caused damage in a single region. Only one event caused damage in more than two regions. Eight events caused damage in two regions that were usually adjacent. Risk against wind damage can be diversified through establishing a portfolio of forests across different regions.

PARKES, HEATH (2023)
FORECASTING THE FOREST GROWING WORKFORCE DEMAND WITHIN THE CANTERBURY/WEST COAST REGION

The forestry industry has grown into becoming a major contributor to New Zealand's economy and employment by becoming one of the country's staple export earners. It is estimated that the industry currently employs over 40,000 individuals, this number has been rising steadily since 2015. Employment within the industry is heavily dependent on the export timber market in the short term and the area by age class distribution of the forestry resource in the long term and can at times create abrupt shortages in job-specific roles within the industry.

A survey of the forest-growing workforce within the Canterbury/West Coast region was conducted in order to characterise the region's employment. A total of 42 businesses were identified during the study, of these businesses a response rate of 69% was achieved. Using data collected from the survey alongside publicly available information, a regional workforce forecasting model was developed in order to forecast regional demand between 2023 – 2053. Results were then analysed to determine the key trends in future workforce demand and more specifically demand which job roles experience the most fluctuation under the forecast conditions.

Results showed that the majority of employment falls within forest harvesting and log transportation. It was found that these two sub-groups are affected the most by changes in wood availability, this is due to the fact that both harvesting and log transportation are completely reliant on future harvest

volumes. It is expected that the Canterbury/West Coast forest workforce demand will contract significantly from 2023 – 2043 as regional wood availability reduces. Workforce demand is expected to recover from 2036 – 2044, however, still expected to be 23% lower than employment levels experienced during 2023.

The Canterbury/West Coast forest industry needs to prepare for a reduction in forest harvest activity and employment. This research quantifies the impact of the decline in harvesting activity on those job roles associated with harvesting. The future trend in forest management and silviculture job roles also depends on the level of investment in new planting and replanting. Employment at the port depends on the volume of wood allocated to the export log market and to domestic processing. It is important to fully quantify how the workforce will be affected in order to make better decisions based on more robust data.

PATIENT, ROBYN (2022)

HOST PREFERENCE, TOLERANCE AND DISPERSAL OF *PAROPSISTERNA CLOELIA* (STÅL) WITHIN MARLBOROUGH

Paropsisterna cloelia (Stål) is a phytophagous leaf beetle native to Australia and closely related to the well-established *Paropsis charybdis* (Stål). The hosts primarily defoliated by *P. cloelia* includes tree species within the *Eucalyptus* genus. Following its discovery in the Hawke's Bay in 2016, *P. cloelia* has since spread south to as far as Oaro on the East Coast of the South Island. *Pst. cloelia* is concerning as it is a gregarious defoliator of juvenile *Eucalyptus* leaves, may potentially be outcompeting *P. charybdis*, and defoliates trees over longer periods.

Two of four key research questions underpinning this dissertation involved investigating whether *Pst. cloelia* exhibits host preferences between *Eucalyptus* species and whether *Pst. cloelia* is out-competing *P. charybdis*. Observed abundance across six *Eucalyptus* species was examined in December 2021 and January 2022 between two NZDFI trials. Strong evidence indicated there was a significant (DDIC > 3) difference in *Pst. cloelia* abundance across the *Eucalyptus* species. In descending order, the four *Symphyomyrtus* species *E. bosistoana, E. cladocalyx, E. tricarpa,* and *E. quadrangulata* harboured the greatest *Pst. cloelia* abundance. Consistently, the two species within the *Eucalyptus* sub-genera *E. globoidea* and *E. macrorhyncha* had a substantially lower presence of *Pst. cloelia.* Significance (DDIC > 3) differences was also found between *Pst. cloelia* and *P. charybdis* abundance at the Dillon site. *Pst. cloelia* had a disproportionately high abundance particularly in January where it displaced *P. charybdis* on *E. bosistoana*.

An additional question emerged as to whether juvenile leaf toughness drives eucalypt tolerance to *Pst. cloelia.* Tensile strength was measured with tensile tests of the preferred *E. bosistoana* and the less preferred *E. globoidea* and *E. macrorhyncha* juvenile leaves. All three species had significantly different ($P < 0.05$) tensile strengths, with greatest strength observed in *E. bosistoana* followed *by E. macrorhyncha,* and *E. globoidea.*

The final key research question involved determining whether *Pst. cloelia* had spread further south along the East Coast of the South Island. Answering this question involved opportunistic sampling in trips between Christchurch and Marlborough from 32 *Eucalyptus* locations. The southern-most sighting of *Pst. cloelia* was Oaro, therefore, the completed sampling could not extend its known distribution range.

PAYNE, BENJAMIN A. (2011)
PREDICTING THE PROBABILITY OF PRODUCING STRUCTURAL MACHINE GRADE TIMBER FROM LOG MEASUREMENT

This research explores the ability of constructing a model using log variables to predict board MoE within logs of *Pinus radiata*. The log variables consisted of average small end diameter, acoustic velocity, green density, heartwood percentage and radial position (radial distance from geometric centre of the log). The variables were introduced successively to evaluate the prediction capability of the variables on board MoE. The models were analysed for both total incorrect grade percentage and total potential value loss.

The research found that the sawmill model (average SED and radial position) was the best model at predicting the least amount of incorrect total grade and value loss. The addition of log acoustic velocity, green density and or heartwood content did not improve the model prediction of board MoE.

PEARSE, GRANT D. (2012)
TESTING THE FUNDAMENTAL SOIL LAYERS (FSL)

This study examined the reliability of the estimates for Profile Available Water (PAW) and Potential Rooting Depth (PRD) held with the Fundamental Soil Layers (FSL) geo-database. A review of the data and methods used to construct the FSL was undertaken and multiple issues were identified with the database. Two datasets were assembled from soil pits dug at a range of locations across New Zealand. One dataset contained measured values for both PAW and PRD, whilst the other contained PRD and soil texture values only. No useful relationship could be found between the FSL estimates and the measured values for PAW or PRD. Intervals estimating the likely range of the true values seldom included measured values. Where the intervals did contain a high proportion of measured values, they were too wide to be of practical use. Data quality as indicated by the lineage of the FSL data did not correlate with better PRD or PAW estimates. Where strong inferences could be made for PRD data, the correlations often contradicted the expected level of accuracy for estimate lineage. Attempts to derive estimates of PAW from texture alone were not successful, while a clear relationship was evident a limited dataset and missing variables prevented useful results from being obtained. The current FSL estimates must be considered unreliable. However, new modelling techniques applied to the existing soil data may yield better estimates in the future. These efforts would be assisted by the collection of additional soil data, as well as the application of newer remote sensing techniques.

PENDLY, MELISSA L. (2012)
ASSESSMENT OF NEW ZEALAND'S FOREST CODES OF PRACTICE FOR EROSION AND SEDIMENT CONTROL

New Zealand's forest industry operates under several codes of practice for erosion and sediment control. Inconsistency between regional forestry regulations led industry to lobby for the Proposed National Environmental Standard for Plantation Forestry (PNESPF). A national code of practice may also need to be introduced to give effect to the PNESPF. This dissertation focuses on what type of code of practice should be adopted, and under what conditions.

The conditions required for a code of practice to succeed in protecting the environment were identified. The 'external' social and legal conditions were identified through analysis of three case studies from the international primary sector, whilst the 'internal' conditions relating to the development, content and implementation of a code of practice were identified through review of

literature. These ideal internal conditions formed the basis of the criteria used to assess New Zealand's codes.

Six of New Zealand's forest codes of practice were classified by their type, the motivation for a corporation to comply with them, and enforcing agency. The internal conditions of these codes were then assessed to determine the strengths and weaknesses of the existing documents. Overall, the codes had well-defined objectives, good planning information and clear communication. The weaknesses included regulatory approach, comprehensiveness, foundation (particularly stakeholder involvement), monitoring information and review process.

The proposed national code of practice, if introduced, should be a prescriptive code. A prescriptive code is better than an outcome-based code because it is difficult to prove liability for sedimentation and erosion. Compliance with a prescriptive code should be like liability insurance, so that if a corporation is fully compliant with a prescriptive code of practice, it should not be held liable for adverse environmental impacts. This is a preliminary recommendation only, as the external conditions operating in New Zealand still need to be investigated.

PERRY, CHRISTOPHER (2013)
ECONOMIC ANALYSIS OF A TARGET DIAMETER HARVESTING SYSTEM IN RADIATA PINE

Target diameter harvesting (TDH) is a forest management system in which all stems above a set minimum diameter are harvested on a periodic basis. There is evidence in the literature that TDH can achieve a rate of return on a similar scale to a clearfelling regime, with added benefits of regular cash flow from partial harvests, and preservation of non-timber values.

Economic analysis was carried out on 12 years of TDH using permanent sample plot (PSP) data from Woodside Forest, a 30ha plantation of radiata pine (*Pinus radiata*). The Woodside Forest management regime has a target diameter of 60cm, and a harvest cycle of two years. Economic analysis considered the option to partial harvest or clearfell every two years, and compared the outcome of each option in terms of land expectation value (LEV). Comparisons are made between regimes with different numbers of partial harvests, assessing the effect of TDH on stand LEV.

Results show that in three of four applicable stands, LEV reached a maximum at ages 30 – 32, (near the time when partial harvesting commenced), and reduced slowly with increased numbers of partial harvests. This shows there is a small opportunity cost associated with choosing TDH over a clearfell system. The effect of revenue from early partial harvesting operations on LEV was small as the majority of stand value is still in the standing crop. This limited the conclusions that can be drawn from this study due to the short time frame analysed.

The study was limited by a small dataset which did not accurately represent average stand values. Because of this, no attempt to quantify the value of the opportunity costs was made. Despite this, the results support the notion that TDH can achieve economic returns similar to clearfelling in radiata pine forests.

POULSON, ERIN (2009)
EFFECTS OF SITE PREPARATION ON ESTABLISHMENT AND GROWTH OF NATIVE WOODY SPECIES IN A DIRECT SEEDING TRIAL, TIROMOANA BUSH, NORTH CANTERBURY

The aim of this study is to assess the success of different pre-sowing cultivation methods on the establishment of native woody plants from seed. There were three different cultivation components

using a standard plough, a bush bog plough and tyne harrows. Establishment success, average height and maximum height were used as indicators to assess the success of different pre-sowing cultivation methods. This study was undertaken in Tiromoana Bush, North Canterbury. The data was collected from an existing trial set up by SCION in 2007. Historically, the site had been extensively grazed by both sheep and cattle but grazing ceased in 2005. The removal of grazing pressure led to the development of extremely long rank grass swards. Tiromoana Bush is now under active conservation management.

The existing trial was 54 m x 36 m and consisted of six different treatments with three replicates of each. 1x7 metre plots were established in each of the replicates, and seedlings were identified and their attributes were measured. It was found that no seedlings established in any of the treatments apart from those that used a standard plough as the cultivation method. The only significant difference between the treatments that used a standard plough was found to be in the establishment rate of poroporo between the treatment that was mown, had herbicide sprayed then ploughed and the treatment that was just ploughed ($p = 0.037$).

It is obvious that pre-sowing cultivation effects the establishment and growth of native woody plants from seed. Results suggest that under the conditions at Tiromoana Bush (strong summer soil moisture deficits), a cultivation method that turns over and exposes a large amount of bare soil is required for direct seeding to be successful. However, given the small data set further research is required to fully validate the results.

RAMLOSE, ROBBIE A. (2012)

EFFECTS OF DIAMMONIUM PHOSPHAGE AND CALCIUM MAGNESIUM FERTILISATION ON *PINUS RADIATA* TRIALS IN SOUTHERN KAINGAROA

This paper presents results from four fertiliser trials established in 2005 on pumice sites in Southern Kaingaroa to examine effects of fertilisation at various times after planting. Significant responses to fertilisation were only found in trees that were fertilised at establishment (age 0) and the only treatments that provided significant growth responses were treatments fertilised with 150g of Diammonium Phosphate (DAP) per tree. Calcium Magnesium (CalMag) fertilisation at any application rate and age of the trees in these trials provided insignificant growth responses. Although initial growth responses to DAP were relatively high for initial ground level diameter and height, these size differences were not sustained over the length of these trials (six years), diminishing to only a small and insignificant relative difference at age six. From the diameter growth after four years it was calculated that there was a time gain of three months from the 150g DAP treatment after six years growth. Time gain analysis then returned a land expectation value (LEV) of $183/ha for fertilised compared to that of $404/ha for an unfertilised regime, showing that the time gained from fertilisation wasn't sufficient to justify the purchase and application costs of the fertiliser. Health and vigour variation was significantly different between fertilised and control treatments at age six. Assuming coefficients of variation of height and diameter measurements were indicators of health and vigour. This lower variation within the stands might allow for a lower and less costly selection ratio.

RAPLEY, BLAKE (2022)

A MORPHOMETRIC APPROACH TO MODELLING COAST REDWOOD PRODUCTIVITY AT HUNDALEE FOREST

Coast redwood (*Sequoia sempervirens*) is an evergreen species native to the coast of California and Southwestern Oregon in the United States. Making up less than 1% of New Zealand's plantation estate, it is a minor commercial species in New Zealand. However, the species' characteristics of

valuable timber, high volume production, and its ability to regrow from stumps after harvesting mean it could become more common as a plantation species.

This dissertation aimed to improve the prediction accuracy of the coast redwood 300 Index model developed by Watt et al. (2021). The model fails to accurately predict 300 Index at Hundalee Forest, a redwood plantation owned by The New Zealand Redwood Company. Only 6.7% of the variation between the observed and predicted 300 Index values are explained by the model. Using an approach similar to that of Salekin (2019), it would investigate how site morphometry influenced redwood productivity.

A combination of site, climate, and morphometric variables were analysed using RStudio to develop a model that could more accurately predict 300 Index at Hundalee Forest. The final model produced was:

*Observed 300 Index ~ Morphometric protection index + Topographic wetness index * Cosine of aspect*

This model produced an adjusted R-squared value of 51.4%, an improvement of 44.7% over the original redwood 300 Index model. Each of the variables in the models had statistically significant P-values (<0.05), which means that each of the variables in the model were significant predictors of redwood productivity at Hundalee Forest and that methods used in Salekin's study of eucalyptus productivity influences applies to coast redwood.

While this study has achieved what it set out to, there were limitations to it. The main limitations were having a small dataset (n=31), which likely reduced the model's explanatory power and prevented validation, as well as some variables not being useful due to high correlations between layers sourced from the internet. In the future, it is recommended that The New Zealand Redwood Company investigates the effectiveness of the model produced on their other plantations around New Zealand and that morphometry is taken into consideration in future coast redwood productivity modelling.

RERITI, BEN (2018)
ESTIMATING WINCH-ASSIST UTILISATION USING GPS TRACKING

Winch-assist systems have become increasingly common in New Zealand as the drive to mechanise forest operations increases, with the aim of reducing accidents and improving the productivity of tree felling on steep slopes. Utilisation rates of forestry machines aid both management and operational decisions, as well as providing an understanding the frequency machines are used. Highlighting factors that influence utilisation rates is crucial in improving the productivity and efficiency of not only the individual machine, but the entire operation.

The results from this study aim to improve the understanding of how often winch-assist machines are utilised, as well as identifying factors that influence their utilisation. This study also aimed to determine how accurate GPS systems are at estimating utilisation rates, as a form of automated data capture that could potentially replace the traditional manual methods.

TeletracNavman GPS units were installed in a purpose built Caterpillar 552 felling machine, with self-levelling capabilities, and a Tractionline winch-assist machine (Hitachi 290 base). These GPS units recorded data used to derive two utilisation rates of the Tractionline winch- assist, based on different criteria relating to machine use. Utilisation Rate 1 was 60%, and derived for just the 88 days the

winch-assist and felling machines worked together. Utilisation Rate 2 was 43%, and derived based on the potential time the winch-assist could have been used during the study period; including a total of 35 days the winch-assist was not used at all. The study highlighted three main factors that influenced the utilisation rate of the winch-assist. These factors were derived from Utilisation Rate 1. The main factors found to influence Utilisation Rate 1 of the winch-assist were:

- Frequency the winch-assist wasn't used.
- Area felled/day.
- Delays
  - Non-operational winch moves
  - Machine Idle

ROCCA, DANIEL (2011)
FACTORS AFFECTING MERCHANTABLE VOLUME LEFT ON SITE

This dissertation assessed how much merchantable material is left in Ernslaw One Limited estate in the Gisborne region and which factors affect it. Froest assessed were Mangatu, Tokomaru and Ruatoria. Transect sampling methods were used to collect the data. All stems, slovens and high stumps were measured. Stack piles in landings were also measured.

On average 1.7% of the total predicted volume is left on site as merchantable material. The volumes vary from 0 m^3/ha to 71 m^3/ha, with an average of 11.7 m^3/ha. The data is fairly consistent with the exception of one setting. Using R, a linear equation was developed but its use is not recommended. The dataset is not large enough to support such level on analysis thus, the linear model was considered not suitable so trends were assessed to analyse relationships between merchantable volume and factors that could affect it.

Slope had a positive trend; however, the data had a large spread. Machine type showed that cable harvesting generated less merchantable volume than ground based. The mean for the latter was slightly lower but the spread was larger. Mangatu forest produces less volume than Tokomaru and Ruatoria, respectively. Ruatoria had the most variety amongst all forests.

ROSE, KIM (2007)
ANALYSES OF SHIFT PATTERN EFFECTS ON PRODUCTIVITY AND VALUE AT THE KAINGAROA PROCESSING PLANT (KPP)

The Kaingaroa Processing Plant (KPP) is a mechanised central processing yard located in the central North Island of New Zealand. The KP processes over 1 million m^3 of stem length radiata pine into 70 to 80 different log grades annually. The KP operates 24 hours a day, 6 days a week. There are four crews of five operators who work a four day on/four day off shift pattern constructed of two day shifts followed by two night shifts. Each shift is 12 hours long and separated by scheduled stoppages or 'smoko' into three distinct work periods. Shift design and pattern can potentially affect performance of operators. The main purpose of this study is to analyse the effect of shift pattern on productivity and value at the KPP.

Software captures details about every stem that is processed at the KPP and it is this data which was uplifted for the use in this study. The study period was 10th January 2006 to 30th June 2006. The performance indicators assessed were productivity, value, pruned grade production, and chip/industrial grade production. These performance indicators were assessed across week in study period, day in week, shift in day (day/night), period in shift, and consecutively worked days. Piece

size is known to have a significant effect on production and therefore was assessed for its relationship with the performance indicators and its variation across the study period.

It was found that all the performance indicators were significantly different across week in study period. However, these indicators all had a significant relationship with piece size and are thought to be a reflection of the increasing piece size across the study period. Night shift was found to be more productive than day shift, however there was no different in piece size to explain this. The night shift was found to be more productive given larger piece sizes and this is thought to drive the difference in overall production across the day and night shifts.

SAATHOF, DAVID A. (2014)

AN INVESTIGATION OF THE MEASUREMENT ACCURACY AND PRODUCTIVITY OF A WARATAH HTH 625C PROCESSOR HEAD

Log processor heads have become increasingly used in New Zealand (NZ) forest harvesting operations to increase productivity and improve worker safety. Information regarding the measurement accuracy and productivity of new model processor heads is limited. As a result, log quality control (QC) is carried out on logs that have been merchandised by a processor head. This task can have a high risk for injury from man-machine interaction. A trend between studies was that older model Waratah's did not have sufficient measurement accuracy to alleviate the requirement for log QC. In this study, a Waratah HTH 625c processor head operating in NZ was analysed for measurement accuracy and productivity.

Measurement accuracy was considered by measuring logs for length, diameter and branch size. A comparison of two methods of processing was also considered to determine measurement accuracy, productivity and production efficiency for the way logs are delimbed and merchandised. Once gathered, the data was then analysed to identify significant effects, trends and relationships between variables.

Length measurements were highly accurate but diameter measurements were under-estimated. It was also evident that although there was absolute accuracy, there was a high variability in measurements with underestimating and overestimating. Branch size was also found to have a significant impact in reducing length measurement accuracy and productivity. Single pass processing has significantly higher production efficiency than two pass processing, although single pass processing had a higher length error associated with it.

The Waratah HTH 625c processor head has better measurement accuracy than older model Waratah's. However, logs are still cut out-of-spec which will require a log QC to identify. As measurement technology is further improved in processor heads, and improvements to NZ's plantation resource (improved form and smaller branching) are realised at harvest age, measurement accuracy and productivity of log processor heads will further improve.

SCOWN, HAMISH (2022)

MACHINABILITY OF 28-YEAR-OLD *EUCALYPTUS GLOBOIDEA* WOOD

The New Zealand timber market is supplied predominately by locally-grown *Pinus radiata*. As evidenced by timber import data, the market for ground-durable, coloured appearance and high stiffness is currently not supplied by locally-grown timbers. In particular, there are concerns about the toxicity of CCA-treated *P. radiata* as a solution for ground durability. Eucalypts have been identified by New Zealand Drylands Forest Initiative (NZDFI) as suitable for supplying these markets.

Three eucalypt species have been selected for development trials, one of which is *Eucalyptus globoidea*. The first genetically improved *E. globoidea* became available for sale in 2021. While some research into the wood quality and processing of this species has been conducted, the machinability of *E. globoidea* was unknown and the subject of this work.

It was found that *E. globoidea* machined better than *P. radiata* in all tested machine tooling parameters except planing and edge shaping, in which performance was the same. While literature suggests easier machining of P. radiata than found in this study (Forest Research Institute, 1988; Young, 1988), the identical machining and grading allowed the comparison of *E. globoidea* and *P. radiata*. This means a wood processing business that machines *P. radiata* does not need to change its tooling to machine *E. globoidea*. Within species, density was not a significant predictor of machining grades for any machine tooling, except the planing of *E. globoidea*, which was inversely proportional to air-dry density (r^2 = 0.111). This implies that a reduction in density will have a net-positive effect on the machinability of *E. globoidea*.

Machining scores (grades 1 and 2) were affected mainly by one aspect of the machined surface. Finding a solution for these can improve the machinability of *E. globoidea*. It was speculated that a careful operator in a home-based workshop should be able to avoid these defects, implying that *E. globoidea* is suited to appearance-grade carpentry and furniture-making and durable outdoor uses such as children's playgrounds or farm buildings.

SCRAGG, MORGAN (2020)

UNDER WHAT CIRCUMSTANCES WILL PERMANENT CARBON FORESTRY WITH THE ADDED BENEFIT OF NATIVE RESTORATION BECOME MORE FAVOURABLE THAN ROTATIONAL CARBON FORESTRY

Long-term financial modelling was undertaken to determine under what circumstances permanent carbon forestry with the added benefit of native restoration would become more favourable than rotational carbon forestry.

The literature noted a distinct lack of long term radiata pine (*Pinus radiata*) nurse crop data available in New Zealand. The use of *Pinus* nurse crops for indigenous restoration has shown promise both in New Zealand and abroad. Canopy gap creation within a pine stand has been found to be one of the most effective strategies for transitioning pine stands into native forests provided browsing ungulates are excluded and there is a viable seed source nearby.

In this study, permanent carbon forestry was found to be more economically viable than rotational carbon forestry. This is the case on all sites when the permanent carbon forest is unthinned. The profitability of permanent carbon forestry in comparison to rotational carbon forestry increases with carbon price. Rotational carbon forestry becomes more competitive with permanent carbon forestry as carbon price and Total Delivered Wood Cost (TDWC) decrease and log price and site productivity increase.

The managed transitional strategy chosen to achieve native restoration, be it canopy gap creation followed by passive native regeneration or underplanting, has a Net Present Value (NPV) significantly less than that of permanent or rotational carbon forestry. However, under an exceptionally low log price, transitioning a radiata pine forest to a native forest will be more profitable than managing it as a rotational forest.

Where canopy gap creation followed by underplanting is required due to the absence of a viable seed source, this will not significantly affect NPV. If a landowner desires a truly permanent native forest,

canopy gap creation or underplanting within a radiata pine carbon nurse crop can achieve this while still making a return on the landowner's investment.

As a result, it is paramount the new permanent forestry activity to be implemented as part of New Zealand's Emissions Trading Scheme (ETS) allows for canopy gap creation to transition permanent carbon pine forests to native forests to better deliver on the climate change mitigation, environmental, social and economic goals of the One Billion Trees Programme and ETS.

SHARP, GEORGIA (2018)
EARLY SELECTION OF STIFFNESS IN RADIATA PINE

This study has investigated the possibility of selecting for the wood property of stiffness at six-years-old. This is of importance to the New Zealand *Pinus radiata* breeding programme as increasingly shorter rotations and lower stockings has resulted in a large proportion of corewood in merchantable timber. This has caused a high quantity of timber which does not meet the minimum structural threshold level of six gigapascals, impacting on New Zealand's *P. radiata* ability to gain higher levels of income achieved by reaching higher grade classes.

The study assessed six-year-old cores for acoustic velocity as a proxy of stiffness, basic density, and volumetric shrinkage. The study contained half-siblings and full-siblings from three different seed source populations: Radiata Pine Breeding Company, Proseed, and a control. Cores were tested to assess if velocity varied between the pith and bark of cores, whether cores displayed stiffness difference between populations, whether cores displayed stiffness differences between pollination methods, and whether stiffness at age two was a good indicator of corewood stiffness at age six.

No statistically significant differences were detected for volumetric shrinkage and basic density between populations or pollination methods. Whereas, statistically significant differences were found for acoustic velocity. Variation was assessed between the pith and bark of cores, suggesting gain within the corewood zone will be beneficial for the outerwood zone of *P. radiata* trees. The cores displayed no significant difference between the seed source population but did display a significant difference between half-siblings and full- siblings. Finally, stiffness at age two was found to be an indicator of stiffness at age six with only 16 of 1205 cores removed in the bottom 25 % of trees age two which would have been in the top 25 % of trees at age six.

The results found in the study support the use of early selection methods for stiffness. Because of this there is the opportunity for the *Pinus radiata* breeding programme to utilise early selection techniques for stiffness. This will allow quicker deployment of superior genotypes into the production population, maximising genetic gain per unit of time. The improvement of stiffness in the corewood zone will allow New Zealand timber to reach higher grade classes and as such create the opportunity for New Zealand wood to gain price premiums.

SCOTT, LAWRIE (2008)
SUITABILITY OF NATURALLY REGENERATED *PINUS RADIATA* FOR RE-ESTABLISHMENT IN THE NELSON REGION

The aim of this study is to test whether natural regeneration of *Pinus radiata* densities are significantly correlated with cone count, and other site and management factors. In doing so a regeneration and cone model was developed that can help forest managers predict natural

regeneration and cone densities. It is realized that cone counting may not always be feasible, so a model was also developed without a cone variable.

317 plots were assessed over two areas in Nelson Forests Ltd. State. The first was in Golden Downs Forest and the second in Rai Valley/Marlborough Forests. Transect plots representing 0.005 of hectare were used with regeneration, cone counts, and site and management factors being recorded on pot sheets.

Cone frequencies were found to significantly increase with decreasing rainfall, increasing percentages of bare round, decreasing gorse and broom densities, non granite soil types, and decreasing altitude. Regeneration frequencies, when using a model with cone count, were found to significantly increase with the number of cones counted, increasing site index, decreasing altitude, and decreasing blackberry and bracken height. Regeneration frequencies, when using a model without cone count, were found to significantly increase, increasing site index, decreasing blackberry and bracken height, decreasing broom density, and non granite soil type. The R^2 for the regeneration model with and without cone count was 0.35 and 0.14 respectively. This proved that cone count was the variable that explained the most variation in natural regeneration densities.

SEWELL, ADAM (2009)

EVALUATING VELOCITY VERSUS STOCKING, PHYSIOLOGICAL AGE AND SPECIES IN A NELDER EXPERIMENT

The aim of this study was to evaluate how initial stocking, physiological age of pine parents and species influenced velocity in wood (as an indicator of wood stiffness) in a Nelder experiment located at Rolleston, Canterbury. Velocity and physical characteristics including diameter, height and stem slenderness were investigated for 456 *Pinus radiata* trees two years after planting and 399 *Eucalyptus nitens* trees one year after planting. Regression analysis was performed using the statistical package R, with velocity as the dependent variable, and stocking, physiological age of pine parents and species as the independent variables. Stocking and stem slenderness significantly influenced velocity for radiata pine, although both variables were highly correlated and therefore only one could be included in the model. Stem slenderness was a more powerful variable for predicting velocity. Stocking and height significantly influenced velocity for *E. nitens*. Species had a significant influence on velocity with *E. nitens* producing wood with velocities that were significantly higher than those of radiata pine.

The Fakopp USV tool was relatively impractical for field measurements of young trees. It was difficult to maintain consistent probe angle, depth, and distance between probes, and the presence of branches reduced the accuracy of the measurements. In addition, it was difficult to obtain accurate measurements of very small trees.

SLUI, BENJAMIN T. (2014)

THE EFFECT OF PLOT CO-REGISTRATION ERROR ON THE STRENGTH OF REGRESSION BETWEEN LIDAR CANOPY METRICS AND TOTAL STANDING VOLUME IN A *PINUS RADIATA* FOREST

Background: The objective of this study was to verify the effect that plot locational errors, termed plot co-registration errors, have on the strength of regression between LiDAR canopy metrics and the measured total standing volume (TSV) of plots in a *Pinus radiata* forest.

Methods: A 737 hectare plantation of mature *Pinus radiata* located in Northern Hawkes Bay was selected for the study. This forest had been measured in a pre-harvest inventory and had aerial LiDAR

assessment. The location of plots was verified using a survey-grade GPS. Least square linear regression models were developed to predict TSV from LiDAR canopy metrics for a sample of 204 plots. The regression strength, accuracy and bias was compared for models developed using either the actual (verified) or the incorrect (intended) locations for these plots. The change to the LiDAR canopy metrics after the plot co-registration errors was also established.

Results: The plot co-registration error in the sample ranged from 0.7 m to 70.3 m, with an average linear spatial error of 10.6 m. The plot co-registration errors substantially reduced the strength of regression between LiDAR canopy metrics and TSV, as the model developed from the actual plot locations had an R^2 of 44%, while the model developed from the incorrect plot locations had R^2 of 19%. The greatest reductions in model strength occurred when there was less than a 60% overlap between the plots defined by correct and incorrect locations. Higher plot co-registration errors also caused significant changes to the height and density LiDAR canopy metrics that were used in the regression models. The lower percentile elevation LiDAR metrics were more sensitive to plot co-registration errors, compared to higher percentile metrics.

Conclusion: Plot co-registration errors have a significant effect on the strength of regressions formed between TSV and LiDAR canopy metrics. This indicates that accurate measurements of plot locations are necessary to fully utilise LiDAR for inventory purposes in forests of *Pinus radiata*.

SMITH, AARON (2008)
PREDICTING CANOPY COVER IN NEW ZEALAND GROWN DOUGLAS-FIR

This study investigates the relationships between measured stand variables and leaf area index (LAI) with the objective of developing a canopy closure model for predicting LAI of New Zealand grown Douglas-fir.

The LiCOR LAI 2000 was used to measure LAI in 181 permanent sample plots (PSPs) throughout the South Island of New Zealand during the summer of 2007/208. Data analysis was broken into three steps: initial basic analysis followed by multivariate analysis and multiple regression.

Initial analysis found the most likely stand variables to have a significant relationship with LAI are: BA, MTH, Vol, Stocking, Green crown length (GC), height ratio (HtRat) and Crown height (CrHt). DBH performed poorly in this initial analysis was not considered in further analysis. Multivariate analysis in SAS found a significant interaction between BA and MTH. The linear form of this interaction was: Square root (Sqrt) BA * MTH. Multiple regression analysis found crown measurements to be insignificant in predicting LAI. The best model was found to be a linear relationship including the variables Sqrt BA, stocking (SPH) and the interaction term (INT). Age slightly improved the model but was left out due to autocorrelation with MTH. The developed model has the following form:

LAI = 1.77013 + Sqrt BA * (0.60119) + INT * (-0.01330) + SPH * (0.00179)

Error in LAI prediction from the developed model may be explained by stand variables that were not considered in this study and could include: site productivity, altitude, and climate. A clumping factor also needs to be applied to the LAI predicted in this study. An additional side study needs to be carried out to determine this adjustment factor.

SOUTAR, JOHN (2006)

THE EFFCTS OF BIOSOLIDS ON *PINUS RADIATA* WOOD QUALITY, FOLIAGE AND TREE VOLUME IN CANTERBURY

Municipal biosolids have been applied to a 22 year old stand of *Pinus radiata* (D. Don) on the Canterbury Plains. Applications were made in two treatments in 2000 and 2004 at two differing rates: control (0 kg/N/ha) and high (800kg/N/ha).

The aim of this study was to assess the effects of the biosolids on the nitrogen content in the foliage, tree volume growth and the modulus of elasticity. There was a significant response in the nitrogen levels in the foliage as a result of the biosolid application with a 0.37% N content increase. Tree volume was not significantly affected. The modulus of elasticity decreased significantly as a result of the biosolids by an average of 22%.

The results indicate that biosolids negatively affect wood quality in terms of stiffness on the Canterbury Plains with no significant volume growth to offset the loss in potential value. However, the social and environmental benefits in disposing of the biosolids in a forest rather than alternative methods such as disposal in landfills and incineration may outweigh the potential loss in wood quality.

Thus, disposal of biosolids in plantation forests in Canterbury may be a viable disposal method if non-financial benefits are taken into account.

STUART, KIRSTEN (2012)

RECONCILIATION OF HARVESTING OPERATIONS AND VALIDATION OF THE HARVESTING, ROADING AND LOG TRANSPORT COST MODEL: A STUDY UNDERTAKEN FOR LAURIE FORESTRY LIMITED IN CANTERBURY, NEW ZEALAND

Laurie Forestry Limited is a small forestry consulting company operating in the Canterbury region of New Zealand. A large portion of their business is based on small woodlot harvesting operations, servicing a wide range of clients. Pre-harvest estimates of log volumes, revenues and costs were provided for 27 previous harvesting operations. The actual log volumes, revenues and costs were also provided. This data was used to determine the accuracy of the pre-harvest estimates of each of these components.

The second part of this study involved the use of this data to validate the Harvesting, Roading and Log Transport Cost Model, created by Rien Visser of the School of Forestry. The purpose of this was to determine if this model could accurately predict harvesting costs, transport costs and roading costs incurred for harvesting operations undertaken by this company.

The results showed that gross revenue and net revenue were usually under-estimated in the pre-harvest estimates. In 20 out of 27 harvest operations the client ended up with a higher return than what they were originally quoted, prior to the operation being undertaken. There was no significant difference detected between the pre-harvest estimates and the actual values for log price, harvesting/loading cost and transport cost. Overall it could be concluded from the analysis showed that net revenue, gross revenue, log prices, harvesting/loading costs and transport costs were usually estimated at a satisfactory level.

The results of the Harvesting, Roading and Log Transport Cost Model validation showed that the harvesting component of the model is not a suitable predictor of harvesting costs incurred for operations undertaken by this company. The transport component of the model is an accurate predictor but it is unlikely that its use would result in any time saving. The roading component of the

model could not be validated properly due to a lack of data to reconcile the model predictions with. Further investigation is advised before this component of the model is used by the company.

STURROCK, NATHAN (2018)
THE INFLUENCE OF HARVEST SYSTEMS ON SEDIMENT DELIVERY ON THE MOUTERE GRAVELS

Fine sediment suspended in waterways is one of the most significant pollutants associated with New Zealand plantation forests, adversely impacting the quality of downstream aquatic ecosystems, and tarnishing public perception of the forestry industry. Nelson Management Limited identified in their plan to improve sedimentation performance that a quantification of the ground disturbance for common harvest systems would help identify the sediment delivery risks for each system on the Moutere gravels. With a combination of ground survey and aerial photography techniques, soil disturbance patterns and sediment breakthroughs were observed over 16 harvested settings that had been exposed to at least one significant rainfall event. Of these sites, 11 sites were cable yarded, and five were ground-based.

For cable yarding sites, breakthroughs were observed every 190 m of ephemeral stream or every 4.55 ha of harvest area. For ground-based sites, on average a breakthrough was found for every 107 m of ephemeral stream or for every 1.82 ha over harvest area. All breakthroughs observed were into ephemeral streams. The majority of sediment breakthroughs were associated with earthworks or harvesting related soil disturbance, rather than landslides. For cable yarding systems, there were large areas of scalping observed, but this had little bearing on sediment delivery as 16 of the 26 breakthroughs were due to machine tracking on the slopes. For ground-based sites, 15 of the 25 breakthroughs were primarily caused by skid and spur roads. Roading density was the only significant predictor of sediment breakthroughs at the significance level $\alpha \leq 0.05$. On the Moutere gravels; slope, stream length per ha, crew and extraction method were not found to be significant predictors of sediment breakthroughs per ha. However, due to the limited selection of harvest settings, there was limited replication of the crew and extraction method factors, making any statistical differences difficult to detect.

The image classification method developed to estimate the bare soil percentage for a site was found to be insufficiently reliable to allow conclusions to be made from the data that was collected for each setting.

Managers should focus on reducing roading density through careful road placement and focusing on breaking the connectivity between sediment generated from earthworks and streams. Further study that focuses on quantifying the rate that sediment is delivered to ephemeral streams gets transported to perennial streams would show how significant the breakthroughs to ephemeral streams are to total sediment yields from harvested catchments.

SWART, LANA J. (2011)
A STUDY INTO THE ADDED VALUE OF PRUNING FOR FORESTS ON THE FOOTHILLS AND SANDY PLAINS IN CANTERBURY

This dissertation aims to provide support for regime decision making in Selwyn Plantation Board Limited (SPBL) forests in Canterbury. PF Olsen currently manage these forests and want an economic analysis of three regimes; pruned, partial pruned and structural for two forests; Coalgate and Bottle Lake. These forests represent the different land forms that the SPBL estate covers. Both forests had site and 300 index values calculated and based on these values were separated into low, medium and high sites.

The literature review led to the hypothesis that a partial pruned regime would be the most profitable regime on low density sites where production of structural timber may be impeded.

A structural regime returned the highest NPV for every site and forest combination assessed. The partial pruned regime was next best and then the pruned regime. A sensitivity analysis revealed discount rate to be the most influential factor on NPV. The least influential factors on NPV were overhead costs, post and pole log prices and domestic pulp and industrial log prices.

Sensitivity analysis was conducted using the highest and lowest three year differential between domestic and export prices. At both the high and low differential, structural regimes returned the highest NPV of any regime for every site and forest. A reduction in acoustic velocity, to the lowest record for each forest, had no change in order of regime with maximum NPV.

Breakeven analysis, performed on pruned log price, found that on average pruned price needed to increase by 39% to make a partial pruned regime viable and 52% to make a pruned regime break even with the structural regime.

This analysis indicates a structural regime should be used for every site, regime and forest combination tested.

TAMBLYN, NICHOLAS (2020)

USING AN ELECTRIC RESISTANCE TOMOGRAPH TO DETECT HEARTWOOD IN *EUCALYPTUS GLOBOIDEA*

The focus of this dissertation was to determine whether or not using electrical resistivity tomography (ERT) was a viable option to replace destructive methods for measuring heartwood in *Eucalyptus globoidea.* The results from this analysis will be applicable to breeding trials conducted by the New Zealand Dryland Forests Initiative (NZDFI) relating to heartwood.

A few selected trees in two of the NZDFI breeding trails were felled and cross-sections were taken and stained to measure actual heartwood area to compare with estimated heartwood area from ERT scans taken before felling. Average heartwood area residuals were calculated to detect precision and bias in the results.

Previous tests of ERT have shown promise, with heartwood area of other species accurately predicted (R^2>0.80). However, the results of this research on *E. globoidea* showed that while the correlation between predicted heartwood area and actual heartwood area was strong (R^2=0.81), the relationship between the two variables varied with site. The standard error of a best-fit model including all these effects was 1.2 cm^2 on a range of predictions from 60 to 1600 cm^2. When site was not included as a random effect the standard error was 54.0 cm^2, and bias between sites was evident.

ERT measurements require calibration for each site and perhaps for each climatic condition. Further research required to test results across a larger range of sites and climates.

One of the main limitations of this study was the limited measurement heights, range of sites, and climatic conditions included. One of the sites was in flood during data collection, and the other main site was subjected to drought at the time of measurement. These factors likely had an influence on the results.

TAN, BOON KHIANG (2009)

A STUDY ON THE USAGE OF WOODEN POLES AND CROSSARMS IN THE NEW ZEALAND ELECTRICITY NETWORK INDUSTRY

Electricity network companies utilise poles and crossarms to support electricity lines in their distribution networks. Various materials are used for poles and crossarms, and this study specifically looks at the total current and potential future demand for wooden poles and crossarms in the New Zealand electricity network industry. In total, there are 27 electricity network companies in the country.

5 companies were initially visited to gather the necessary data and gain industry knowledge, and then the remaining 22 companies were surveyed by phone. The survey was designed to gather both qualitative and quantitative data. The qualitative survey was carried out in a 30 minute phone interview to gather information on trends in pole and crossarm utilisation, and a total of 23 companies provided information. 19 companies responded to the quantitative survey, which provided data on current stock and annual consumption of poles and crossarms, and product prices and specifications. Estimation of current stock and consumption of poles and crossarms was carried out for the entire industry using these data, and other data from published sources. The annual pole consumption preference is dominated by concrete poles (63%), followed by Softwood (21%), hardwood (14%), steel (0.21%) and other (1.61%). The estimated annual volume consumed by the industry is 1,812 m^3 for hardwood poles, and 2,108 m^3 for softwood poles. Significant portion of wooden poles are used in the South Island (81% of total annual wood consumption). This is mainly related to the ability of wooden poles to withstand dynamic load in snow loading areas. Annual crossarm consumption is dominated by hardwood (97%), and followed by steel (3%). The estimated annual volume requirements for hardwood crossarms is 740 m3. Wooden pole consumption is expected by industry participants to decline in the near future (especially hardwood), with the increasing competition from concrete poles. However, hardwood poles will likely remain competitive for special applications, and an increase in company confidence in softwood poles is required for it to be used more widely. Hardwood timber is expected to remain the preferred material for crossarms in the future.

TANSEY, JOSHUA T.E. (2014)

THE EFFECTS OF CLUMPED LOG DISTRIBUTION ON LINE INTERSECT SAMPLING

Line intersect sampling (LIS) is a method used for quantifying post-harvest waste. It is often used by forest managers to quantify merchantable volume remaining on the cutover so that compensation may be exacted under stumpage contracts.

The theory has been extensively studied and will produce an accurate measure of harvest waste given the basic theoretical assumptions that: all logs are cylindrical, occur horizontally, are randomly orientated and randomly distrivuted. When these assumptions are violated, the method is not biased, although precision decreases substantially.

A computer simulation was completed to determine whether or not the LIS method is appropriate, given a clumped distribution of logs produced by processing at central sites in cutover before using a forwarder to extract to the landing. The software ArcGIS with the application ModelBuilder was used to produce the LIS Model for running LIS assessments.

It was determined through simulation that the conventional LIS method is not appropriate given these harvesting methods, as a level of bias was found in sampling determining that the LIS method underestimated true volume. T-tests confirmed the significance of this bias.

LIS volume estimates were not precise, with the range of estimates ranging from 0 m^3/ha to double the true volume. An increase in sampling length by a third was found to increase precision by only a small amount. Therefore, it was determined that increased sampling is not worthwhile as the costs associated with it do not justify the small increase in precision.

TINNELLY, BLAIR (2011)
GEOGRID IN FOREST ROADS

Geogrid is a well known product, is readily available and used extensively in civil engineering applications including stabilizing slopes and soil erosion. In forestry, it can be installed over a forest road subgrade to provide additional strength and stability for the overlying aggregate. While it has been used in forest roading applications in various countries and under different conditions, little literature is available to help the forest industry understand the expected performance and potential benefits of geogrid. Ten trials were set up in four different regions throughout New Zealand to compare new roads built with and without geogrid to understand potential improvement, compare different aggregate thickness layers and provide a cost benefit analysis of installing geogrid.

The trials were trafficked during the winter period and were measured for strength, road shape deformation and common road defects. Results show there was no significant difference when a road was reinforced with geogrid (p-value, 0.4258). The cost benefit analysis found geogrid was economically viable when aggregate cost was high ($50-$60/m^3) and a large aggregate depth was required (over 300mm). The lack of traffic over all trials was a limiting factor, as was the maintenance which some results received during the winter. Construction of the trials limited the confidence of the treatment with a reduced depth of aggregate.

TROTTER, SIMON (2012)
MONITORING THE PROFITABILITY OF FORESTRY: AN OTAGO/SOUTHLAND CASE STUDY

Currently in New Zealand, the profitability of commercial forestry is not monitored, as it is for other productive land uses, by The Ministry for Primary Industries. This study presents a method to annually evaluate the profitability of commercial forestry by region, to enable economic comparisons with other land uses and encourage land use change where it is more profitable. The effects the New Zealand Emissions Trading Scheme (NZETS) on monitoring are assessed, and methods to monitor small-scale forest profitability investigated.

Forest structure has a major effect on year-to-year profitability. To mitigate this, the business model used to measure profitability is based on a normal forest structure. Existing data sources for timber yield, log price, and carbon were utilised. Additional cost data were obtained by survey of commercial companies in the Otago/Southland region. Profitability was found to be most sensitive to eight key model inputs: log price; log yield; interest rate; land price; and harvesting, cartage, roading and management costs.

The model is unable to monitor the typical effects of entering the NZETS. Enhanced revenues last only for a limited initial period, owing to the Kyoto protocol's Afforestation/Reforestation Debit-Credit (ARDC) clause. The ARDC was not retained in recent international negotiations and may be removed from the NZETS in the future. Without the ARDC there is no benefit from entering the model forest in the NZETS.

The model can be modified to represent small-scale forest growers; however profitability is more influenced by differences in costs than model structure. Further understanding of the relationship between scale and cost increases is required for accurate monitoring of small-scale operations.

By only surveying the key inputs identified, the costs of monitoring profitability are minimised. The model is able to present profitability so that it can be easily compared with the profitability of other land uses on a regional level.

VAN BRUCHEM, BORIS (2020)
ANALYSIS OF THE TREATED WOOD MARKET FOR AGRICULTURAL AND HORTICULTURAL USES IN NEW ZEALAND

This study analysed the treated wood market for agricultural and horticultural uses in New Zealand. Treated wood refers to fence posts for stock and crops, kiwifruit pergolas, vineyards posts and other horticultural supporting structures. Radiata pine (*Pinus radiata*) is the predominant species used in these industries and requires chromated copper arsenate (CCA) preservative treatment for outdoor application. This research is pertinent as there are concerns about CCA treated wood disposal, while there has been no publicly available analysis of the market. The information presented here will aid the New Zealand Dryland Forests Initiative (NZDFI) and elucidate the importance of the small dimension log resource.

Three sources of data were used to produce independent estimates of the market:

1. a use per hectare estimate
2. a manufacturers' estimate
3. a resource use estimate

It was estimated that approximately 6.9 million m^3 of CCA treated wood is currently present in the agricultural and horticultural industries using the use per hectare method. This presents a significant disposal liability, with policy and a country-wide disposal strategy potentially required. Annually, based on sector expansions and replacement rates, ~290,000 m^3 per year is used. The manufacturers' method estimated a range of ~270,000 m^3 to ~310,000 m^3 per year based on information from two independent CCA organisations. Lastly, the resource use method estimated ~390,000 m^3 per year based on forest grower surveys.

The market is most likely between approximately ~270,000 m^3 to ~310,000 m^3 per year, as the resource use estimate presumably overestimates as survey responders indicated that house pile, pulp log, saw log and firewood volumes were included. The use per hectare estimate may also be an overestimation as non-wood products such as plastic and metal posts were not accounted for although experts indicated that these products only represent a small proportion of the market.

From the NZDFI perspective, the organic sector estimate of ~6,000 m^3 per year to ~14,000 m^3 per year is relevant. The lower estimate is based on a conservative expansion rate, while the upper estimate uses a high expansion rate, indicating the range. Further work regarding the feasibility of the NZDFI alternative eucalypt products is appropriate.

Concerning the small dimension log resource, the importance to forestry companies tends to depend on regions. Roundwood producers are concentrated in the Nelson, Central North Island (CNI) and Northland regions which are areas with low fertility soils typically producing trees with less taper and smaller branches. The requirements for roundwood products are reasonably strict and prices

generally do not justify their production in comparison with the main competition of export pulp and K grades. This was especially true for forests located near ports.

VAN HAANDEL, ANDRE (2014)

IRRADIATION AS AN ALTERNATIVE PHYTOSANITARY TREATMENT FOR *ARHOPALUS FERUS* AND *HYLURGUS LIGNIPERDA*

Wood products all require treatment to mitigate phytosanitary risk prior to exportation. The most common phytosanitary treatment applied to *Pinus radiata* logs is Methyl Bromide (MeBr). The Environmental Protection Agency (EPA) in 2010 stated that MeBr must not be released into the atmosphere past 2020. This poses a problem for New Zealand log exports. Radiation has been identified as a possible alternative phytosanitary treatment for export wood products.

This study aimed to quantify the effective dose of radiation necessary to sterilise two forest pest species; *Arhopalus ferus* and *Hylurgus ligniperda*. These species are representative of two different types of forestry pests; bark beetles (*H. ligniperda*) and wood borers (*A. ferus*). All applicable life stages for both species were tested.

Arhopalus ferus adults were the most susceptible life stage identified with an LD99 of 30.2Gy ± 13.5Gy (95% confidence interval). *Arhopalus ferus* eggs were less susceptible with a LD99 of 750Gy ± 776Gy observed; however there is low confidence in this result due to a methodological issue in one treatment replicate. *Hylurgus ligniperda* eggs were observed to be less susceptible than *A. ferus* eggs with a LD99 of 289Gy ± 92Gy. Results for the other life stages were inconclusive due to poor control survival, however the information gained was used to develop improved methods for further experimentation, which is on-going and showing positive results so far.

The results of this experiment have indicated that radiation can be an effective method of sterilising forestry pests. To date radiation has not been used as phytosanitary risk mitigation for wood exports; however it is widely used for risk mitigation in agricultural products. Currently there remains a large amount of unknown information regarding the effectiveness for irradiation of logs, the effective does require for sterilisation of the most tolerant forestry pest and public acceptability of irradiation as a phytosanitary treatment. These knowledge gaps and an economic assessment must be completed before irradiation can be used as a phytosanitary risk mitigation technique for forestry products.

VAN HAANDEL, NICK (2010)

THE EFFECT OF SILVICULTURE AND GENOTYPE ON SPIRAL GRAIN ANGLE

Spiral grain affects the strength and stability of sawn timber. The purpose of this study was to investigate the effect of silviculture and genotype on spiral grain angle in radiata pine. A trial was established southwest of Rolleston town ship in 2005. The trial was a multi level split plot design. 192 trees were harvested in 2009/2010 summer and the effects of stocking, weed control, fertiliser and clone on spiral grain angle. The data were transferred into the statistical software package R. The data describing spiral grain were tested for normality was found to be significantly (p-value < 2.20E-16) non normal, and so they were transformed using asin (sqrt (spiral grain /90). After the transformation the data were still significantly (p-value < 2.20E-16) non-normal but less so than they had been (Shapiro-Wilk=0.9161).

Silviculture treatments of stocking, weed control, fertiliser and wind sway were found not to have significantly affected spiral grain (p values - 0.504, 0.8627, 0.5753 and 0.8383, respectively). Clone, clone × height and direction that the spiral grain angle was measured at did significantly influence spiral grain (p-values 0.03134, 8.50E-06, 2.53E-10).

A trend was identified between the level of correlation and the spatial relatedness of the measurements within heights. The measurements that were beside each other were more correlated than measurements at the opposite positions on the stem. The pattern is highlighted in Figure 6. Higher correlations between measurements indicate that spiral grain is very likely being measured, but it does not entirely rule out measurement error or bias.

The implication was that the best way to reduce the effects of spiral grain given our current knowledge is through breeding, although the overall influence of clone was relatively small compared to total variation in spiral grain.

VAN LIERDE, JULOT (2013)
WHAT CAUSES NATURAL DURABILITY IN *EUCALYPTUS BOSISTOANA* TIMBER?

This study investigated the natural durability of 8 and 60 year old *Eucalyptus bosistoana* (coast grey box). The sample's heartwood compounds were extracted with an optimised extraction process and then incorporated into agar. *Trametes versicolour* (white rot) and *Gloeophyllum trabeum* (brown rot) fungi were grown upon these agars and their growth rate was used to assess the fungicidal abilities of the extracts.

The extraction method of cell wall compounds was optimised. An Accelerated Solvent Extraction shstem (ASE) was used with the following settings:

- 2 cycles per sample
- 70°C extraction temperature
- 50% rinse
- 5 minute static time

Ethanol was found to extract the compounds of the highest fungicidal activity. Ethanol was found to extract similar amounts to water (~13% of dry weight for a 60 year old sample), however analysis of both water and ethanol extracts with a FTIR spectrometer, found that they were of different chemical composition.

A difference in fungicidal activity of extracts was found between the 8 year old and 60 year old samples. There was a large difference in the percentage of extracts present between the samples as well as the type of compounds present, show by FTIR.

The image classification method developed to estimate the bare soil percentage for a site was found to be insufficiently reliable to allow conclusions to be made from the data that was collected for each setting.

Managers should focus on reducing roading density through careful road placement and focusing on breaking the connectivity between sediment generated from earthworks and streams. Further study that focuses on quantifying the rate that sediment is delivered to ephemeral streams gets transported to perennial streams would show how significant the breakthroughs to ephemeral streams are to total sediment yields from harvested catchments.

VISSER, MILAN (2018)

EXPLORING OPPORTUNITIES FOR BIO-OIL WITHIN THE NEW ZEALAND FORESTRY INDUSTRY

For any forest harvesting operations, either chainsaws or barsaws in harvesting heads are pivotal tools for felling and processing the trees. These cutting chains can only run on the bar if they are lubricated to avoid excessive wear and deterioration of the machinery. Lubrication of chainsaws and harvesting heads work on a total loss system, meaning that any chainbar oil will be discharged into the environment. Mineral oil is currently predominantly used in New Zealand as lubricants, but mineral oil can be toxic to the natural ecosystems, and the people who use it. This highlights the need to investigate alternative, more environmentally friendly lubrication options for cutting systems within the forestry industry such as bio-oils made from plant material (usually rape seed). Benefits that are claimed for bio-oil include a reduction in oil flow by up to 50% without any added wear, that it is more environmentally friendly and degrades within 28 days, is better for the machinery, and people that use them. Bio-oil is however almost double the price of standard mineral oil deterring many contractors from considering using it.

In this study nine contractors from around New Zealand trialled bio-oil for a one-month period. There were surveys sent to the contractors to get pre-trial and post-trial data on the bio-oil; the contractor's oil usage for both mineral and bio-oils and any other benefits they saw from the change to bio-oil. The second part of this study involved measuring the heat produced off the tip of the bar of the chainsaw to see what effect the two different oils had on cutting temperature. The flow of both oils on to the chain and bar was reduced to test the extent that oil-flow can be reduced before added wear becomes a risk.

All crews were able to reduce lubrication oil consumption with an average of 39%. However, there was a large variance in oil reduction, ranging from the maximum reduction seen was 51% to a low of 16%. From this an average cost saving from the contractor trial was 6%, with a maximum saving of 19%.

In the chainsaw trials where bar heat was measured under standardised test conditions, the lubrication was reduced for both oil types. The bio-oil was able to be reduced by 50% before an increase in heat was seen. The mineral oil however, was unable to be reduced from full flow before temperature increased. When the bio-oil flow was reduced by 50%, and the mineral oil unchanged at 0%, they ran at very similar temperatures (p-value of 0.48). This demonstrated that the bio-oils were able to be made cost competitive against mineral oils whilst not adding any extra wear to the chainsaw.

This study highlights the benefits of bio-oil and the possibilities of its industry application. It demonstrates a local example to New Zealand contractors of how bio-oil can be used in operations without any added wear or stress on machinery, in addition to its cost saving and environmental benefits. This dissertation can also be used as a basis for bio-oil policy within New Zealand forest management companies; especially in high risk areas such as waterways or near native remnants.

WALKER, LIAM (2023)

COMPARING PERFORMANCE OF DOUGLAS FIR GROWTH AND YIELD MODELS IN THE SOUTH ISLAND OF NEW ZEALAND

Douglas fir (*Pseudotsuga menziesii*) is New Zealand's second most important plantation tree species. Of the total plantation area (100,105 ha), approximately 75% is planted in the South Island regions of Canterbury, Otago, and Southland. There are three common growth and yield models for Douglas fir in the South Island: the 500 Index model (500 Index), South Island Douglas fir model (SIDFIR) and

the Douglas fir National model (DFNAT). Although frequently used, it is unknown how the models perform on datasets outside those used for initial validation.

Predictions of mean top height (MTH), basal area/ha and stocking by the three models were compared to 315 growth measurements across 8,376 ha of Douglas fir forests throughout Canterbury, Otago, and Southland. The ability of each model to match actual historical growth measurements in an independent dataset formed the basis for comparison. The effects of region and several site characteristics were also tested for their impact on residual errors of model predictions. Site characteristics shown to affect residual errors significantly were used to adjust model predictions to increase precision and reduce bias.

Substantial imprecision, systematic bias, and regional variations were found in predictions of MTH, basal area/ha and stocking by the 500 Index, SIDFIR and DFNAT growth and yield models. Regional variations and significant effects of site characteristics were also shown to exist. The SIDFIR model performed the best with the most precision and least bias of the three models; however, predictions still displayed considerable imprecision and bias.

Thus, developing a new growth and yield model for Douglas fir in the South Island is recommended. This model should utilise a hybrid modelling approach to account for climatic variations between sites and provide increased precision and reduced regional variation. A new model would allow forest managers to make effective decisions to ensure the productivity, profitability, and sustainability of Douglas fir forests in the South Island of New Zealand.

WALTERS, EMMA (2023)

AN ASSESSMENT OF ECOSYSTEM RESTORATION AT STYX MILL CONSERVATION RESERVE, CHRISTCHURCH, NEW ZEALAND

With human arrival in New Zealand, many indigenous flora and fauna have become extinct or endangered. The 90% loss of lowland wetlands, due to conversion and fragmentation, is of significant concern. Large-scale restoration efforts must occur across the country to preserve the remaining ecosystems and re-establish degraded areas. Styx Mill Conservation Reserve (SMCR), Christchurch, New Zealand is a remnant freshwater wetland where restoration activities are occurring. The progress of ecosystem restoration at SMCR will be assessed by understanding how species composition varies across the reserve, determining whether the restoration efforts are creating an 'ecologically authentic' representation of the historic ecosystem, and identifying whether, and where, natural seedling regeneration is occurring.

A hierarchical cluster analysis used vascular species composition to identify four vegetation communities at SMCR (low forest, high grassland, riparian/marshland, and low shrubland). An nMDS ordination showed that the low forest community was most distinct from the other communities. The low forest community was abundant in indigenous *Griselinia littoralis* and *Cordyline australis*. The other three communities were abundant in exotic *Lotus pedunculatus*; suggesting that its abundance reduces as forest canopy closes.

Indigenous species that are present in the four Ōt autahi Christchurch Ecosystems Map plant lists (Wet plains – Kahikatea, Dry plains – Tussock, Dry plains – Ti Kouka, and Dry plains – Houhere) were most dominant (mean importance value= 0.22) across the reserve (exotic species= 0.12, indigenous species not present on lists= 0.07). The low forest plots were the only community where the indigenous – present species were significantly greater (p-value= 2.21×10^{-6}) than the indigenous – not present and exotic species.

The species regenerating the most were *Coprosma robusta* (0.45 seedlings/m^2) and *Griselinia littoralis* (0.42 seedlings/m^2). All seedlings were found in the low forest plots, aside from one *Coprosma robusta* seedling in a riparian/marshland plot.

Restoration at SMCR can be thought of as incomplete, due to the high abundance of exotic species and lack of seedling regeneration in all areas of the reserve apart from the low forest community. The incomplete areas of restoration will require the most attention by management and efforts should be focused on assisting these areas to move to a composition similar to that of the low forest community.

WARREN, EDWARD (2006)

THE EFFECT OF STOCKING ON STIFFNESS FOR THREE *EUCALYPTUS* SPECIES IN THE COFFS HARBOUR DISTRICT, NEW SOUTH WALES

Studies of ways in which stocking regulates wood stiffness (modulus of elasticity – MOE) for three *Eucalyptus* species (*E. dunnii, E. pilularis* and *E. cloeziana*) have never been undertaken. This dissertation quantifies the effect of stocking on wood stiffness for these three species, using a 5 year-old trial established by Forests New South Wales (NSW) in the Coffs Harbour district, NSW. An acoustic time-of-flight tool, TreeTap, was used to measure the stiffness on the standing trees.

Four different stocking levels (714, 1000, 1667 and 3333 sph) were examined. Stiffness varied significantly ($p < 0.05$) with stocking for *E. dunnii* ($p = 0.0086$), mean stiffness 11.3 GPa) and *E. pilularis* ($p = 0.0388$, mean stiffness 12.5 GPa), but not for *E. cloeziana* ($P = 0.2545$, mean stiffness 14.4 GPa). However, stiffness varied significantly only between the two lowest stocking levels for *E. dunnii* and *E. pilularis* (714 sph and 1000 sph): stockings above 1000 sph did not significantly increase tree stiffness in any species. These findings have implications for managers establishing plantations of these species. Where stiffness is a high priority then forest managers could reduce establishment costs by planting with low stockings (i.e. 1000 sph or less).

High mortality at a young age (from heavy frosting) in 5 of the twelve *E. cloeziana* plots is the likely reason for the lack of significant differences in stiffness between stockings for *E. cloeziana*. This high mortality confounds the 'true' plot stocking, affecting tree stiffness and hence the validity of these results.

The secondary objective was to investigate the relationship between four growth variables (dbh, height, green crown height and tape) and wood stiffness for these three species. Here the main finding is that there is a high degree of inter-correlation between growth variables, which confounds their effects on tree stiffness.

WATSON, LIAM (2013)

EVALUATING THE EFFECTS OF INITIAL STOCKING, PHYSIOLOGICAL AGE AND SPECIES ON WOOD STIFFNESS

The influence of initial stocking and physiologically aged cuttings (taken from 1-year-old and 5-year-old parents) on corewood modulus of elasticity (MOE) in 6-year-old *Pinus radiata* D. Don was studied in a Nelder-design experiment in Rolleston, Canterbury. In the same experiment, the influence of initial stocking on MOE in 5-year-old *Eucalyptus nitens* was also investigated. The study incorporated 19 different stocking levels ranging from 207 to 40,446 stems/ha. Green dynamic modulus of elasticity was assessed in standing trees using the TreeTap stress-wave method over the lower part of the stem (0.3 – 1.9m) for 151 *P. radiata* trees and 115 *E. nitens* trees.

The interaction between species and stocking significantly influenced MOE (P<0.001). MOE of *P. radiata* increased by 55% (or 3.9 GPa) between 271 and 40,466 stems/ha, and by 41% (or 2.2 GPa) between 271 and 4370 stems/ha. MOE of *E. nitens* was also influenced by stocking but the slope was significantly lower indicating that the effect of stocking was less pronounced than for *P. radiata*. Over the usual range of stockings for *E. nitens* there was an insignificant relationship between stocking and stiffness (P=0.335). Trees were also assessed for DBH, height, and stem slenderness (height/DBH). None of these latter variables had a significant influence on MOE after the effects of stocking and species were accounted for. No effects of physiological age of cuttings were detected in this study.

The findings of this study highlight the importance of stocking as a tool that forest managers can utilize to regulate corewood stiffness in *P. radiata* trees. These results also suggest that for *E. nitens*, where wood stiffness is a priority, forest managers could reduce establishment costs by planting at much lower initial stockings. This study also highlights the superior stiffness of *E. nitens* in direct comparison with *P. radiata*, with many trees in the experiment already exceeding stiffness thresholds for structural timber in New Zealand.

WESTON, LAUCHLAN (2018)

THE IMPLICATIONS OF LOG TAPER ON THE EXPECTED DIFFERENCE OF JAS SCALING TO 3D SCALE IN NEW ZEALAND

As a result of the strong price and demand trends observed in the export market, the importance of value recovery from log exports is emphasised by suppliers/owners.

Two methods of analysis were used for the duration of this study. The first was using real log measurements, utilising SED, LED and Length of logs. The second was through modelling of volume, estimated using the same three variables as the above. This data was presented in a matrix that predicts taper and estimation differences based on the log measurement inputs.

Analysis was performed utilising two datasets; one from the North Island (East Coast) and one from the South Island (Southern South Island). The taper ranges for each study area were calculated as base data. The North Island on average had taper of 1.45cm/m, whereas the South Island data showed average taper of 1.83cm/m. The logs were separated into their respective grades; overall the logs that displayed the most taper were South Island Pulp and K grade logs.

The overarching question of the study was to determine the volume logs measured with a JAS scale and then compare that to the volume predicted by a 3D scale (assumed to be as close to the true volume as possible for this study). The analysis showed that for the South Island estimation differences of; -15.8%, -4.7%, 3.7% and 6% for Pulp, K, A and Pruned grades respectively. The North Island dataset showed estimation differences of; 2.7%, 8.7%, 6.4%, 3.5% for Pulp, KI, A and Pruned grades respectively. The main trend that is observed through these estimations of difference is that the smaller SED logs; South Island Pulp grade (average SED of 21.4cm) and South Island K grade (average SED of 27.5cm) are more likely to be underestimated. The remaining log grades for the North and South Island all have average SED values over 30cm, therefore it can be assumed that when the SED is over 30cm, the difference of JAS/m^3 will be overestimated. Using the prediction matrix created, the taper that is required for underestimation to occur for small SED logs (10-20cm) which are seen as the most susceptible to differences are; 0.276 – 0.925cm/m for 5.8m logs and 0.421 – 1.447cm/m for 3.8m logs. The tapers required for larger SED logs are larger and tend not to be underestimated using JAS.

The study highlights the tapers and associated differences of JAS/m^3. Knowledge of the causal factors of this difference is valuable for exporters in order to adjust prices etc.

WIGNALL, GREER (2006)
A CLONAL FORESTRY TRIAL LOOKING AT IMPROVING CANKER RESISTANCE WITHIN *CUPRESSUS MACROCARPA*

A trial aimed at tracking canker resistance in *Cupressus macrocarpa* (macrocarpa) and *C. lusitanica* (lusitanica) was conducted at the Forest Research Institute, Rotorua, New Zealand. The goal of the trial was primarily to improve the breeding population of these cypress species, while keeping a genetic base a broad as possible.

Early analysis of the lusitanica data found unusually high rates of death and infection. With results too difficult to successfully interpret, the following report was based on data derived from the macrocarpa clones only.

Each stem was subjected to eight different inoculations of agar carrying one of two canker strains under observation, either *Seiridium unicorne* (unicorne) or *S. cardinale* (cardinale). One of the inoculations was a control (simply agar only).

The analysis of this report investigated whether or not there was a significant difference between the effects of the two canker strains on the macrocarpa inoculations. Also analysed was the presence of any differences in canker tolerance between tree families and within trial replicates.

Results from analysis showed that 2030 of the macrocarpa inoculations because diseased with canker, and 867 remained healthy. A significant difference was found between the effects of the two canker strains, with more inoculations becoming diseased with cardinale than unicorne. There was much variation in canker tolerance found to exist between tree families, and to a lesser extent, between the trial replicates.

Management implications are discussed, as is the design of the trial and the consequential influence on the results it has. Possible improvements to the trial include increasing the number of families under observation, maintaining consistency between inoculation runs and reducing microsite differences. A less severe method of inoculation has also been suggested to improve the quality of the data.

WRIGHT, NATHAN (2023)
ASSESSMENT OF WOOD STIFFNESS BY SPECIES AND AGING: A NELDER EXPERIMENT

Pinus radiata timber is inherently hindered by low stiffness due to high microfibril angle in the corewood zone. Determining how foresters can manipulate microfibril angle in plantation forests to increase stiffness is of high economic and silvicultural importance. A Nelder systematic spacing design in Canterbury was used to assess the stiffness and tree dimensions of 16-year-old *P. radiata* (n = 344) and 15-year-old *Eucalyptus nitens* (n = 211) at stocking levels ranging from 271 stems per hectare to 40,466 stems per ha. Using regression modelling independent variables species, aging and stocking were used to predict response variables outerwood stiffness, diameter at breast height (DBH) and tree height. Stocking, species and physiological aging had a significant effect on modulus of elasticity (MOE). Outerwood MOE significantly increased with increasing stocking for *P. radiata* up to 17,564 stems per hectare and up to 1,023 stems per hectare for *E. nitens* ($P < 0.001$). There was little stiffness gain in planting *E. nitens* at a greater stocking than 1,023 stems per hectare. By planting *P. radiata* at

2,505 rather than 823 stems per hectare, stiffness can increase by 14%. Stiffness was 41% greater for *E. nitens* however, *P. radiata* stiffness can be significantly ($P < 0.001$) increased by up to 1.2 GPa by planting physiologically aged clones. Stocking had significant effects on tree dimensions ($P < 0.001$) for both species: DBH decreased in an exponential trend, whereas tree height decreased more linearly. Physiological aging significantly affected DBH ($P < 0.0067$) but not tree height ($P = 0.31$). Wind direction was a significant predictor of MOE and as such standing tree stiffness should be measured on the windward and leeward sides of the tree to account for compression wood. At present, the potential of *E. nitens* as an alternative structural timber species is limited by its poor sawing and machinability due to growth stresses. However, the increasing trend of MOE seen with increasing stocking demonstrates that foresters have a lot of control over the stiffness of a tree crop through the choice and manipulation of stocking, seed stock and species.

XU, CONG (VEGA) (2008)

USE OF A HYDROTHERMAL TIME MODEL TO PREDICT SEED GERMINATION UNDER VARIABLE CONDITIONS FOR *BUDDLEIA DAVIDII*

Buddleia davidii is an invasive weed in New Zealand *Pinus radiata* plantations. Understanding the germinati0n pattern of this weed would assist the scheduling of spray operations. Temperature and water potential are two primary factors that determine seed germination. The hydrothermal time (HTT) model combines the effect of temperature (T) and water potential (ψ) on germination and has been widely used to model seed germination. A recent study by Watt *et al*. (submitted, see Appendix) modelled *B. davidii* germination pattern under a range of constant sub-optimal temperatures and water potential using a HTT model. The objectives of this study were to (i) determine the accuracy of this model under variable temperatures and water potentials, and (ii) determine if priming occurs for *B. davidii*.

Buddleia davidii seeds were collected from Rotorua, New Zealand. Seeds were germinated at laboratory under prescribed water potentials using polyethylene glycol 6000 (PEG) solution, and at controlled temperatures in growth cabinets. This study assessed the accuracy of the HTT mode to predict germination at 21°C under both constant and variable water potentials (0 to -1.0 MPa), as well as at alternating temperatures 25/12°C under both constant and variable water potentials (0 to -1.0 MPa). An experiment was set up to determine if priming occurred by exposing seed to water potentials below the base water potential of -1.8 MPa (-2.1 to -5.0 MPa) for 14 days, and then germinating these seed at 0 MPa. The presence of priming would be indicated by germination for these treated seeds occurring more rapidly than untreated controls.

The model accurately fitted the germination data at 1°C under constant condition, explaining 96% of the variation in germination data. The germination at 21°C under variable water potential was also well estimated except for underestimation for the driest treatment. At alternating temperatures 25/12°C, the model predicted germination reasonably well under constant water potentials, but the model appeared to underestimate the germination under variable temperature and variable water potentials. Priming of *B. davidii* was found to occur above -2.64 MPa.

YALLOP, KATHERINE (2021)

EFFECT OF SILVICULTURAL REGIMES ON CARBON SEQUESTRATION IN *PINUS RADIATA* FOREST IN CANTERBURY

This study explored effects of silvicultural treatments on carbon sequestration in juvenile *Pinus radiata* forest in Canterbury. Financial modelling was then employed to determine what regimes would be most profitable given current carbon prices. Deciding how best to manage stands for

carbon sequestration is important given the thriving carbon market and the current climate crisis requiring us to reduce net GHG emissions.

Relevant literature noted that biomass growth is highly influenced by local environments and site factors. Analysing biomass assays with a tree-level mixed-effect model to predict biomass through time takes into account variance caused by local factors and was found to be an effective way to predict carbon stocks. A comparison against existing national models found that these could generally be applied to a Canterbury site, however a localised model is superior, with less variance in predictions compared to the existing national models.

A comparison of carbon estimates between the localised model based on biomass assays and the default yield table for Canterbury under the Emission Trading Scheme (ETS) showed that the default yield table markedly underestimated carbon stocks during the initial 15 years. This was most prevalent at the highest stockings where table carbon estimates were 67% less than localised model estimates based on biomass assessments.

The effect of initial stocking was found to significantly ($p<0.05$) influence carbon sequestration, and low (625 stems/ha), medium (1250 stems/ha) and high (2500 stems/ha) stockings were all statistically different from each other. The presence of weed control also had a statistically significant effect ($p<0.05$) on carbon sequestration however fertiliser did not. An interaction effect between stocking and weed control was only present early at age 5 and was likely due to different rates of canopy closure based on the varying stockings. These findings were similar to previous studies on biomass production where treatments that encouraged rapid above-ground growth such as high initial stockings were shown to sequester significantly higher amounts of carbon.

Financial analyses showed that a stand of 2500 stems/ha, no thinning, and a long rotation age of 44 years, returned the highest Land Expectation Value (LEV). Permanent carbon forestry also returned a high LEV and given a longer rotation age (>60 years) may be more profitable than rotational forestry. Forest managers aiming for higher biomass will need to sacrifice large piece size. Growing higher stocked stands with no thinning will require accepting a higher level of risk and ensuring there is a large enough market for lower grade timber.

YANG, CHEN (2008)

VARIABILITY OF WOOD QUALITY IN VERY YOUNG UNIMPROVED *EUCALYPTUS NITENS*

The variation in twenty-five very young unimproved *Eucalyptus nitens* at 16 months was evaluated for wood properties including green density, green stiffness, growth stress and basic wood density for different positions up the stem. Correlations between green stiffness before and after debarking, growth stress, and basic wood density were estimated. There were statistical differences within and between each stem-section. Some bottom stem-section showed good correlations between the wood properties. There was no correlation between stiffness and basic density. The variabilities in wood properties were large. Thus this scoping study indicates that very early selection for better wood quality properties is an achievable and desirable objective.