

NZ SCHOOL OF FORESTRY

ABSTRACTS OF POSTGRADUATE THESES AND REPORTS

2006 ONWARDS

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

DOCTOR OF PHILOSOPHY

The PhD is an original piece of research that is examined to the highest contemporary international standard. The research generally takes three or more years and usually there will be publications in refereed journals arising directly from the thesis.

MASTER OF FORESTRY SCIENCE

There are two types of Masters degree. In the first the major output is the thesis, which is a research project of at least one and sometimes up to two years' duration. The thesis is expected to be of a high standard but the scope is often broader, and the extent of analysis and research less than that of the PhD. The second is by papers and report. Because of the requirements for coursework, the report is a smaller piece of work than the thesis and usually takes from a few months up to one year to produce.

MASTER OF SCIENCE (ENVR)

As with the MForSc, the MSc(ENVR) has two pathways, but in all cases candidates are required to present a thesis. Only those candidates who are directly supervised by academic staff within the School of Forestry at greater than 50% supervision, have their abstracts included within this publication.

Abstracts from years preceding this document can be obtained by contacting the School of Forestry in the first instance. The full theses are sourced through the University of Canterbury Library and can generally be located within the Library Electronic collection by searching under the author's name. Where a thesis requires reprinting, there will be a charge involved. Information can be found on the University of Canterbury Library web site.

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PHD ABSTRACTS

BOWN, HORACIO E. (2007)

REPRESENTING NUTRITION OF *PINUS RADIATA* IN PHYSIOLOGICAL HYBRID PRODUCTIVITY MODELS

Hybrid physiological models are being increasingly used to assess productivity, carbon sequestration, water and nutrient use and environmental impacts of management decision. Users include forest managers, politicians, environmental agencies and scientists. However a wider use of these models has been prevented as a result of an incomplete understanding of the mechanisms regulating carbon allocation, nutrient availability in soils and nutrient uptake by trees. On-going innovation in clonal forestry, genetic improvement and vegetation management techniques is also poorly represented in hybrid models.

This thesis examines means to represent nutrition and genotype-nutrition interactions in productivity physiological hybrid models. Nutrient limitations and growth differences between genotypes were hypothesized to operate through key physiological processes: photosynthesis, carbon allocation and nutrient internal cycling. In order to accomplish the aims of the study both greenhouse and field experimentation were carried out.

In a first experiment, responses of photosynthesis (A) to intercellular CO_2 concentration (C_i) were measured in a fast- and a slow-growing clone of *Pinus radiata* D. Don cultivated in a greenhouse in a factorial combination of nitrogen and phosphorus supply, and analysed using the biochemical model of leaf photosynthesis described by Farquhar *et al.* (1980). There were significant positive linear relationships between the parameters, V_{cmax} , J_{max} , and T_p and both foliar nitrogen (N_a) and phosphorus (P_a) concentration on an area basis. The study showed that the effects of nitrogen and phosphorus supply on photosynthesis were statistically independent and that the photosynthetic behaviour of the two clones was equivalent.

In a similar study, gas exchange and chlorophyll fluorescence were simultaneously measured to determine internal transfer conductance (g_m) based on the “constant J method”. Transfer conductance may pose significant limitations to photosynthesis which may be differentially affected by nutrition and genotype in *Pinus radiata*. Values of g_m were similar to those of stomatal conductance (g_s) and their ratio (g_m/g_s) was not influenced by nutrient supply or clone being on average (± 1 SE) 1.22 ± 0.04 . Relative mesophyll limitations (L_M , 16%) to photosynthesis were marginally greater than those imposed by stomata (L_S , 13%), and together smaller than the relative limitations posed to photosynthesis by biochemical processes (L_B , 71%). The CO_2 concentration in the intercellular air spaces (C_i) was (± 1 SE) $53 \pm 3 \mu\text{mol mol}^{-1}$ lower than in the atmosphere (C_a) while CO_2 concentration in the chloroplasts (C_c) was (± 1 SE) $48 \pm 2 \mu\text{mol mol}^{-1}$ less than C_i . Values of L_S , L_M and L_B and CO_2 diffusion gradients posted by g_s ($C_a - C_i$) and g_m ($C_i - C_c$) did not change with nutrient supply or clone.

In a third experiment, one-year old *Pinus radiata* cuttings from four genotypes were cultivated in silica sand with a factorial combination of nitrogen ($N_0=1.43$ and $N_1=7.14$ mM) and phosphorus ($P_0=0.084$ and $P_1=0.420$ mM) supply for 24 months. N supply was enriched with ^{15}N , $\delta^{15}\text{N}$ 0.5115%) provided by the source of N in nutrient solution applied during the second year. Recovery of labelled and unlabelled N was used to estimate N remobilisation. N remobilisation scaled with plant growth, N content and N and P supply. In relative terms,

65% of all stored N was remobilised in the high-nutrient supply regime compared to 42-48% at lower N and P addition rates. Most N remobilisation occurred during spring-summer (77%), coincidentally with the largest proportion of needle development (80%), indicating that N remobilisation was driven by sink-strength. Foliage was by far the main source for internal cycling while roots were the main sink (40%). Clones exhibited differences in N remobilisation capacity, but these differences were completely explained by the size of the N pool before remobilisation took place, indicating that N remobilisation performance was similar among clones.

In a fourth study, four clones were cultivated in silica sand with a factorial combination of nitrogen and phosphorus supply for ten months, and patterns of carbon allocation examined using a carbon balance approach. Gross-primary productivity (GPP) scaled mainly with nitrogen but also with phosphorus supply. The fraction of GPP ($GPP = ANPP + APR + TBA$) allocated to above-ground components (ANPP) increased with N and P supply at the expense of total-below ground C allocation (TBCA) with no apparent effect on the fraction of GPP partitioned to above-ground plant respiration (APR). Carbon use efficiency (NPP:GPP) scaled with nutrient supply, being 0.42 in the low-nutrient supply regime compared to 0.51 in the high-nutrient supply regime, suggesting that in poor fertility environments a larger proportion of the C budget is respired compared to the net productivity. Fast-growing clones allocated about 2-4% more carbon to above-ground components (ANPP) at the expense of carbon allocated below-ground (TBCA) with no effect on carbon respired above-ground (APR), indicating that faster-growing genotype allocate more carbon to leaf area which may compound and increase overall GPP over time.

The field component of this thesis was conducted in a subset of locations where ENSIS (formerly New Zealand Forest Research Institute) had established trials to test the influence of species, soil disturbance and plant nutrition on sustainability indicators. Plots were small in size (3 m x 3 m) with trees spaced at 0.5 m x 0.5 m (40 000 trees ha⁻¹) with nine measurement trees surrounded by a two-row buffer. All sites were planted in winter 2001 and harvested in spring 2005. The aim of this pilot study was to examine patterns of carbon allocation during the fourth year after planting in control and fertilized mini-plots of *Pinus radiata* in five sites with contrasting climate and soil conditions in the South Island of New Zealand. The study showed that the fraction of gross-primary productivity allocated belowground increased as the soil C:N ratio increased. However, these results should be interpreted with caution due to the unusual nature of the trial and the reduced number of sites studied.

Two existing physiological models were selected for the discussion in this thesis (3-PG, Landsberg and Waring 1997; canopy net carbon exchange model, Whitehead *et al.* 2002). Potential improvements for the nutritional component of 3-PG comprise: accounting for reductions in carbon use efficiency (NPP:GPP) in poor-fertility environments, adding a preliminary fertility modifier (F_N , 0-1) driven by soil C : N ratio and soil N, adding a preliminary relationship between carbon allocation to roots and the soil C : N ratio and representing faster-growing genotypes by increasing their leaf area but not their photosynthetic performance. The canopy net carbon exchange model (NCE) combines the coupled model of leaf photosynthesis – stomatal conductance described by Leuning (1995) with canopy structure and a water balance model to scale carbon assimilation from leaves to canopies. Potential improvements to account for nutrient deficiencies in the leaf model by Leuning (1995), comprise using nutrient ratios to discriminate nitrogen ($N_a/P_a < 23 \text{ mol mol}^{-1}$) from deficiencies ($N_a/P_a > 23 \text{ mol mol}^{-1}$), adding relationships between

photosynthetic model parameters V_{cmax} and J_{max} to P_a , and correcting the estimation of photosynthetic parameters V_{cmax} and J_{max} by accounting for transfer conductance (g_m). The canopy net carbon exchange model may be also modified to account for carbon-use efficiency, carbon allocation to roots and genotype in a similar form to that proposed for 3-PG.

The results previously outlined provide a preliminary framework to represent tree and soil nutrition in physiological hybrid productivity models.

DUBEY, MANOJ (2010)

IMPROVEMENTS IN STABILITY, DURABILITY AND MECHANICAL PROPERTIES OF RADIATA PINE WOOD AFTER HEAT-TREATMENT IN A VEGETABLE OIL

Radiata pine is a major plantation grown wood in the Southern hemisphere, but has inferior dimensional stability and low durability compared to other commercial species and the improvement of these features is the focus of this thesis.

Specifically this thesis examines the dimensional stability, durability and mechanical properties of radiata pine after heat-treatment (160-210°C) in linseed oil. Changes in colour, micro-structure and chemistry with heat-treatment were studied. To optimise the treatment results, oil heat-treatment of wood was also carried out after thermo-mechanical compression of wood and the effect of the prior thermo-mechanical compression on stability, durability and mechanical properties were examined.

The oil heat-treated wood turned uniformly darker in colour. The hydrophobicity (Water Repellence Efficiency-WRE up to 30%), dimensional stability (Ant-Swelling Efficiency-ASE up to 60%) and fungal resistance (up to 36%) were improved with the extent of the changes mainly depending on treatment temperature. However, the mechanical properties of oil heat-treated wood were reduced compared to the untreated control group. Accelerated UV weathering tests have shown that the oil heat-treated wood retained its colour and dimensional stability better than the untreated wood (the control group).

The cell wall of treated wood was intact and no distinct structural changes were observed even at the most severe treatment (210°C for 6 hrs). The treatment resulted in changes to the wood chemical constituents, mainly the degradation of hemicelluloses which is believed to be principal reason for alterations in wood properties.

A study of the effect of prolong heating on the linseed oil showed an increase in viscosity with heating time which in turn reduced the oil uptake and water repellency of treated wood. However, no significant difference in the colour and dimensional stability of the treated wood was noticed with oil of different heating ages. Oil absorbed by the wood during heat treatment was removed by organic solvent extraction and its contribution to the weight percentage change and moisture related properties were evaluated. The oil uptake percentage, determined by organic solvent extraction, was greater than the weight percentage loss that was deduced to occur during the heat treatment phase, which was attributed to mass losses or thermal degradation of wood constituents. Moisture excluding efficiency decreased after removal of the oil from treated wood, which suggested that the hydrophobicity of treated wood is affected by oil absorption. The influence of the post-treatment cooling period on properties of treated wood was studied separately. Oil uptake

increased substantially with the post-treatment cooling time which in turn affected the hydrophobicity of treated wood although this effect was less important to dimensional stability.

The loss of mechanical properties due to heat-treatment was successfully countered by thermo-mechanical compression of wood prior to the oil heat-treatment. The wood was compressed to 39% of its original thickness without any visible surface checks and cracks. Spring back and compression set recovery in densified wood decreased after oil heat-treatment. This combination treatment also resulted in improved fungal resistance compared to untreated wood.

From this research, it is concluded that oil heat-treatment of radiata pine wood can improve its dimensional stability and durability obviating the need to introduce any persistent toxic chemicals. Thermo-mechanical densification of wood prior to oil heat-treatment can counter the loss of mechanical properties due to heat-treatment. The heating oil can be re-used in subsequent treatments and oil uptake can be minimised by limiting the post-treatment cooling time without any significant effect on the dimensional stability of treated wood.

HUSTEDT, SINA (2010)

A RISK ANALYSIS OF NEW ZEALAND'S BIOSECURITY MANAGEMENT SYSTEM: THE SEA CONTAINER PATHWAY

It is widely acknowledged that international trade is a major pathway for the spread of invasive species. International agreements and domestic legislation aim to reach a balance between facilitating trade and providing nations with the right to protect their environmental, public and economic health. This is achieved through the development of standards that prescribe procedures that must be followed before a commodity is imported. Under Section 22 of the Biosecurity Act (1993) Biosecurity New Zealand of the Ministry of Agriculture and Forestry (MAF) develops import health standards for the importation of commodities and sea containers and for the approval and management of transitional facilities.

Under current regulations, before being allowed to enter New Zealand, a sea container must first be accompanied by appropriate documentation for the sea container itself and any contents (this includes cargo manifests, any required treatment certificates for the cargo and cleaning certificates for the sea container itself). Upon arriving in New Zealand the sea container is transported to a transitional facility for inspection and unloaded once biosecurity clearance has been obtained. There are approximately 7,000 transitional facilities (both on and off wharf) throughout New Zealand and inspections are conducted by persons that have obtained accreditation from MAF for inspections (MAF accredited persons).

Based on current importation procedures and other information made available, mathematical models were developed for three sea importation pathways (sea containers, woodpackaging and used vehicles) that involved the inspection of imported units by MAF accredited persons. These models were designed to predict the effectiveness of the current border inspection policies and procedures. Inspection accuracy was found to have the most influential impact on slippage (the rate at which contamination passes through border procedures undetected) along the measured pathways. Under current conditions, an estimated 5.75% of all sea containers, 4.12% of all sea containers containing

woodpackaging and 1.63% of all used vehicles that enter New Zealand annually are contaminated in some manner despite having biosecurity clearance. A 3% increase in inspection efficiency reduced slippage to 0.5% of sea containers, 2.16% of woodpackaging and 0.001% of used vehicles entering New Zealand annually.

Given that the accuracy of the inspection was the most influential aspect of the border management procedures, mathematical models were developed to predict the cost of compliance recovered by MAF if all inspections were conducted by MAF inspectors as opposed to MAF accredited persons. Under current regulations the cost of compliance (if MAF inspector conducted inspections of all imported units) was estimated to be \$117.36 million for sea containers, \$35.16 million for woodpackaging and \$5.44 million for used vehicles. Increasing the inspection accuracy to the ideal 100% increased the cost of compliance by 75.36%, 61.96% and 61.92% for sea containers, woodpackaging and used vehicles respectively.

These findings indicate that Government investment in the training of inspectors throughout New Zealand would improve current border detection rates. Under current regulations, the cost incurred by MAF inspectors inspecting all imported units is recoverable. Currently the cost of compliance is approximately 1% of the value of annual imports. These costs are seen by the import sector as part of their daily business and understand that these measures are in place for the long term sustainability of their businesses (Anon. 2005).

LOZA-BALBUENA, ISABEL (2009)

POTENTIAL OF THE NEW ZEALAND FOREST SECTOR TO MITIGATE CLIMATE CHANGE

New Zealand is both an Annex I Party to the UNFCCC, and an Annex B country of the Kyoto Protocol. By ratifying the latter, NZ has committed to reduce greenhouse gas emission to 1990 levels. The country should take domestic actions and can also use any of the Kyoto Protocol flexible mechanisms. Afforestation and reforestation on low carbon density land has been recognised as a carbon sink and hence a possible mitigation option for climate change. The current situation for New Zealand is that at last over the first commitment period (2008-2012) the country is in deficit, because emissions have continued to grow over the 1990 level, there is an increase in the deforestation rate and lower rates of new planting.

The objective of this study is to analyse the potential of the New Zealand forest sector as an integrated system to mitigate climate change. It also analyses the impact of different mechanisms on potential area of new land planting, management of stands, and the supply, allocation, and demand of wood, and wood products.

The New Zealand forest industry carbon balance (i.e. net atmospheric exchange minus emissions) is modelled for different national estate scenarios, log allocation of harvested volume and residues used for bioenergy. The net present value of these scenarios is estimated and the economic viability assessed. The level of incentives needed to increase the returns to an economically viable level is estimated in term of carbon unit value (\$/tC). Moreover the land use economics at a project level (land market value vs land expectation value) is assessed. Incentives needed in monetary terms and carbon value are also estimated. The implications of discounting carbon benefits are discussed.

It was found that the carbon balance of the whole industry should be analysed for policy development on climate change mitigation options. New planting, longer rotation ages,

avoiding deforestation, and allocating additional harvested volume to sawmills showed positive impact to the atmosphere. New planting appeared to be not economically viable, thus incentives are needed. It is acknowledged that, there are emissions from the sector that were not included, and that data and models used need further research to improve the accuracy of the results. Moreover, assumptions on the economic issue and an analysis of simultaneous implementation of more than one mitigation option would also improve the results.

MORENO CHAN, JULIAN (2007)

MOISTURE CONTENT IN RADIATA PINE WOOD: IMPLICATIONS FOR WOOD QUALITY AND WATER-STRESS RESPONSE

This thesis studied the influence of moisture content on the dynamic estimation of stiffness in wood of *Pinus radiata* D. Don. This is an important non-destructive measure for estimation of stiffness in standing trees, logs and lumber. Moisture content affects both acoustic velocity and density in the fundamental equation of dynamic MOE ($DMOE = V^2\rho$, where V = acoustic velocity and ρ = density). Investigation included measurements with boards in the laboratory considering moisture contents below and above FSP as well as temperatures below and above 0°C. This also included field measurements of trees in contrasting climate sites and over different seasons including a long drought. Methods for measuring green density and moisture content and the patterns of variation of these parameters were also investigated. A secondary component of this thesis explored the wood quality and some mechanisms of tree response to water stress in two contrasting sites in terms of rainfall and water deficits in a region of Australia.

The large increases in DMOE for frozen wood above the FSP (4.5 to 6 GPa) will limit the use of DMOE for grading logs in regions with freezing winters. Results from the experiment remeasuring young trees and the upper range of moisture content and temperatures above 0°C from the experiment with boards showed small to moderate variation in DMOE (0.1 to 1 GPa) which calls for further investigation on analytical procedures for adjustment of DMOE. Such procedures should consider that variations in acoustic velocity and density with changes in moisture content are not proportional and that there are counteracting effects between the two parameters. It remains to be investigated whether the typical variation (under normal climate conditions) in sapwood green density observed in our experiments has some implications for the use of DMOE. On the other hand, it is anticipated that the large differences along the stem and among stands in whole-section green density may bias DMOE measurements in logs for resource assessment. This also needs to be investigated. A comparison between acoustic velocity alone and DMOE for resource assessment under different scenarios is recommended.

The study in two contrasting climate sites (high-altitude vs. warm-dry) in the Hume region of Forests NSW, Australia, including young (10-11 years) and mature trees (34-36 years) of radiata pine showed distinctive short and long-term responses of trees to cope with the water-limiting environment. In response to long-term water deficits the warm-dry site developed heartwood and thus reduced sapwood earlier and at faster rates than the high-altitude site. The onset of heartwood formation seemed to be triggered by some site threshold for water use as broadly indicated by the sapwood area/ha. The warm-dry site also showed increased short-term responses to water stress and these were interpreted as seasonal mechanisms of the trees to cope with the limiting environment. The trees compensated for

the lower available moisture and higher transpiration rates by lowering their saturation and disrupting water conduction at some points (cavitation). The inverse trends of cavitation spots and cavitation bands with height in the stem suggested the trees have different strategies to sacrifice conducting xylem depending on the position on the stem. Finally, it is suggested that saturation tended to fall to critical 'safe' levels as a result of water stress and this varied depending on age, site, and position in the stem.

Significant decreases in DMOE and basic density were observed for the warm-dry site and were attributed to lower proportions of latewood due to lower rainfall for that site during the period of latewood formation. These showed no obvious association with any of the long-term water-stress traits (sapwood percentage and number of heartwood rings).

MURPHY, BRENDAN D. (2008)

BIOLOGICAL CONTROL OF *PAROPSIS CHARYBDIS* STÅL (COLEOPTERA: CHRYSOMELIDAE) AND THE PAROPSINE THREAT TO *EUCALYPTUS* IN NEW ZEALAND

Ineffective biological control of the *Eucalyptus* pest *paropsis charybdis* Stål (Coleoptera: Chrysomelidae: Paropsini) in cold areas of New Zealand was believed to be caused by climatic mismatch of the egg parasitoid *Enoggera nassau* Girault (Hymenoptera: Pteromalidae). Two Tasmanian strains of the parasitoid were introduced to test climate-matching theory in 2000, with approximately 7000 wasps released. Establishment of the Florentine Valley strain was detected in 2002 using the Mitochondrial (mtDNA) gene Cytochrome Oxidase I (COI) as a strain specific marker. The hyperparasitoid *Baeoanusia albifunicle* Girault (Hymenoptera: Encyrtidae) and primary parasitoid *Neopolycystus insectifurax* Girault (Hymenoptera: Pteromalidae) were detected for the first time in New Zealand.

As paropsines have proven highly invasive internationally, a risk assessment of the paropsine threat to New Zealand was undertaken by evaluating the host range of *E. nassau* and a reproductive assessment of 23 paropsine species in the genera *Dicranosterna* Motschulsky, *Chrysophtharta* Weise, *Paropsis* Olivier, *Paropsisterna* Motchulsky and *Trachymela* Weise. *Enoggera nassau* proved polyphagous, but bioassay results proved that *Paropsis* species were significantly more susceptible to the egg parasitoid than *Chrysophtharta* species. Resistance within *Chrysophtharta* was attributed to spine-like chorion modifications. A COI derived *Chrysophtharta* phylogeny divided the genus into two distinct groupings, which was supported by chorion morphology.

Paropsine reproductive output was tested for key parameters indicating pest potential. Pest specie displayed fecundity exceeding 600 eggs at an oviposition rate of 10 eggs per day⁻¹. Several non-pest species were identified as potential pests based on these parameters. The *Chrysophtharta* phylogeny suggested a moderate relationship between genetic relatedness and reproductive output. The *Acacia* defoliating paropsine *Dicranosterna semipunctata* (Chapuis) was evaluated for its susceptibility to *E. nassau* and reproductive output. Egg parasitism occurring in bioassay did not translate into biological suppression following a specifically targeted release of *E. nassau*, and the fecundity and oviposition rates fell below the thresholds predicted for a pest paropsine species.

Despite establishment of Tasmanian *E. nassaui*, hyperparasitism has now rendered this control agent ineffective in New Zealand. *Neopolycystus insectifurax* offers the best hope for future biological control of paropsine species in New Zealand.

PINJUV, GUY L. (2006)

HYBRID FOREST MODELLING OF *PINUS RADIATA* D. DON IN CANTERBURY, NEW ZEALAND

During this study two models were developed to predict growth of *Pinus radiata* D. Don plantations in Canterbury, New Zealand. The first, CanSPBL(1.2), is a model for whole rotations of stands owned by Selwyn Plantation Limited in Canterbury. The second model, CanSPBL(water) is a hybrid growth model for the Selwyn estate in Canterbury that incorporates an index of root zone water balance over the simulation period. An existing stand growth and yield model CanSPBL was examined using a validation dataset of PSP measurements that were not used in model fitting. Projection bias was shown for mean top height, basal area per hectare, and residual stand stocking particularly for stand at elevations exceeding 450 metres.

The new model, CanSPBL(1.2) showed an increase in precision of 4-46% over CanSPBL(1.0) at a stand level. The components of the stand model include mean top height, basal area per hectare, stems per hectare, and diameter distribution. The mortality model was made in conjunction with managers at CanSPBL to exclude catastrophic mortality events from model projections. Data used for model fitting was filtered using a mortality index based on the $-3/2$ power law. An examination of this model with an independent dataset showed little apparent bias.

The new model, CanSPBL(water) was developed to include an index of water balance over the simulation period. Water balance estimates were made using a sub model for root zone water balance included in the hybrid physiological model 3-PG (Landsberg and Waring, 1997). The new model showed an increase in precision of 1-4% over CanSPBL(1.2) at a stand level (with the exception of the model for maximum diameter which showed a decrease in precision of 0.78%) using climatic inputs that included yearly variation. However the model showed increases of precision from 0.5 to 8% (with the exception of maximum diameter again, showing a decrease in precision of 0.13%) using long term monthly average climatic inputs. The components of the stand model also include mean top height, basal area per hectare, stems per hectare, and diameter distribution. The mortality model was also fitted with a data set filtered using a mortality severity index based on the $-3/2$ power law to exclude catastrophic mortality events. An examination of this model with an independent dataset showed little apparent bias.

Two models to predict a one sided canopy leaf area index (LAI) of radiata pine stands in the Canterbury Plains of New Zealand were also developed. The models were fitted using non-linear least squares regression of LAI estimates against stem measurements and stand characteristics. LAI estimates were derived from digital analysis of fisheye lens photography. The models were kept simple to avoid computational circularity for physiological modelling applications.

This study included an objective comparison and validation of a range of model types. The models CANTY (Goulding, 1995), CanSPBL(1.2 (Pinjuv, 2005), CanSPBL-water (Pinjuv, 2005), and 3-PG (Landsberg and Waring, 1997) were compared and validated with the main

criteria for comparison being each model's ability to match actual historical measurements of forest growth in an independent data set. Overall, the models CanSPBL(water), and CanSPBL(1.2) showed a slightly worse fit in predictions of stocking than did the model CANTY. The hybrid model 3-PG showed a better fit for the prediction of basal area than the statistically based model CANTY, but showed a worse fit for the prediction of final stocking than all other models. In terms of distribution of residuals, CanSPBL(1.2) had overall the lowest skewness, kurtosis, and all model parameters tested significant for normality. E-PG performed the worst on average, in terms of the distribution of residuals, and all models tested positively for the normality of residual distribution.

RIVAS PALMA, ROSA M. (2008)

ENVIRONMENTAL AND SOCIAL VALUES FROM PLANTATION FORESTS: A STUDY IN NEW ZEALAND WITH FOCUS ON THE HAWKE'S BAY REGION

Plantation forests ecosystem functions provide a range of indirect benefits known as forest services. There is lack of knowledge and estimation of the value of forest services. The main aim of the research was to investigate the environmental and social value of plantation forests in New Zealand.

Each step of the research was built up on the perspectives of the stakeholder groups identified. A stakeholder analysis revealed that the most relevant stakeholder group was *Adjacent neighbours*. Through a postal survey forest managers and stakeholders indicated they considered as most relevant *Erosion control* and *Water regulation* (quality and quantity) *Employment*, *Increased living standard*, and *Recreation*. These services became the focus for the rest of the study.

Through focus groups, the most relevant stakeholder groups, identified and ranked positive and negative aspects in forestry, and selected attributes describing the forest services. These were: *Amount of sediment in water* (water quality), *Algae in water* (water quality), *Percentage of land stabilisation* (erosion control), and *Level of water flow* (water quantity). The attributes for the attitudinal questions were classified as *Community*, *Employment*, and *Recreation*.

The environmental value of plantation forests was estimated through choice modelling. The valuation survey was carried out only in Hawke's Bay. The payment vehicle used was increased regional council rates with the objective of monitoring environmental quality of soil and water. Several models were estimated by adding interactions between variables. Model 15b was selected as it provided best model fit and integrated respondents' demographic and attitudinal characteristics. The results of the model indicated that respondents who had university studies and positive attitude towards plantation forest community values were more willing to pay for improved levels of land stabilisation. The implicit prices estimated indicated that the wider community in Hawke's Bay have a greater appreciation for water quality (lower levels of algae and sediments). The responses to the attitudinal questions indicated that most respondents had positive attitudes towards the community and practical uses of plantations and employment-related values, particularly older respondents.

The environmental and social values identified were linked with forest operations in order to analyse the impact they have. Land preparation and planting, road construction, and

harvesting are the forest operations that have a greater impact on the levels of sediment in water.

SHARMA, RAJESH K (2008)

COMPARISON OF DEVELOPMENT OF RADIATA PINE (*PINUS RADIATA* D. DON) CLONES IN MONOCLONAL AND CLONAL MIXTURE PLOTS

The development of radiata pine (*Pinus radiata* D. Don) clones was compared in monoclonal and clonal mixture plots planted in an experiment established at Dalethorpe, Canterbury, New Zealand with ten radiata pine clones in September 1993. Clones were deployed in a randomised complete block plot design with three replications. Each replication contained ten treatments of monoclonal plots and one in which all the clones were intimately mixed in equal proportions.

Clones significantly differed in initial morphologies, survival and stem slenderness. Sturdiness and initial heights were found to be the best predictors of initial survivals. The study revealed that mode of deployment did not affect overall productivity, but individual clone exhibited significantly different productivities between modes of deployment. All clones contributed similarly to overall productivity in the monoclonal mode of deployment, whereas the contribution of clones in the clonal mixture mode of deployment was disproportionate. A minority of the clones contributed a majority of overall productivity in the clonal mixture mode of deployment.

The inclusion of competition index as an independent variable in a distance-dependent individual tree diameter increment model explained a significant amount of variability in diameter growth. The use of an inverse-squared distance to neighbouring plants in the competition index provided a slightly superior fit to the data compared to one that employed a simple inverse of distance. Addition of genotype information in the competition index further improved the fit of the model. Clones experienced different levels of competition in monoclonal and clonal mixture modes of deployment. Competition in monoclonal plots remained uniform over time, whereas some clones experienced greater competition in clonal mixture plots which led to greater variability in their tree sizes. This study indicated that single tree plot progeny test selections and early selections may miss out some good genotypes that can grow rapidly if deployed monoclally.

Stand level modelling revealed that clones differed significantly in modelled yield patterns and model asymptotes. Clones formed two distinct groups having significantly different yield models. The study also demonstrated that models developed from an initial few years' data were biased indicators of their relative future performances.

Evaluation of effectiveness of the 3-PG hybrid model using parameter values obtained from destructive sampling and species-specific values from different studies revealed that it is possible to calibrate this model for simulating the productivity of clones, and predictions from this model might inform clonal selections at different sites under differing climatic conditions. Destructive sampling at age 5 years revealed that clones significantly differed in foliage and stem biomass. The differences in productivities of clones were mainly due to differences in biomass partitioning and specific leaf areas.

Clones significantly differed in dynamic wood stiffness, stem-slenderness, branch diameter, branch index and branch angle at an initial stocking of 1250 stems/ha. Mode of deployment affected stem slenderness, which is sometimes related to stiffness. Although dynamic stiffness was correlated with stem slenderness and stem slenderness exhibited a significant influence on stiffness, clones did not exhibit statistically significant differences in dynamic stiffness. Increasing initial stocking from 833 stems/ha to 2500 stems/ha resulted in a 56% decrease in branch diameter and a 17% increase in branch angle.

Trees in the monoclonal mode of deployment exhibited greater uniformity with respect to tree size, stem-slenderness, and competition experienced by clones compared to those in the clonal mixture mode of deployment. Susceptibility of one clone to Woolly aphid suggested that greater risks were associated with large scale deployment of susceptible clones in a monoclonal mode of deployment.

This study also indicated that if the plants were to be deployed in a monoclonal mode then block plot selections would have greater potential to enhance productivity.

MFORSC THESIS ABSTRACTS

ANDERSON, STUART (2009)

FUEL MOISTURE AND DEVELOPMENT OF IGNITION AND FIRE SPREAD THRESHOLDS IN GORSE (*ULEX EUROPAEUS*)

Shrub fuels are capable of extreme fire behaviour under conditions that are often moderate in other fuels. There is also a narrow range of conditions that determine fire success in these fuels, below which fires may ignite but hardly spread and above which they ignite and develop into fast moving and high intensity fires. This is due to the elevated dead fine fuels that dry rapidly and carry fire. Fire danger rating systems designed for forest and grassland fuels do not predict fire potential in shrub fuels very well. Fire management requires fire danger rating systems to provide accurate and timely information on fire potential for all important fuel types.

Studies of fuel moisture, ignition and fire spread were carried out in the field in gorse (*Ulex europaeus* L.) shrub fuels to predict the moisture content of the elevated dead fuels and to define the conditions that govern fire development. The accuracy of the Fine Fuel Moisture Code (FFMC) of the Canadian Forest Fire Weather Index (FWI) System to predict moisture content of this layer was assessed. A bookkeeping method to predict moisture content was developed based on semi-physical models of equilibrium moisture content, fuel response time and the FFMC.

The FFMC predicted moisture content poorly, because the FWI System is based on the litter layer of a mature conifer forest. The gorse elevated dead fuel layer is more aerated and dries faster than this conifer forest litter layer. The bookkeeping method was reliable and allowed adjustment of fuel response time based on weather conditions. Difficulties in modelling meteorological conditions under the gorse canopy limited its accuracy. Separate thresholds determined ignition and fire spread success, with both based on the elevated dead fuel moisture content. Options to improve the shrub fire danger rating system were presented based on these findings. The results are significant because they are based on data collected in the field under real conditions. Validation of these results and extension to other shrub fuels is required before the findings are used to change current models. However, the study has significantly advanced the knowledge of fire behaviour in shrub fuels and will contribute to safe and effective fire management in these fuels.

COKER, GRAHAM W.R. (2006)

LEAF AREA INDEX IN CLOSED CANOPIES: AN INDICATOR OF SITE QUALITY

This study examined leaf area index (LAI) and relationships with corresponding tree growth, climate and soil characteristics across New Zealand forest plantations. The aim of this study was to determine if quick measures of projected leaf area across environmental gradients of New Zealand were an accurate indicator of site quality. Projected leaf areas of *Pinus radiata* D. Don and *Cupressus lusitanica* Mills seedlings were measured using a Li-Cor LAI-2000 plant canopy analyser at 22 locations representing the soil and climatic diversity across New Zealand plantation forests. Seedlings planted at 40 000 stems per hectare were used to test treatment effects of fertiliser, site disturbance and species over a 4 year period. It was

hypothesised that collected climate and soil information would explain differences in LAI development patterns across sites as the canopies approached site and seasonal maxima.

Averaged across sites *Cupressus lusitanica* 7.28 (\pm 2.59 Std.) m^2m^{-2} had significantly ($p = 0.0094$) greater projected LAI's than *Pinus radiata* 6.47 (\pm 2.29) m^2m^{-2} . Maximum site LAI (LAI_{max}) varied from 2.9 to 11.8 m^2m^{-2} for *Pinus radiata* and from 3.1 to 12.6 m^2m^{-2} for *Cupressus lusitanica*. LAI_{max} of both species was significantly and positively correlated with vapour pressure deficit, soil carbon, nitrogen, phosphorous and CEC, but negatively with solar radiation, temperature and soil bulk density. A seasonal model of LAI across sites illustrated an 8.5% fluctuation in LAI of established canopies over the course of a year. Despite considerable variation in climate and soil characteristics across sites the combined effects of LAI at harvest and temperature were significantly correlated with site productivity ($r^2 = 0.84$ and 0.76 for *Pinus radiata* and *Cupressus lusitanica* respectively). A national model of LAI_{max} ($r^2 = 0.96$) was proposed for *Pinus radiata* across climate and soil environments and the significance of LAI_{max} as a component of site quality monitoring tools is discussed.

CUEVAS, EDMUND B (2005)

BIOSECURITY AND BIOSAFETY SYSTEMS IN THE PHILIPPINES AND NEW ZEALAND: A CROSS-CASE ANALYSIS

There is a growing importance for both biosecurity and biosafety globally and locally. In this context, this study examined and compared the biosecurity and biosafety systems of the Philippines and New Zealand. This study also considered the central issue of whether the international idea that biosecurity should be the strategic and integrated approach covering and encompassing biosafety and other related instruments, is present or being practised in the national context. This study utilised a qualitative research framework. It followed a case study approach as a process and a product of analysis, and employed triangulation technique of in-depth interviews, observation and used of pertinent/documents in gathering the relevant data and information. This study found that there are complexity of systems, policies, legislation, regulations, and cross-cutting issues that surround biosecurity and biosafety in the Philippines and New Zealand. In terms of biosecurity encompassing biosafety in the local context, this study revealed that such a concept is not yet present in the Philippines, whilst, to some extent it is happening in New Zealand. This study concluded that unless steps are taken to make national policies better informed, enhance understanding of the nature and relevance of biosecurity, and set strategic and operational priorities, then there will be a continuing overlap between biosecurity and biosafety at the national or local level.

FORTUNE, ADRIENNE L. (2006)

BIOSECURITY AT THE EXTREME: PATHWAYS AND VECTORS BETWEEN NEW ZEALAND AND SCOTT BASE, ANTARCTICA

Biosecurity is one of the main mechanisms used to protect and mitigate the introduction of non-indigenous species. Effective biosecurity requires a knowledge and understanding of pathways and vectors along which invasion can occur. This study contributes to our knowledge and understanding of possible biosecurity risk factors in the Antarctic by identifying potential vectors for invasive species in the pathway between New Zealand and

the Antarctic. The Antarctic has important indigenous terrestrial and marine, plant and animal species, all of which contribute to the food chain in Antarctica and the Southern Ocean.

This study seeks to contribute some baseline data about pathways and vectors between the two regions and the implications for the biosecurity of both. An assessment of some of the risks associated with human activities within the Antarctic region, including the traffic of people and goods to and from the area, are the focus of this thesis. Current biosecurity practices with regard to personnel, shipping containers, and fresh produce are examined and where appropriate, recommendations to alleviate any detected risks are made.

The results of the research indicate a significant volume of seed and plant material being unintentionally transported to Antarctica. The most striking finding was the presence of seeds in new clothes, which have previously been assumed not to be vectors. The presence of seeds in soil samples in Antarctica suggests that seeds have probably already been transported to Antarctica. Presently the climate in Scott Base seems to prevent non-indigenous species from becoming established. However, with the increases in temperature being experienced in Antarctica, this may not always be the case, therefore greater attention to biosecurity legislation and its implementation is required.

HANSEN, HELGE (2006) **ACOUSTIC STUDIES ON WOOD**

Several acoustic techniques have been used to determine elastic and damping properties of trees, logs and beams.

Time of flight (TOF) measurements in the outerwood of 14-year-old *Pinus radiata* trees showed that pruning operations increased the outerwood stiffness by up to 25% compared with unpruned trees. However, at the most 5% to 10% of the increased stiffness can be explained by the fact that the outerwood of the pruned trees is free of knots, as TOF measurements are little affected by knots. Thus, it is not known what causes the increase of outerwood stiffness in the pruned trees. One possible explanation could be a smaller microfibril angle (MFA) in the S2 layer of the outerwood cells, which would cause a significant increase in stiffness. Thinning operations decreased the outerwood stiffness by up to 8%.

In small *Eucalyptus nitens* and *Pinus radiata* logs, which had branch nodes and nodal whorls at specific locations, MOE calculations (using the resonance technique) based on different harmonics gave different results. This indicates that defects do interact with acoustic waves.

Acoustic tests on laminated beams with artificial defects (holes filled with dowels) at specific locations also had a significant impact on the MOE. Moreover, it was evident that the damping ratio (evaluated from the Q- factor) of the beams increased with increasing diameter of the holes.

However, it was found that holes in laminated beams decreased stiffness while branch nodes and nodal whorls increased stiffness. This shows that relatively small defects, occupying a small volume of the beam, have an impact on acoustic measurements. It is not appropriate to

base the MOE calculation on a single harmonic, considering that different harmonics investigate different parts of the specimen.

McDONALD, TIMOTHY M. (2009)

MAKING SENSE OF GENOTYPE X ENVIRONMENT INTERACTION OF PINUS RADIATA IN NEW ZEALAND

In New Zealand, a formal tree improvement and breeding programme for *Pinus radiata* (D. Don) commenced in 1952. A countrywide series of progeny trials was progressively established on over seventy sites, and is managed by the Radiata Pine Breeding Company (RPBC). Diameter at breast height data from the series were used to investigate genotype x environment interaction with a view to establishing the need for partitioning breeding and deployment efforts for *P. radiata*. Nearly 300,000 measurements made this study one of the largest for genotype x environment interaction ever done.

Bivariate analyses were conducted between all pairs of sites to determine genetic correlations between sites. Genetic correlations were used to construct a proximity matrix by subtracting each correlation from unity. The process of constructing the matrix highlighted issues of low connectivity between sites; whereby meaningful correlations between sites were established with just 5 % of the pairs. However, nearly two-thirds of these genetic correlations were between -1.0 and 0.6, indicating the presence of strong genotype x environment interactions.

A technique known as multiple regression on resemblance matrices was carried out by regressing a number of environmental correlation matrices on the diameter at breast height correlation matrix. Genotype x environment interactions were found to be driven by extreme maximum temperatures (t-statistic of 2.03 against critical t-value of 1.96 at 95 % confidence level). When tested on its own, altitude was significant with genetic correlations between sites at the 90 % confidence level (t-statistic of 1.92 against critical t-value of 1.645).

In addition, a method from Graph Theory using proximity thresholds was utilised as a form of clustering. However, this study highlighted the existence of high internal cohesion within trial series, and high external isolation between trial series. That is, grouping of sites (in terms of diameter) was observed to be a reflection of the series of trials for which each site was established. This characteristic is particularly unhelpful for partitioning sites into regions of similar propensity to genotype x environment interaction, as the genotype x environment effect is effectively over-ridden by the genotype effect.

Better cohesion between past, present and future trial series, and more accurate bioclimatic data should allow more useful groupings of sites to be extracted from the data. Given this, however, it is clear that there are a large number of interactive families contained in the RPBC dataset. It is concluded that partitioning of New Zealand's *P. radiata* breeding programme cannot be ruled out as an advantageous option.

MANSELL, JEREMY D. (2007)

DRAFT FOREST MANAGEMENT PLAN FOR CASHMERE FOREST, PORT HILLS

Cashmere Forest is currently a production forest comprised of mostly radiata pine (c. 85%), Douglas fir (c. 5%) and some non-plantation areas. The Port Hills Park Trust Board (PHPTB) is interested in purchasing Cashmere Forest for the purpose of creating a public forest park environment where forestry, indigenous biodiversity, recreation and the environment are goals of sustainable management. For this purpose this draft forest management (DFM) plan has been prepared.

The preparation of the Cashmere DFM plan comprised three main components:

1. An economic analysis of the current plantation component of Cashmere Forest;
2. Preparation of a draft forest management plan which encompasses the management of plantation and non-plantation areas; and
3. Preparation of a geographic information system (GIS) for Cashmere Forest.

Economic analysis evaluated clearfell, coupe (2 to 5 ha), and a mixture of coupe and continuous canopy management (CCM) as harvesting scenarios. The coupe CCM mix was recommended for implementation primarily as it best suited long term management goals for Cashmere Forest Park while also returning modest value (NPV \$561,966). Normal cashflow analysis was also used to analyse cashflow over the first thirty years of operation from 2007.

Under coupe/CCM, accrued profit does not become permanently positive until around 2019 due to initial infrastructure costs. Accrued revenue culminates at around 4 million after 30 years. This figure may drop following implementation of high pruning, alternative growth models and indigenous restoration.

The Cashmere DFM plan begins with the 200-year vision which sees a Forest Park ecosystem that achieves production, environmental, ecological and recreational goals appropriate to its Port Hills location. Production forestry is practiced through the selective harvesting of a range of naturally regenerated exotic and restored indigenous species. Landscape, soil and water resources are sustainably managed through the retention of a mixed forest canopy. The forest park has been significantly augmented with indigenous flora and fauna typical of the Port Hills and ecologically significant areas are managed specifically for their indigenous biodiversity. Park recreational users are enjoying ongoing utilisation of a unique Canterbury landscape. Plantation forest management involves coupes of between 2 to 5 ha which will be harvested with cable or ground based systems with areas split approximately 50:50 between the two. Cable harvesting will be carried out with a swing yarder system with ground based operations carried out with track skidders. CCM will be carried out on a trial basis in three compartments. Re-establishment of plantation areas will aim towards occupying around 58% of Cashmere Forest, comprised of areas of radiata pine 65%, radiata pine/eucalypt 24%, Douglas fir/eucalypt 5% and Alternative species 6%.

Non-plantation areas are identified as either bluff, track or clearing. Within each area there may be one or more vegetation type including tussock grassland, mixed shrubland, rock association and any mixture of the three. It is proposed that the non-plantation area will

eventually increase to include riparian buffers 31%, restored native 55%, bluff 10% and track 4% areas, reflecting the long term vision of increased native areas in Cashmere Forest.

Monitoring of forest operations, restoration, recreation and management progress will be integral to the successful implementation of the Cashmere DFM plan. A database of information will be created to allow periodical reviews of processes and predictions and reconciliation of costs and revenues associated with the management of Cashmere Forest. Periodical reviews will also be undertaken by an independent management advisory group who can liaise with the project manager of Cashmere Forest Park to discuss issues and aid planning and ensure the successful establishment of this unique park resource.

O'KELLY, GLEN (2008)

FOREST-MILL INTEGRATION FROM A TRANSACTION COSTS PERSPECTIVE

Fibre sourcing is a critical strategic question for all sawmills and pulpmills, but the degree of supply integration through long-term contract and forest ownership varies widely. The purpose of this research was to investigate the extent to which forest-mill integration patterns can be explained by the transaction cost economics (TCE) theory.

TCE theory holds that organizations will choose transaction governance forms that minimize transaction costs. The TCE factors expected to influence that choice can be grouped into three categories: transaction frequency, market uncertainty, and asset specificity. Interviews with various industry representatives suggested that factors from all three categories are relevant to the question of forest-mill integration.

A survey was conducted of mills in New Zealand and Sweden, providing data on their supply mix and various TCE factors. Of an estimated population of approximately 450 mills, 136 mills were sampled and 88 responded to the survey. Fractional logit models were developed to explore the factors that may influence the integration decision.

Considerable evidence was found for the importance of TCE factors in driving fibre supply integration. The evidence was strongest for factors related to asset specificity, including forest owner concentration and the specificity of a mill's fibre requirements. Transaction frequency appears less important; while integration was found to be significantly associated with the number of mills an organization has within the supply basin, the influence of mill capacity was found to vary. There was weak evidence for the importance of uncertainty, and perhaps only through the impact of forest owner concentration on market conduct.

Integration was found significantly higher for pulpmills than sawmills, and higher in Sweden than in New Zealand. The latter result is difficult to explain by TCE theory, and suggests that non-TCE factors play a significant role. Survey responses also indicated that non-TCE factors are important. Further research is required to enlarge the sample size and better understand the role of TCE factors in forest-mill integration.

OUNEKHAM, KHAMSENE (2009)

DEVELOPING VOLUME AND TAPER EQUATIONS FOR *STYRAX TONKINENSIS* IN LAOS

A volume equation for predicting individual tree volume, and a taper function for describing a stem profile were developed for a little known species, *Styrax tonkinensis* (Siam benzoin) in northern Laos. The species has high potential commercial value and can make an important contribution to the local economy. It can provide two different types of products, a non-wood product (benzoin resin) and timber. In Laos, the most important product is currently resin, and the use of timber for commercial purposes is rare. One reason is that information about the timber is not available. In Vietnam, on the other hand, the species is an import pulpwood species.

Data used in this study came from 73 trees. Trees were purposely selected to ensure coverage of a full range of tree sizes. Measurement was undertaken only on over-bark diameters due to some constraints, limitations and problems during the field data collection. However, due to the importance of under-bark volume for this species, a small available dataset was used to build a bark model as an interim guide to the errors associated with using over-bark models for estimating under-bark volumes. From this bark model, errors in estimating under-bark volumes of trees with diameters at breast height between 10cm and 17 cm were approximately 18%.

Nineteen individual volume models, and 7 individual taper functions were compared for bias and precision. Collective names for the volume equations tested include single-entry, double-entry, logarithmic, combined variables. Most volume models had similar bias but a few were clearly biased. The models with similar bias were further evaluated by four common statistics including bias, standard error of estimates, standard deviation of residuals and mean absolute deviation. The results showed that a five parameter model was ranked first, and was the most precise model. However, the magnitudes of difference in prediction errors between this model and other models, particularly the three parameter model were not significant. For practical purposes, the simpler model was preferred.

Seven taper functions tested here belong to three different groups including single taper equations, compatible taper equations and segmented taper equations. Evaluation of taper equations used the same residual analysis procedures and criteria as those applied with volume equations. Graphical residual analysis showed that most taper models had similar precision with their errors in diameter predictions being similar in range. However, some models showed obvious bias. The most highly ranked taper model was a compatible taper model of polynomial form. It was the least biased model. The second ranked model was a single, simple model. This latter model is relatively simple to apply, but it is not compatible with the volume model, yielding slightly different estimates of volume if it is integrated and rotated around the longitudinal axis of a tree. However, if the sole purpose is to describe tree taper, it is the best model to use.

ROBERTSON, KIMBERLY (2006)

ESTIMATING REGIONAL SUPPLY AND DELIVERED COST OF FOREST AND WOOD PROCESSING BIOMASS AVAILABLE FOR BIOENERGY

New Zealand has ratified the Kyoto Protocol and agreed to reduce greenhouse gas emissions to 1990 levels by 2008. Energy generated from renewable sources, such as New Zealand

plantation forests and wood processing sites, is considered greenhouse gas neutral. But the use of biomass for bioenergy in New Zealand is very small. Some of the reasons for this include a lack of information about the future fuel supply and delivered cost.

This thesis aims to provide a methodology to estimate biomass fuel availability and the delivered cost, or a range of forest and wood processing sources within a district, and to analyse the impact of harvest age, harvesting practices, terrain, collection and chipping costs, opportunity cost and transport costs on the availability and delivered cost of biomass for bioenergy. The six biomass streams included were chiplogs, forest landing residues, cutover residues, sawdust, bark and chip.

The methodology was developed based on an area in Canterbury, and tested on an area in the Nelson/Marlborough region. It utilises forest growth models, Geographic Information Systems and Microsoft Excel. Growth models allow the analysis to be customised to a particular area or region, while the use of GIS allows the model to take spatial aspects (for example slope and transport distance) into consideration. Developing the overall framework within Excel allows easy analysis of the results and changes to the underlying assumptions.

Opportunity costs make up a large proportion of the total cost of delivery for the chiplog, sawdust, bark and chip biomass and need to be included in any estimate of cost for these biomass streams. The logistic system chosen for collecting and chipping the forest residues has a large impact on their delivered cost as do the transport costs. However transport cost is not the most significant influence on the delivered cost of other biomass stream. The use of biomass for electricity generation only is not currently economic in either of the areas analysed. The use of biomass for heat production is currently economic if compared to the electricity purchase price.

WAGHORN, MATTHEW J. (2006)

EFFECT OF INITIAL STAND SPACING AND BREED ON DYNAMIC MODULUS OF ELASTICITY OF *PINUS RADIATA*

Wood stiffness or modulus of elasticity (MOE) is one of the most important wood properties for solid timber applications, and as such, the efficacy of wood use, especially for structural timber is strongly related to MOE. MOE in *Pinus radiata* is highly variable and poorly understood. In this study, the effect of initial stand spacing and breed on outerwood MOE and the vertical distribution of MOE of *Pinus radiata* was assessed. Understanding positive or negative influences of growth caused by initial stand spacing and genetic material on MOE is appealing because it could enable us to better comprehend how forest growers could adapt silvicultural operations to the demand of wood processing.

Physical characteristics of different breeds and propagation methods of *Pinus radiata* were assessed at a variety of initial stand spacings. Stem diameter, crown height, stem slenderness and branch size were all heavily influenced by stand spacing. Breed had a marginally significant influence on diameter and stem slenderness. Internode length was not affected by stand spacing, but showed sizeable differences, especially between the long internode 870 breed and the remaining growth and form (GF) breeds.

Outerwood MOE was significantly ($P < 0.0001$) influenced by stand spacing and breed, but not their interaction ($P > 0.05$). MOE scaled positively with stand spacing. MOE increased by

39% from 5.4 GPa at 209 stems ha⁻¹ to 7.5 GPa at 2551 stems ha⁻¹. The majority of this increase (33%) occurred between 209 and 835 stems ha⁻¹. Physiologically aged cuttings of greater maturation status exhibited greater MOE, with the three-year-old cuttings being stiffer than the one-year-old cuttings, seedlings from the 870, 268 and 850 series, by 15, 17, 22 and 27% respectively. Stem slenderness exhibited the strongest significant ($P<0.0001$) relationship with MOE ($r^2=0.49$), followed by green crown height ($r^2=0.46$) and diameter ($r^2=0.44$). Stem slenderness and green crown height had a direct influence on MOE that explained 53% of the variance in MOE.

MOE was also significantly ($P<0.0001$) influenced by spacing and breed when using the resonance technique to assess whole stem MOE. The vertical distribution of MOE showed that the lowest portion of the stem (bolt 1) was approximately 30% less stiff than bolts 2 and 3. After the greatest MOE value had been obtained at bolt 3, MOE gently declined to the top of the measured stem. Variation of MOE within trees was significant (58%) at the high stockings of 1457 and 2551 stems ha⁻¹, but somewhat lower (36%) at the lower stockings. The 870 breed was approximately 8% and 16% stiffer than the 268 and 850 breeding series respectively, across all stockings, with the three-year-old cuttings being 7% stiffer than the one-year-old cuttings. At stockings of 481 stems ha⁻¹ and less, the proportional height at which MOE was greatest within a tree was between 25% and 50% of stem height. At stockings above 481 stems ha⁻¹ the proportional height at which maximum MOE was obtained was between 15% and 40% of stem height. Bolt slenderness was found to be the most significant factor impacting on MOE of the bolt.

Regression of critical buckling height against diameter at ground level yielded a scaling exponent of 0.55, which was lower than the scaling exponent of 0.67 predicted with constant density-specific stiffness. There was a tendency for some bolts with lower mean diameter to display significantly higher safety margins than bolts with higher mean diameter, suggesting that the largest bolts, which occur at the base of tree, are the point of most likely critical failure.

WAKELIN, HEATHER (2010)

IGNITION THRESHOLDS FOR GRASSLAND FUELS AND IMPLICATIONS FOR ACTIVITY CONTROLS ON PUBLIC CONSERVATION LAND IN CANTERBURY

Grassland fuels quickly respond to moisture changes in the environment, and successfully ignite more readily compared with other wildland fuel types. In recent years in New Zealand grasslands, wildfire ignitions have increased due to recreational activities on public conservation land. Ignition sources have included off-road vehicles, sparks from machinery, and campfires, cooking stoves, etc. This research investigated ignition thresholds for fully cured tussock (*Festuca novae-zelandiae*) and exotic (*Agrostis capillaris*) grasses, with the aim of providing a scientific basis for wildfire prevention through decision-support tools for activity controls.

Five ignition sources of concern to the Department of Conservation were tested in the laboratory, and results were validated against field experiments. Experiments were innovative, and were designed to simulate ignitions from: hot exhaust systems on off-road vehicles (hot metal); sparks from vehicle exhausts (carbon emissions); grinding operations (metal sparks); smouldering debris dropped onto grass fuels from hot vehicle parts (organic embers); and ordinary cigarette lighters (open flame). Fuel moisture content (MC), and wind

speed were varied, but ambient temperature and relative humidity were kept relatively constant in the laboratory.

Logistic regression was used to analyse data for each ignition source, except organic embers because no ignitions occurred. Ignition thresholds were determined for a probability of ignition success of 50%, and all models were statistically significant. The thresholds are listed in terms of model accuracy for each experiment: open flame was 28% MC without wind, and 55% MC with light wind (1 m/s); metal sparks was 37% MC; hot metal, with a wind speed of 2 m/s and MC of 1%, was 398°C hot metal temperature; and carbon emissions was 65% MC.

The results represent a significant contribution to knowledge of the ignition behaviour of grassland fuels. Further research is required to verify and extend the results; but, initial findings provide a scientific basis for management, investigations of wildfire causes, and decisions around controls on recreational activities to protect highly sensitive ecosystems and natural areas from damaging wildfires.

ZORIC, BRANISLAV (2008)

MODELLING THE INFLUENCE OF STOCKING ON LONGITUDINAL AND RADIAL VARIATION IN WOOD PROPERTIES OF *PINUS RADIATA* ON A WARM NORTHLAND SITE

The objective of this study was to determine how final stocking influences tree growth and radial and longitudinal variation in wood properties at a *Pinus radiata* D. Don plantation located at one of the warmest forest sites in New Zealand, Forsyth Downs forest in Northland. This thesis addressed both the effect of stocking on stand basal area, height, diameter and branch diameter and the effect of stocking on wood properties microfibril angle (MFA), module of elasticity and density. Finally, how ring width influences wood properties and whether this variable accounts for the treatment effects was investigated.

Stocking, height and ring number and all interactions between these variables significantly affected ring width. Ring width by itself was significant as a predictor of density, but when it was combined with other class level variables it was insignificant (i.e. does not account for treatment effects), and it did not add anything to a model with only class effects. There was a significant impact of ring number on density while ring width was insignificant in the same model.

MFA was significantly affected by ring width, height and ring number in the tree, and all interactions, apart from the three way interaction, but not by stocking. Ring width was significant in the MFA model both by itself and when it was combined with other variables. Ring width accounted for the stocking effect.

The best model of MOE included the class level effects of stocking, height and ring number within the tree, and all interactions between these variables, and ring width, as a continuous variable. While there was a significant effect between stockings this was relatively weak compared to the other main effects. Ring width largely accounted for the effect of stocking, but not that of ring number, or height.

MFORSC REPORT ABSTRACTS

ARIHABA, ARISON (2008)

THE USE OF A GEOGRAPHIC INFORMATION SYSTEM (GIS) IN DETERMINING THE PAST AND PRESENT VEGETATION PATTERN OF TIROMOANA BUSH, NORTHERN CANTERBURY, 1950-2005

A GIS (geographic information system) database was created to quantify and spatially distinguish historical changes in vegetation cover in the 423 ha of Tiromoana Bush in New Zealand. Four main land cover types (forest, shrubland, pasture and wetland) were classified in this study. In Part A of the study, I conducted a field survey to produce the 2008 vegetation map (FMD2008) in order to compare it with the Land Cover Database (LCDB2) map of the same area created from remotely sensed satellite data. Overestimation and underestimation of vegetation classes were evident in LCDB2 map. 30% of the total land cover was incorrectly represented in LCDB2, while there were more patches of each vegetation type identified by field mapping than by the use of LCDB2. These data suggest caution in using LCDB alone to accurately map vegetation pattern, especially at the scale of my study. In Part B, four land cover aerial photographs from 1950-2005 were imported, registered and rectified into the GIS under a common legend. The total area of shrubland and native forest increased, while that of pasture decreased over the study period in a 99 ha portion of Tiromoana Bush. More areas of pasture and grassland covers were lost to forest while less forest cover was lost to other vegetation types during this period. There was an increase in the forest growth rate from 0.15 ha/yr in the period 1950-1985 to 0.74 ha/yr in the period 1985-2005. Furthermore, the total number of forest patches increased from 1950-1985, but it decreased from 1985-2005. Unlike that of the pre-1985 period, the increase in the forest cover in the post-1985 period is likely an effect of the government's removal of agricultural subsidies and therefore fewer disturbances. The data presented in this report provides an excellent basis for mapping longer-term vegetation change that result from the restoration project at Tiromoana Bush.

BIERLIN, TIMO R. (2007)

HARE'S AND RABBIT'S HABITAT UTILIZATION: A REVIEW AND PRONENESS MODEL

The European rabbit (*Oryctolagus cuniculus* L.) was, and in some areas still is, a significant pest in arid and semi-arid parts of New Zealand. High rabbit densities can cause great financial and ecological losses. In contrast, in most parts of Europe and especially in its area of origin, the Iberian Peninsula, the European rabbit is considered to be a game animal rather than a pest. It is also, not only for endangered species, one of the most important vertebrate prey species and its decline in numbers is worrying. In many areas where the European rabbit is present, the brown hare (*Lepus europaeus* Pallas) can also be found. Both species show a certain habitat and diet overlap and its interaction is discussed controversially. The first part of this report gives an overview of both species' biology, focusing on habitat and diet requirements. The overview is based on a wide literature review on Lagomorphs, including European, as well as Australian and New Zealand studies and reports.

In the second part of this report, the results of the literature view, historical kill data of European rabbits and brown hares from 1991 to 2006 recorded during pest control operations at the Otematata Station, and digital data sets of vegetation cover and soil types,

are used to create a rabbit proneness model. To evaluate rabbit density, the data set of 'rabbit kills per hour' is used. The kill data have been statistically analysed and a regression has been performed on rabbit kills per hour and on the characteristics of soil type and vegetation cover. The regression does not show statistical significance between these data and consequently were excluded from the further modelling process. To analyse interactions between European rabbit and brown hare numbers, a regression with dummy variables was performed on the total number of annually killed rabbits and the total number of annual killed hares. The result indicates a statistical significance of the parameter and explains the increase in hare numbers after rabbit numbers have dropped sharply in 1997. Spatial analysis of the data sets was applied to form the 'Otematata Station rabbit proneness model'. Under this model, areas where rabbit proneness is most likely are determined primarily by the availability of certain soil types suitable for building warrens and the availability of preferred feeding grounds. It is also suggested that the factors altitude, aspect, and slope affect the suitability of certain areas for rabbit abundance.

DAUGHERTY, JAMIELYN (2007)
THE STYX RIVER: A REVIEW

The Styx 40-year Vision is a comprehensive management programme geared towards the ultimate restoration of natural areas from the source of the river to the sea. The vision requires a detailed understanding of the many ecological aspects within the system as well as human activity throughout the catchment. Human activity can be measured through development or recreation. This gives rise to a large selection of potential research projects from environmental engineering to community volunteering. This report will take a brief look at the five key visions in the plan. An overview of the primary aspects of the Styx River and surrounding catchment will then be looked at. Tributaries, reserves and wildlife communities as well as recreational use will be outlined to help gain a better understanding of the issues needed to fulfil the 40-year Vision.

KLEIN, NORBERT (2007)
HABITAT SELECTION MODEL FOR FERAL GOATS (*CAPRA HIRCUS*) AT ISOLATED HILL SCENIC RESERVE: REPRESENTED BY A GEOGRAPHIC INFORMATION SYSTEM

The introduced feral goat (*Capra hircus*) occupies approximately 14% of New Zealand and about half of this land is administered for conservation purposes. Feral goats have a well-documented history of being one of the most destructive animal pests found in forests. Therefore, organised government control has been an ongoing issue since the mid-1930s. Conservation managers could benefit from a robust method of estimating the spatial attributes of the target, the simple but vital information of where feral goats live in a certain area.

A literature review about animal-habitat relationships followed by an overview of different modelling approaches provided useful aspects for the main task of this report: the development of a habitat selection model for Isolated Hill Scenic Reserve. The Reserve is approximately 2850 ha in size and is one of the largest forest remnant areas in Southern Marlborough on the South Island of New Zealand. The data for the habitat selection model is mainly based on an earlier study by Cochrane (1999) and was supplemented by relevant key environmental variables that were identified through an extensive literature review. In

the model building process, the GIS ArcView 3.2a was used for analysing the data and a graphical representation. Patches throughout the Reserve, totalling 446 ha (15%), that have the utmost probability of high goat densities were determined. The validation of the habitat selection model was carried out by digitising and analysing numerousness kill data. More than 50% of the kill locations that were found exactly within the predicted area and 94% within a 300 m perimeter or 98.7% in a 500 perimeter provided a very high accuracy for the model.

The resulting topographical map assists hunters to increase their encounter-rates, as well as their hourly kill-rates. Furthermore, the incorporation of the habitat selection model on a strategic level would provide a surveillance tool and a post-operational monitoring tool for both the pest and biodiversity. Further research to extend the habitat selection model on a broader scale for regions with known feral goat distribution areas and the development of a goat index linked to the Land Cover Database 2 is advisable.

MAKROSIMNOK, LUCAS B. (2008)

ESTABLISHMENT AND GROWTH OF FOREST SEEDLINGS IN REGENERATING FOREST, TIROMOANA BUSH, NORTH CANTERBURY

Many years of consistent sheep and cattle grazing had drastically deteriorated the ecosystem and biodiversity in much of the Canterbury region. Thirteen permanent natural seedling regeneration plots were established within Tiromoana Bush, North Canterbury. The aim of the Tiromoana Restoration Project is to monitor and assess the dynamics of the native forest regeneration that may result in the restoration of an example of lowland forest so that the ecosystem and biodiversity can be restored in the future.

The data analysis was undertaken to examine the relationship between a number of dependent variables and independent factors. Dependent variables examined were: total seedling density present in 2008, total tree seedling density present in 2008, average change in height of tree species seedlings between 2007 and 2008 measurements, percentage change in height of tree species seedlings between 2007 and 2008, and density of new seedlings that were measured for the first time in 2008. Four independent variables that were measured for each vegetation monitoring plot and used to predict the seedling variables include: canopy openness, soil pH, aspect expressed on north-south gradient, and distance from plots to the potential seed sources, expressed in 3-point scale.

Significant correlations ($P \leq 0.05$) occurred between tree seedling density and density of new seedlings and distance from potential seed sources, and between percentage change in tree seedling height and aspect. All other correlations were not significant ($P > 0.05$). Despite developing significant regression models for above key predator variables, the variance explained in the regression models was low, suggesting that the relationship was not that strong. This vegetation monitoring study showed that more tree species would establish under the open canopy with potential seed sources within close proximity. Fast growth of tree seedlings was occurring in gully and slopes facing South direction with rich environmental resources (water, soil nutrient, light).

NORIA, ANDREW (2008)

ASSESSING THE SUCCESS OF RESTORATION PLANTINGS AT CAPE FOULWIND, BULLER, NEW ZEALAND

The success of restoration plantings in restoring farmland adjacent to the Cape Foulwind limestone quarry was assessed at two sites. The results obtained in this study suggest that restoration plantings at the nursery site are facilitating the recolonisation of new species such as *Dacrycarpus dacrydioides* and *Melicytus ramiflorus*, while those at the beach site are failing. Seedlings regenerating at the nursery site are progressing well with a wide range of indigenous species establishing under the canopy species. The presence of novel seedlings at the study sites indicates that seed dispersal agents are present. However, the restoration plantings at the beach site have failed. The restoration failure at the beach site is due to the high mortality rate of the initial plantings. Sunlight has penetrated through the open canopies causing an influx of weeds and exotic grass. The grass swards have dominated the planting site and smothered the seedlings. Selection of species for the restoration plantings that are inappropriate to the site have also contributed to the restoration failure. The difference between the nursery site and the beach site suggest that weed control and species choice had a major impact on the regeneration, succession and overall success of restoration plantings at these sites.

TAMANIKAIVAVALAGI, SAIMONI S.R. (2007)

“FIJI MAHOGANY” – ADDING VALUE AND MAXIMISING OPPORTUNITIES FOR EXPORT TO THE UNITED STATES OF AMERICA AND ITS FUTURE ON FIJI’S ECONOMY

Fiji Mahogany, *Swietenia macrophylla*, King, commonly known world-wide as the big-leaf mahogany, is a medium density hardwood species which originated from Belize in the early 1900s. With similar characteristics, wood properties and growth conditions as the Brazilian mahogany, the species has been plantation grown for more than forty (40) years in the Republic of the Fiji Islands. Fiji Mahogany were originally planted as avenue trees but later converted by the Fiji Forestry Department to be a reforestation species on logged-over native forest areas. Plantations now reach more than 40 000 hectares (ha). Regarded as being a luxury timber with a reputation as the most valuable commercial timber, mahogany has prompted the Fiji Government to establish the Fiji Hardwood Corporation Limited to manage all mahogany plantations and oversee the commercial undertakings of Fiji Mahogany.

The restrictions placed on the mahogany trade through the listing of the species on the Appendix II of the Convention on International Trade in Endangered Species (CITES) by most Southern American mahogany suppliers, has presented the Fiji Government with an opportunity to benefit immensely from the sale of Fiji Mahogany products. The harvesting of mahogany is now in its initial stage of operation. The Fiji Hardwood Corporation Limited in cooperation with the Fiji Mahogany Trust who is responsible for the welfare of landowners whose land is leased by Fiji Hardwood Corporation for mahogany plantations are involved in the harvesting operation. Before harvesting commenced, the actual value of Fiji Mahogany plantations is the subject of debate with conflicting monetary values put forward by various forest consultant companies. This has brought about a sense of uncertainty among the major mahogany stakeholders.

In reality, to attain the “true” value of the species is to formulate a marketing strategy on how to fully maximise the utilisation of Fiji Mahogany logs for value-added products, with a defined market for Fiji Hardwood Corporation Limited. Currently, sawn timber has been the sole major product from Fiji Mahogany. The Fiji Hardwood Corporation Limited ought to put more focus into producing value-added products such as moulding parts, furniture, flooring, decking, lining and slice veneer. Furthermore, mahogany residues can also be utilised for the production of electricity through combustion by generated steam turbines. Although the technology for down streaming processing of value-added products is to some extent lacking in Fiji at the moment, the Fiji Government, Fiji Forestry Department, Fiji Hardwood Corporation and the Fiji Mahogany Trust must work together to find ways for training of personnel, create a partnership of investment for capital funding, and assist in the purchasing and installation of value-added machinery. Emphasis must be placed on creativity in the nature of design for value-added machinery. Emphasis must be placed on creativity in the nature of design for value-added products that can compete with what is on offer on the current market. Only then can the full utilisation of mahogany logs from the first branch sawlog to the upper branch logs accomplish for the production of value-added products.

The mahogany markets in the United States of America have been recommended for the marketing of Fiji Mahogany value-added products. Although there are other mahogany markets around the world that the Fiji Hardwood Corporation Limited can choose from, the American market is more valuable for such mahogany products. First and foremost, the American market is currently the largest importer of mahogany products, contribution approximately US\$60 million in revenues annually which is part of the US\$13 billion in total timber imports for the whole country per year. This mahogany consumption simply implies the high demand of the species corresponding to a large population with a vast number of buyers spread out geographically, demographically and psychographically with variations in needs, tastes, specifics and demands. Hence, with an available mahogany resource of 40 000 ha it is simply not enough to satisfy the demands of the whole American market.

The second important criteria of the American market are that prices paid for mahogany products are quite high as compared to other mahogany importing countries. Hence, for Fiji Mahogany value-added products to achieve these price premiums is to implement an efficient market research that will focus on narrowing the market to target a niche which Fiji Mahogany can use to satisfy customer needs and maximise market profitably. It would seem logical to find an initial target niche market which is located within the state of California, the urban and metropolitan areas of the two major cities of Los Angeles (one of the 5 most populous cities in the United States of America) and Sacramento before diverting into the other states or Canada. Furthermore, the assistance of the Fiji Trade Commission based in Los Angeles and other Fiji Government representatives (Fiji Embassy, Honorary Consuls and Fiji Mission to the United Nations) having professional background knowledge of the United States trading regulations, standards and mahogany traders on the American market, is an advantage in finding a suitable market for Fiji Mahogany value-added products.

Working in collaboration with the Fiji Trade Commission in Los Angeles will be a market representative appointed by Fiji Hardwood Corporation Limited to oversee the negotiations and market research on the marketing of Fiji Mahogany. Having an office in Los Angeles (may be within the Fiji Trade Commission) is vital; the major task of the marketing representative is to identify who are the end-users of the product, the type of mahogany

products used by the end-users and the price premiums paid for such products. Information gathered by the marketing representative is relayed back to Fiji Hardwood Corporation Limited in Fiji, which will assist in the decision-making and approval for the manufacture of value-added products. The results of this market research are the most critical aspects for Fiji Hardwood Corporation Limited in determining the capabilities of Fiji Mahogany as a value-added product on the American market.

One of the marketing principles include the market positioning of Fiji Mahogany on the American market where it must have a competitive edge on other mahogany suppliers and distinguish itself in terms of high quality product, wood characteristics and wood properties to enhance its marketing abilities. The advantage of having a few similarities in physical characteristics and wood properties with naturally grown mahoganies from South American countries solidifies the image of Fiji Mahogany on the market. This would build up its reputation as to what it promises it can deliver for that specific need which strengthens customer relationships, builds-up customer trust, loyalty and influences customer confidence to trade on the species in the long term. It has to produce a value-added product that has an end-user and with its high demand strengthens the product's position on the market.

The detail formulation of a marketing mix (product, place, price and promotion) would allow Fiji Mahogany value-added products to portray the highest standard of quality to meet the American quality standards that would compete well and perhaps do better in terms of price than other mahogany suppliers in the same market. Value-added products from mahogany such as mouldings, furniture, decking and flooring are now attracting very high prices on the American market from antique dealers, DIY (Do It Yourself) stores, retailers and wholesalers. Hence, Fiji Mahogany must keep a competitive edge to ensure that it stays ahead of other competitors in terms of high quality products. The dwindling supply of mahogany world-wide and the increase in demand for the species product are now the main factors influencing the price hike.

Finding a customer (end-user) for direct trading within the state of California that offers the best possible price (same or better than prices paid to South American value-added products) would result in effective and efficient communication for produce confirmation, one-dealing negotiation would incur maximum premium price paid for the product, less inconsistency in produce paperwork clearance, specific arrangement of product distribution channels and logistics to reach the customer. The three sea ports of Los Angeles is the ideal distribution channel since the majority of the shipping lines from the Pacific rim use these ports for their cargo distribution. Again, the presence of the Fiji Trades Commission in Los Angeles is a huge benefit for effective communication in product marketing and assistance for any bureaucratic discrepancy that may arise from American customs or trade personnel on product clearance and distribution.

Promoting this criterion of high quality product through the internet, sales promotion expositions, media advertising or even presenting a sample of the product during market research will give potential customers a glimpse of the quality standards that Fiji Mahogany offers as a product. In addition, correct profiling, packaging and wrapping and labelling of the products is a necessity and an incentive for the promotion of Fiji Mahogany. The brand name itself should distinguish Fiji Mahogany from other mahogany producers indicating its origin and identity. The stamping of a certification logo on the wrapper will indicate to the importing authorities that the product comes from a sustainable forest, hence, confirming to CITES regulation for mahogany importation on the American market.

Fiji Mahogany is unique in that 50% of the estimated 40 000 ha plantations are planned for harvesting in the next five to ten years. It has taken more than forty years for the first mahogany to be harvested and without any form of forest certification and sustainable forest management, the effect on the fundamentals of the marketing principles for the marketing of Fiji Mahogany will be severely hampered. The main consequence of the above undertaking will fall heavily on the Fiji Government and Fiji Hardwood Corporation, where customer relationship, trust and confidence are severely affected. It is an expensive exercise to implement a market research, but the benefits in the long term for the marketability of Fiji Mahogany is quite enormous; it outweighs the cost of its implementation. However, the cost of breaking a customer relationship from not fulfilling customer needs due to lack of resource supply is the one critical issue that outweighs all the costs involved in the marketing of Fiji Mahogany. In other words, the customer has the option to choose another mahogany producer where it can get a continuous supply or an alternative product species. To re-negotiate with the customer or find a new customer (the non-supply issue is communicated around the customers quite easily), costs a lot more than the initial negotiation to get customer confidence and trust for trading. Forest certification is unavoidable in the current world mahogany trade markets. This is one criterion that is required under the United States of America mahogany trade import laws that Fiji Mahogany value-added product must be compliant with. Hence, without forest certification, direct dealing with customers on the American market would be impossible.

What does the future hold for Fiji Mahogany? Currently, the Fiji Government is focussing its attention on the marketing of Fiji Mahogany through Fiji Hardwood Corporation Limited for much needed revenue to boost the shrinking economy of Fiji after the December 6th 2007 military coup. The Government must show its credibility to all mahogany stakeholders and the people of Fiji and uphold the reputation of the species as a highly valuable commercial timber. This credibility must be founded on the implementation of a well-defined marketing strategy to ensure the species is marketed efficiently and effectively. To accomplish this, the Fiji Government and its subsidiary organizations, Fiji Hardwood Corporation, Fiji Mahogany Trust and the Fiji Forestry Department must devise a working framework that will be effective and responsible for the improvements of Fiji Mahogany from its current establishment to the marketing of its products.

This working framework would involve integrating the roles of the Fiji Forestry Department and Fiji Hardwood Corporation limited for the establishment of forest genetic research programs, finding alternative species to Fiji Mahogany that are commercially viable for quicker revenues and the establishment of down-streaming industry for value-added products. The long-term benefits of forest genetic research are quite enormous not only for Fiji Mahogany but for other potential forest commercial species. As for Fiji Mahogany, it provides a more in-depth knowledge for the establishment of tree breeding programs for superior trees that are disease resistant, has good wood quality attributes and growth form far more improved than the current trees. It is also an incentive to further improve the current forest research laboratories in terms of modern computerised equipment and advanced knowledge through training programs for research personnel.

The result of this integrating in responsibilities based on research will also inform the Fiji Government of an alternative species to Fiji Mahogany that would provide revenues in the medium term before mahoganies are mature. Since Fiji Mahogany takes more than 40 years to mature, it is an opportunity for the Fiji Mahogany Trust, other interested landowners or

investors to implement the planting of species that take a lot quicker to mature and harvested for quick returns. Species such as Sandalwood, Teak, Eucalyptus and lesser-known Bamboo are now more established on the market with premium prices paid for its products. The critical factor to comprehend with these species is that it can be plantation grown quite easily in the Republic of Fiji Islands.

Production of value-added products requires modern machinery and expertise. Again the result of this integrating role allows the implementation of training programs on the different ways for producing value-added products. Having this knowledge would provide incentives for Fiji Mahogany Trust to attract investors for the purpose of capital funding, machine installation, advance training in the production of value-added products and assist in the establishment of markets for these products. The potential benefit to Fiji Mahogany landowners in the long term will be quite enormous.

The organizational structure within Fiji Hardwood Corporation Limited must distinguish between the production and the marketing divisions. This is to ensure that there is a two-way definite line of communication on what value-added products recommended by the marketing division that are on demand which needs to be produced for sales. On the other hand, information relayed back to the marketing division if the product desired cannot be produced for some unforeseen problems as lack of resources or equipment unavailability. It is vital that these two major divisions are given priority by the Fiji Hardwood Corporation Management to ensure Fiji Mahogany's reputation to supply and meet market demands.

Lastly, the way forward for Fiji Mahogany right now is to maximise its utilization. The Fiji Hardwood Corporation Limited must be given the opportunity to function as a commercial entity to the terms it was initially formalised in 1998 without political interference from the Fiji Government of the day, landowners and other mahogany stakeholders. The people of Fiji would like to see the reality in the value of Fiji Mahogany right now. After the past mistakes from its management, the time is "ripe" for the people of Fiji and future generations to enjoy the benefits of this valuable resource.

TITIULU, TERENCE (2009)

OPPORTUNITIES FOR PLANTATION FORESTRY AS AN ALTERNATIVE TO UNSUSTAINABLE COMMERCIAL LOGGING IN THE SOLOMON ISLANDS

Log exports remain the major foreign exchange earner for Solomon Islands, but the current level of harvest is unsustainable. Log exports from natural forests have been the major export earner for the Solomon Islands since 2000, currently accounting for over two thirds of total exports by value. The current harvest volume is estimated to be four times the sustainable rate. There remains a significant gap in understanding about alternatives for future development of the remaining natural forest and an enhanced plantation forest industry to assure a sustainable economic return from forestry in the future.

Small-scale processing may be competitive in domestic niche markets, but is unlikely to be competitive internationally. There are a number of plantations that have been successfully established on customary land with local community involvement. The support of, and leadership by, the local community has been critical in successful plantation establishment.

Current forest policies do not encourage sustainable management of forest resources. Current policies aimed at reducing natural forest harvesting and attaining sustainability does not offer alternative income-generating options for local landowners. Effective policies need to take account of the diversity in language, culture, geography, government interests and customary systems of land tenure. This study will propose solutions that are consistent with the principles of sustainability, and compatible with the existing customary land tenure system. The main objective of these policies should be to allow fundamental features of customary ownership to remain intact while allowing some new types of land use to occur.

The study approach uses both qualitative and quantitative methods of analysis using national level economic data and a review of literature to identify lessons from the experiences of other comparable Pacific countries faced with similar problems. Strategic analysis was used to identify options for creating a sustainable Solomon Island forestry sector. Plantation forestry was identified as the primary means of improving sustainability, with an assumption that customary land would form a major component of the land required for future forest industry development. The role of increased marketing effort and “value-added” manufacturing were also considered.

Reducing the merchantable volume for natural forest harvest from 60cm dbh so that the amount of wood flow available increases was considered. This will enable higher wood flow from natural forest and maturing plantations to cover the anticipated economic downfall gap. Customary land registration will give greater investment opportunities for large plantation establishment.

DPS price scheduled for quarterly changes occur only infrequently, and therefore may not reflect actual international price changes. It is recommended for that an alternative mechanism be in place to include CIF price changes considered for the DPS. Direct entry of local producers of sawn timber into the export niche markets will give producers opportunities to understand market requirements and maximize revenue.

XIAN, ZHUO (WENDY) (2009)

THE CURRENT SITUATION OF FURNITURE MARKET IN SHANGHAI AND BEIJING

This study was focus on the current situation of Chinese furniture and interior decoration material market. Observation and in-depth interviews were chosen as main research methods to collect the first hand information and data. Beijing and Shanghai were the objectives of this study, and several furniture and decoration material retail stores were visited. 11 experienced sales staffs were picked up from these stores as the responders to undertake the respondent-interviews. Guanrong Xu, the secretary-general of Shanghai Furniture Association and Liying Ma, the section chief of Beijing Furniture Association were interviewed for the informant-interview.

Based on the information gathered from these research methods, it seems there is a big potential market for New Zealand high value products in DIY home improvement materials market and high grade furniture market. Several marketing strategies were discussed in this report.

MSC (ENVIRONMENTAL SCIENCE) THESIS ABSTRACTS

BLOOR, MARCUS (2009)

REVIEW OF CURRENT VEGETATION MONITORING ON PRIVATELY PROTECTED LAND UNDER ONGOING ECONOMIC USE (GRAZING)

There has been a noticeable shift in focus in biodiversity research in New Zealand over recent decades. Research has traditionally focused on biodiversity protection on the public estate, which was comprised primarily of ecosystems with lower productive potential (generally over 500m asl). Private lands generally have higher production potential and are often used for intensive cultivation and agricultural practices. They still however have significant potential for protecting biodiversity values. One of the key tools for protecting biodiversity values on privately owned lands in the Canterbury region are through legally binding QEII open space covenants and there is significant potential through industry certifications.

QEII covenants are placed on the land in perpetuity and provide legally binding protection for biodiversity or landscape values within the covenant. This protection is voluntary and allows the land owner to continue to use the land for economic benefit providing it does not prove detrimental to biodiversity through monitoring outcomes. Case studies of QEII covenants that contain grazing clauses in the Canterbury region were used to determine what values are present and what monitoring is occurring in the field within these ecosystems. Photopoints and informal visual monitoring were the primary methods used by the QEII representatives to monitor vegetation in all of the covenants.

Monitoring forms a critical feedback for all biodiversity protection. It is especially important to have an accurate feedback on vegetation condition and change from monitoring on properties that are grazed. Monitoring needs to be capable of providing sufficient information on vegetation change on these sites so that the most suitable grazing levels can be obtained by land managers. This thesis focuses on monitoring methods to ensure that this feedback is suitable and that the methods are cost effective.

Current vegetation monitoring techniques were reviewed to determine which methods would be most suited to monitoring in these ecosystems where resources are tightly restricted and observers may not have existing skills and experience in monitoring these ecosystems. Methods reviewed were quadrats, transects, height-frequencies, photopoints, needle point, biomass, tagged plants, visual rank and remote sensing. Each method is described and then assessed on its suitability for monitoring tussock shrublands, with cost effectiveness being an important criterion. Of these methods quadrats, transects and height-frequencies were the most robust but also the most intensive and least cost effective methods. Visual rank, needle point and photopoints were the most cost effective, but are generally suited to monitoring single objectives. In most cases a combination of methods would be ideal to suit the objectives of the monitoring. QEII photopoint monitoring should follow guidelines more closely and include more complimentary information with their photographs. Clear monitoring objectives should be developed for every covenant that is grazed and these need to be determined before it is possible to accurately select appropriate monitoring methods. These objectives will also provide the monitoring program with more structure and direction. If possible a detailed management plan for each grazed covenant would be

beneficial for values present. QEII are in a unique position, where they have the potential to develop a database of biodiversity information for private land and contribute to other projects like the National Vegetation Survey (NVS).

DICKINSON, YVETTE L. (2008)

THE SPATIAL PATTERNING OF *HIERACIUM PILOSELLA* INVADED SHORT TUSSOCK GRASSLANDS

Hieracium pilosella is an invasive weed of New Zealand's short tussock grasslands. Since the 1960s, the abundance of *H. pilosella* has dramatically increased; it is now thought to occur in 6 million hectares of New Zealand (Espie, 2001), predominantly in grasslands. It is at least common in 42% of this area (Espie, 2001).

Ecology is inherently spatial and as plants closely interact with their direct neighbours, the spatial arrangement of plants is vital to their functioning. A handful of recently published articles have implicated spatial structure of plant communities in theories of plant competition, resource use and the invasion of plant communities. The aims of this thesis were to: 1) determine if there are consistent spatial patterns in New Zealand's short tussock grasslands at relatively small scales (i.e. spatial relationships between individuals); 2) investigate how the invasion of *H. pilosella* may be altering these spatial patterns; and 3) establish if the spatial patterns of species, life-forms and root systems are being altered in different ways.

Spatial patterns of both tussock and inter-tussock species, life-forms and root functional groups were evaluated at a range of short tussock grassland sites across a gradient of *H. pilosella* invasion levels in Canterbury, using both join-count statistics and Ripley's K-function. A classification system for the root functional groups of vascular species in these communities was developed and applied. It was found that species, life-forms and root functional groups in short tussock grasslands had generally consistent spatial patterns across sites both within and between species. These patterns were variable between significantly different levels of *H. pilosella* ground cover. The type of spatial pattern exhibited, and the way it was altered differed between species, life-form and root functional groups. For example, tussocks exhibited increased regularity up to scale of 160 cm and increasing aggregation at scales up to 500 cm, with increases in *H. pilosella* abundance. In contrast, both *Agrostis capillaris* and herbaceous chamaephytes had increased aggregation across scales up to 160 cm. These differences in spatial patterns along the gradient of invasion are a strong indication that *H. pilosella* is structurally fragmenting New Zealand's short tussock grasslands. This fragmentation is likely to have far reaching effects including the disturbance of invertebrate communities and the disruption of ecosystem services including pollination, vegetation regeneration, and nutrient cycling.

HU, QINGLIN (2006)

TEMPORAL VARIATION AND INTER-RELATIONSHIP OF MOVEMENT AND RESOURCE SELECTION OF RED DEER (*CERVUS ELAPHUS*) WITH RESPECT TO CLIMATE: A CASE STUDY

Red deer (*Cervus elaphus*) is one of at least 31 herbivorous exotic mammals existing in New Zealand. All of these species have the potential to affect environmental and production values. Reducing their impacts on their values, strengthening effective managements are

important issues to a variety of agencies within New Zealand including the Department of Conservation (DOC), Ministry of Agriculture and Forestry (MAF), local and regional governments.

This research studied animal movement pattern and habitat use of 2 GPS-collared red deer in the Canterbury high country and found (1) deer movement was affected by climatic variables such as rainfall and temperature, which had positive or negative effect on it, and had seasonal variation; (2) deer had dominant landcover use categories, depending on climate, season, and individual characteristics; and (3) deer had different movement patterns in terms of hourly distances.

The purpose of the study is to draw accurate inferences from spatially explicit data for biosecurity managers and policy-makers through: (1) using global positioning system (GPS) as a tool to elucidate the application of GPS on red deer in wildlife management; (2) animal movement analysis Arc View® 3.2 Extension under Arc View® Geographic Information System (GIS); and (3) animal movement analysis which used Generalized Additive Models (GAMs) to show how the movement of red deer was affected by different periods of time, seasons, months and climatic variables (for example, rainfall and temperature).

LAGERSTEDT, M. AMY (2007)

***DIDYMOSPHENIA GEMINATA*; AN EXAMPLE OF A BIOSECURITY LEAK IN NEW ZEALAND**

Didymosphenia geminata is a diatom that has been accidentally introduced to New Zealand's South Island rivers. It has grown to bloom conditions in all rivers it inhabits, which has caused impacts to the river systems, loss in recreation value, and economic losses. The pathways and vectors of dispersal are difficult to control and hence it continues to spread throughout the South Island. Laboratory experiments assessed the survivability of *D. geminata* in different environmental conditions, a range of combinations of light availability, temperature and moisture. Experiments in the field were based in the Waitaki River to determine growth rates of *D. geminata*.

D. geminata is growing in a greater range of temperature and light conditions than previously recognised. In cool to cold conditions with a little water this diatom can survive up to 1500h, the colder temperatures also increase survivability in the dark. However, *D. geminata* has reduced survivability in warm, damp conditions, up to 60h. In the Waitaki River *D. geminata* is attaining biomass of 2.51mg mm⁻² over six weeks during summer. This high biomass is causing a change in biotic and abiotic conditions. Longevity of survival and the range of conditions in which it can survive increases the risk of spread throughout New Zealand and the world.

There are considerable problems with invasive species and international trade. Policies aiming to reduce international invasions due to trade are becoming more prevalent as the consequences of invasion are more obvious and costly. New Zealand has been able to implement policies in the last decade that has reduced the number and variety of incursions. However these policies did not stop *D. geminata* arriving. This shows that even with the best policies species can invade fragile ecosystems. Central and local government policies surrounding management of invasive aquatic species were reviewed. Central and local government policies were developed to reduce the spread of *D. geminata*, however they are not effective as the diatom is still dispersing. Further research is required to elucidate means

of dispersal in New Zealand, in particular the importance of dispersal by animals compared with that by humans, and the importance of continuing international dispersal.

SQUIRES (NÉE WOOD), CAROLYN (2007)

AN ASSESSMENT OF TRAMPLING IMPACT ON ALPINE VEGETATION, FIORDLAND AND MOUNT ASPIRING NATIONAL PARKS, NEW ZEALAND

The objectives of this study were two-fold. The first was to quantify the nature and extent of current levels of human impact in alpine areas at four sites within Fiordland and Mount Aspiring National Parks along walking tracks at Key Summit, Gertrude Saddle, Borland Saddle and Sugarloaf Pass. In order to do so, a survey was carried out with transects placed perpendicular to the track, and distributed among different vegetation types. In each transect, plant structural and compositional aspects, and soil and environmental parameters were measured. Transects were divided into track, transition, undisturbed and control zones, and changes to dependent variables were compared with distance from the track centre. Damage from visitor impact was largely restricted to within 1m from the track centre. The most significant impacts were to structural aspects of plant and soil properties with significant reductions in plant height, total vegetation cover and bryophyte cover, and increases in bareground and erosion on tracks. Erosion was more prevalent on slopes greater than 25°, while tracks on peat soils contained greater bareground exposure, particularly of organic soil.

The second study objective was to investigate the relationship between specific levels of impact and the resulting damage to two key alpine vegetation types, tussock herbfield and cushion bog. This was undertaken by carrying out controlled trampling experiments, measuring changes to plant structural and compositional aspects four weeks and one year after treatment. Both vegetation types saw dramatic reductions in total vegetation cover and height immediately after trampling, however overall composition and species richness varied little. These two alpine vegetation types showed moderate-low resistance to initial impact and low resilience, with very little recovery evident one year later.

Research into these two areas is important for managing visitor use within alpine areas in order to meet conservation and recreation goals. The survey indicates that alpine community types are very sensitive to visitor use, showing significant structural damage, however the spatial extent of impact is limited within the broader landscape. Instead, visitor impacts associated with tracks are likely to be more visually and aesthetically significant, influencing the visitor experience. The trampling experiments indicate that use levels over 25-75 passes per year within tussock herbfield and cushion bog vegetation on peat soils will result in ongoing damage to previously undisturbed sites. Methods for minimising impacts include limiting visitor numbers, public education in low impact practices, redirection of tracks and use to areas that are less sensitive, the dispersal of visitor activity at very low use intensities (less than 75 direct passes per year) and the concentration of activity on tracks above this level.