PROGRAMA DE FORMACIÓN PARA
LA INNOVACIÓN AGRARIA
- PARTICIPACIÓN-

INFORME TÉCNICO

	CÓDIGO (uso interno)	FP-V-2002-1-F-37

1.- ANTECEDENTES GENERALES DE LA PROPUESTA

NOMBRE DE LA PROPUESTA

Asistencia a Seminario técnico: "Connection between Forest Resources and Wood Quality: Modelling Approaches and Simulation Software" (Conexión entre los recursos forestales y la calidad de la madera: Modelación y softwares de simulación)

LUGAR DE REALIZACIÓN DE LA ACTIVIDAD

País: Canadá
Ciudad : Harrison Hot Springs Resort (cerca de Vancouver, British Columbia)

TIPO O MODALIDAD DE FORMACIÓN

Seminario Técnico (Workshop)

AREA DE LA ACTIVIDAD

Rubro: Forestal

Tema : Conexión entre recursos forestales y calidad de madera: Modelación y softwares de simulación. (Grupo de trabajo en Mejoramiento biológico de propiedades de la madera)

INSTITUCIÖN O ENTIDAD RESPONSABLE QUE DICTA U ORGANIZA LA ACTIVIDAD DE FORMACIÓN A LA CUAL SE POSTULA

Nombre: IUFRO (International Union of Forest Research Organizations), Working Party S5.01-04 (Forest Products/ Wood Quality/ Connection between forest resources and wood quality : modelling approaches and simulation software.

Unión Internacional de Organizaciones para la Investigación Forestal, Grupo de trabajo Nº 05.01.04 (Productos Forestales / Calidad de Madera / Conexión entre los recursos forestales y la calidad de la madera: modelación y softwares de simulación.

Página Web: http://iufro.boku.ac.at/ (Marcar "Scientific Structure and Divisions" / "Divisions" /"Division 5" / "Division 5.01.04")

POSTULANTE INDIVIDUAL

Nombre: María Paulina Fernández Quiroga
RUT:
Dirección particular: Carlos Sabat 6336, Vitacura
Fono: 2478176
Institución o empresa donde trabaja: Pontifica Universidad Católica de Chile
Facultad de Agronomía e Ingeniería Forestal / Departamento de Ciencias Forestales

Cargo actual y relación contractual : Profesor Auxiliar Asociado / Jornada Completa

Dirección comercial: Av. Vicuña Mackenna 4860
Fono: 6864884 (directo) 6864169 (secretaria)

Fax: 6865982 E-mail: pfernan@puc.cl

Firma

[redacted]

Nombre Entidad Patrocinante:

Pontificia Universidad Católica de Chile
Facultad de Agronomía e Ingeniería Forestal

RUT : 81.698.900-0

Dirección : Alameda 340

Fono : 6862346 Fax : 2225612 E-mail :

Nombre Representante Legal del Patrocinante:

Dr. Carlos Vio Lagos

RUT :

Dirección : Alameda 340

Fono : 6862346 Fax : 2225612

E-mail : gdonosoh@puc.cl

[redacted]

Inicio : 8 de Septiembre de 2002

Término : 15 de Septiembre de 2002

1. **Participantes**: presentación de acuerdo al siguiente cuadro:

Nombre	Institución/Empresa	Cargo/Actividad
M. Paulina Fernández Q.	Departamento de Ciencias Forestales Facultad de Agronomía e Ingeniería Forestal Pontifica Universidad Católica de Chile	Profesor Auxiliar jornada completa

2. Problema a Resolver:

La cada vez creciente competitividad de los mercados forestales, exige un aumento constante de la calidad de los productos madereros. En los mercados internacionales la calidad es un factor fundamental en la diferenciación y calificación de los productos como así también para el acceso a mercados (Ministry of Forestry, New Zealand 1995). Esta calidad se comienza a gestar en el bosque. Debido a esto, la silvicultura o manejo de los bosques a nivel internacional, en los últimos años, se ha concentrado fuertemente en no sólo mejorar el rendimiento de los bosques, sino que la calidad de sus productos. Esto ha llevado a crear una línea de modelación de calidad de madera, de manera de poder optimizar el proceso productivo a través de

- Manejo adecuado del bosque (genético, silvícola) para obtener productos de alta calidad
- Conocimiento adecuado de la calidad potencial de madera existente en el bosque de manera de destinar la madera al mercado o proceso productivo adecuado
- Conocimiento adecuado de la calidad de la materia prima al momento de entrar al proceso de conversión (planta de aserrío, de debobinado, por ejemplo) de manera de aprovechar al máximo las potencialidades que esa materia prima ofrece dentro del proceso de conversión

En Chile el desarrollo de modelos ha ido más bien orientado a modelos de crecimiento y volumen de madera, como el Simulador Radiata Plus, que ha apoyado fuertemente la gestión forestal. En el último tiempo el tema calidad, debido a los requerimientos cada vez mayores de la industria y mercados internacionales, ha tomado más fuerza. En la Pontificia Universidad Católica de Chile se está desarrollando esta línea de investigación a través de dos áreas: desarrollo de modelos funcionales y estructurales de crecimiento relacionados con calidad de madera y desarrollo de herramientas de análisis no destructivo de calidad de madera a través de Resonancia Magnética. Esto se está haciendo en conjunto entre el Departamento de Ciencias Forestales y el Departamento de Ingeniería Eléctrica.

Con la participación en el Seminario Técnico se buscó mostrar a un grupo internacional selecto de investigadores en modelación de silvicultura y calidad de madera los avances logrados en Chile, y por otra parte recoger de la presentación y discusión de los distintos trabajos a ser expuestos en el Seminario técnico, los últimos adelantos en materia de modelación de calidad de madera y su relación con el bosque y la industria, las tendencias a futuro, generar contactos para el desarrollo de nuevas líneas y grupos de investigación, entre otros. El Seminario técnico se convierte por lo tanto en una valiosa oportunidad de formación y actualización, que permitirá a este grupo de investigación potenciar y orientar su investigación para el desarrollo de tecnologías de vanguardia en el sector productivo forestal y encontrar nuevas aplicaciones a los desarrollos en curso.

3. Objetivos de la Propuesta

Objetivos Generales:

1.Presentar y discutir las experiencias del equipo de investigadores chilenos en reconocimiento no destructivo de características de la madera y su modelación a través de Resonancia Nuclear Magnética ante la comunidad científica internacional

2.Incorporar nuevas ideas y enfoques a los desarrollos obtenidos por el equipo de investigadores a través de la experiencia y discusión con otros científicos

Objetivos Específicos:

1 Posicionar la investigación de vanguardia realizada en Chile en la comunidad científica internacional a través de la presentación de resultados en el Seminario técnico

2 Crear lazos con investigadores trabajando en la misma área de manera de acelerar el logro de resultados, a través del intercambio de información y experiencias

3 Promover el uso de los futuros desarrollos obtenidos en Chile a nivel internacional

4 Aprovechar las experiencias desarrolladas por la comunidad internacional en el desarrollo de nuevas herramientas basadas en esta tecnología u otras similares

5 Difundir en la comunidad nacional los avances logrados por el grupo de investigación chileno y los avances en el extranjero en el área de modelación de calidad de madera y relaciones con el recurso forestal y la producción industrial

4. Antecedentes Generales: describir si se lograron adquirir los conocimientos y/o experiencias en la actividad en la cual se participó (no más de 2 páginas).

El Seminario Técnico consistió en 25 posters y 47 presentaciones orales (se adjuntan los resúmenes) sobre modelación de calidad de madera a través de modelación de ramificaciones, de densidad de la madera, de problemas de madera de tensión y compresión, madera juvenil, distribución de biomasa de acuerdo a condiciones de competencia, entre otros, todos modelos relacionados con el efecto del origen genético, o el manejo y/o el sitio. Un elemento importante es que la mayoría de las modelaciones están siendo realizadas en tres dimensiones, de manera de poder modelar las condiciones de las trozas que se pueden obtener del bosque. Luego estas trozas virtuales son analizadas a través de simuladores de aserrío o debobinado, con lo cual se valoriza la madera a partir de los productos que realmente se podrían obtener de ellas. Esta forma de evaluación de la calidad de la madera es la predominante en este momento a nivel mundial. El Seminario Técnico sirvió para poder analizar distintas formas de modelación, discutir las técnicas más eficientes con los especialistas y establecer contactos para desarrollar más ciertos puntos en conjunto con investigadores extranjeros. Se recibieron ofertas de cooperación y de uso de softwares de aserrío ya desarrollados en otras partes, para poder evaluar nuestros modelos.

La diversidad de técnicas empleadas por los distintos investigadores para resolver problemas similares, permitió detectar aquellas herramientas más promisorias para modelación de calidad, de manera de avanzar más rápidamente en esta área acá en Chile.

Por otra parte se presentaron en el seminario una serie de trabajos relacionados con la integración de modelos para ir creando sistemas de apoyo a la gestión que consideren información tradicional de inventarios forestales y respondan a las preguntas asociadas a procesos productivos forestales.

Esto permitió visualizar el tipo de información que es necesaria que generen los modelos que desarrollemos, de manera que se convierta realmente en instrumentos de apoyo a la gestión.

Se presentó una tercera línea de investigación correspondiente a la detección no destructiva de características de la madera para uso industrial (CT-Scanner, Resonancia Magnética). En este ámbito se presentaron metodologías para lograr adquisición más rápida de información, y desarrollo de algoritmos para detección de defectos en la madera con miras a su uso industrial. En este aspecto el seminario fue muy positivo, porque permitió contactarse con las personas que está n desarrollando estos sistemas para CT-Scanner pero que son trasladables a Resonancia Magnética (el sistema usado por la P. Universidad Católica). Sirvió para discutir con los expertos desventajas y ventajas de cada método, y surgió la idea de crear un grupo de trabajo internacional en torno a detección no destructiva de características de la madera y construcción de imágenes. Desde el seminario hasta ahora se ha intercambiado información vía e-mail. Forintek (Instituto Forestal Canadiense de Tecnología de la Madera) y la Universidad de Laval en Quebec, en un proyecto conjunto, nos han solicitado a la P. Universidad Católica les enviemos algún investigador joven interesado en hacer un Doctorado, en procesamiento de imágenes de CT-Scanner. Esto debido a las potencialidades que detectaron en nosotros a través de nuestro trabajo. En este momento se están detectando posibles interesados de la Facultad de Ingeniería. Con esto se lograría un lazo concreto de cooperación con estas instituciones canadienses.

5. **Itinerario Realizado**: presentación de acuerdo al siguiente cuadro:

Fecha	Actividad	Objetivo	Lugar
9 y 10 de Sept.	Presentaciones orales y de posters	Compartir resultados científicos	Harrison Hot Springs Resort
11 de Sept.	Visita a UBC Malcolm Knapp Research Forest	Visitar ensayos de espaciamiento en Pino Oregón, Thuja spp. y Larix spp. Visitar un aserradero portátil de uso para investigación	University of British Columbia
	Visita UBC Centre for Advanced Wood Processing	Visitar el centro más avanzado de Canadá para formación de ingenieros y técnicos en el área de industrias de la madera.	
	Visita a Forintek, Canada Corp.	Visitar el Instituto de Investigación en tecnología de la Madera, para conocer sus líneas de investigación e instalaciones. Notable es la instalación recién hecha de un CT-Scanner especialmente diseñado para análisis de árboles	
12 y 13 de Sept.	Presentaciones orales y de posters	Compartir resultados científicos	Harrison Hot Springs Resort

Señalar las razones por las cuales algunas de las actividades programadas no se realizaron o se modificaron.

Todas las actividades programadas fueron realizadas.

6. Resultados Obtenidos: descripción detallada de los conocimientos adquiridos. Explicar el grado de cumplimiento de los objetivos propuestos, de acuerdo a los resultados obtenidos. Incorporar en este punto fotografías relevantes que contribuyan a describir las actividades realizadas.

Objetivo Específico 1: Posicionar la investigación de vanguardia realizada en Chile en la comunidad científica internacional a través de la presentación de resultados en el Seminario técnico

El objetivo fue plenamente logrado. La presentación fue ampliamente discutida durante el seminario pues llamó la atención la aplicación de Resonancia Magnética en madera, lo novedoso del tema, las posibles aplicaciones y proyecciones de la técnica. Trascendió a otros investigadores que no participaron en el seminario técnico y que se han contactado con nosotros para ver posibilidades de investigación conjunta, intercambio de información, etc.

Objetivo Específico 2: Crear lazos con investigadores trabajando en la misma área de manera de acelerar el logro de resultados, a través del intercambio de información y experiencias

Este objetivo fue plenamente logrado.

Se detectaron en el seminario tres grupos de investigación trabajando en el tema de detección no destructiva de características de la madera. Los tres grupos trabajan con CT-Scanner (Rayos X). El único grupo trabajando con Resonancia Magnética es el grupo de la Católica. Se le propuso a la Católica el formar un grupo de discusión internacional del tema de detección y modelación de características de la madera en CT-Scanner/MRI, ya que en las discusiones técnicas se concluyó que MRI tiene un gran potencial, y podría convertirse en la tecnología de competencia para el CT-Scanner. Los grupos identificados son FORINTEK Vancouver, FORINTEK-Universidad de Laval, Quebec, y Universidad de Lulea en Suecia.

Se tomó contacto con investigadores de VTT, Finlandia, centro de investigación tecnológica que ha desarrollado un simulador tridimensional de aserrío y debobinado optimizado de trozas de madera. El director de esta línea de investigación, Dr. Arto Usenius, ofreció a la Católica el uso para fines de investigación de su software WOODSIM@ de manera de procesar a través de él los resultados obtenidos con los modelos generados a partir de imágenes del resonador. Con esto se puede validar la propuesta de que el uso de Resonancia Magnética permitiría integrar información del interior de la troza a sistemas productivos.

Además, se tomó contacto con una variedad de investigadores trabajando en modelación de calidad de madera en el bosque, tema que la autora está trabajando a través de análisis arquitectural y modelación de calidad de madera. Por lo tanto se consolidaron contactos con investigadores de esa área.

Objetivo Específico 3: Promover el uso de los futuros desarrollos obtenidos en Chile a nivel internacional

Este objetivo fue plenamente logrado.

Se ha recibido solicitud del grupo de investigación de Lulea, Suecia, para usar el resonador y capacidad científica nuestra para un proyecto que ellos mantienen con el Instituto Forestal de Concepción, en el uso de CT-Scanner. Esto significa que a pesar de que su línea de investigación es en CT-Scanning, reconocen en Resonancia Magnética un gran potencial que los ha entusiasmado a incursionar en la técnica.

Objetivo Específico 4 Aprovechar las experiencias desarrolladas por la comunidad internacional en el desarrollo de nuevas herramientas basadas en esta tecnología u otras similares

Objetivo logrado.

Se intercambió y discutió ampliamente metodologías y técnicas con las personas relacionadas con el tema. Esto ya nos ha permitido fortalecer con ideas nuevas los próximos pasos a seguir en investigación en Resonancia Magnética y madera. Se ha mantenido contacto por e-mail e intercambio de información vía este medio.

Objetivo Específico 5 Difundir en la comunidad nacional los avances logrados por el grupo de investigación chileno y los avances en el extranjero en el área de modelación de calidad de madera y relaciones con el recurso forestal y la producción industrial

Objetivo plenamente logrado.

Este punto se discute en detalle en el informe de difusión.

7. **Aplicabilidad**: explicar la situación actual del rubro en Chile (región), compararla con la tendencias y perspectivas en el país (región) visitado y explicar la posible incorporación de los conocimientos adquiridos, en el corto, mediano o largo plazo, los procesos de adaptación necesarios, las zonas potenciales y los apoyos tanto técnicos como financieros necesarios para hacer posible su incorporación en nuestro país (región).

Actualmente los aserraderos y plantas de debobinado no cuentan con tecnología que permita visualizar el interior de las trozas antes de entra al proceso productivo de manera de optimizar su utilización. A nivel mundial se reconoce que la integración de este tipo de tecnología a los procesos industriales forestales aumentaría considerablemente el rendimiento económico de la materia prima el proceso productivo primario (aserrío o debobinado). De las discusiones sostenidas durante el seminario técnico se desprende que es un objetivo prioritario desarrollar este tipo de tecnología, y que el uso de Resonancia Magnética tendría muchas posibilidades. Sin embargo se necesita aún bastante investigación. Durante el seminario se determinó que avances hechos en tecnología CT-Scanner, a pesar de ser una tecnología distinta, sirven de base para el desarrollo de tecnología en resonancia magnética para madera. Por lo tanto resultados observables en el seminario son transferibles ya a la investigación en curso en Chile. Se trata de tecnología que en el mediano plazo podría ser traspasable a la industria, probablemente con una fuerte inversión inicial en investigación. Se están explorando en este momento alianzas estratégicas para llevar a cabo esa investigación.

En el seminario se presentaron también gran cantidad de trabajos en torno a modelación de calidad de madera a partir del recurso bosque. En Chile ha predominado la modelación de los volúmenes a obtener del bosque con muy pocas variables de calidad. En el seminario se presentaron las principales tendencias en modelación de calidad, algunas de las cuales escasamente se han considerado en Chile, como modelación tridimensional, o funcional-estructural. Los conocimientos adquiridos durante el seminario son absolutamente traspasables a la investigación chilena, para mejorar nuestra capacidad de modelación y manejo del recurso forestal.

8. Contactos Establecidos: presentación de acuerdo al siguiente cuadro:

Se presentan aquellos contactos más relevantes en términos de posibilidades de cooperación futura

Institución/Empresa	Persona de Contacto	Cargo/Actividad	Fono/Fax	Dirección	E-mail
Forintek Canada Corp. (Vancouver)	Sencer Alkan	Investigador	604-222-5684	2665 East Mall Vancouver BC, Canada V6T 1W5	alkan@van.forintek.ca
Forintek Canada Corp. (Quebec)	Tony Zhang	Investigador			
Universite Laval Dep. Des Sciences du Bois et de la Foret Pavillon Abitibi-Price	Robert Beauregard	Investigador	418-656-7684	Universite Laval QB, Canada G1K 7P4	Robert.Beauregard@sbf.ulaval.ca
Institut für Forstbenutzung und Forst. Albert Ludwig Universität Freiburg	Gero Becker	Decano Facultad Forestal	49-761-203-3764	Werderring 6 79085 Freiburg, Alemania	fobawi@uni-freiburg.de
New Zealand Forest Research Institute	Dave Cown	Investigador	64-7-343-5525	Private Bag 3020, Rotorua, New Zealand	Dave.cown@forestresearch.co.nz
Warnell School of Forest Resources University of Georgia	Richard Daniels	Investigador	706-542-7298	Athens GA, 30602	ddaniels@uga.edu
BC Ministry of Forests Research Branch	Mario Di Lucca	Investigador	250-387-6679	PO Box 9519 Stn. Prov. Govt. Victoria BC, Canada V8W 1L4	Mario.dilucca@gems4.gov.bc.ca
Oregon State University Dept. of Wood Science and Engr.	James Funck	Investigador	541-737-4207	119 Richardson Hall Corvallis OR, 97331-5751 USA	Jim.Funck@orst.edu
Oregon State University Dept. of Forest Science	Douglas Maguire	Investigador	541-737-4215	119 Richardson Hall Corvallis OR, 97331-5751 USA	Doug.maguire@orst.edu
Lulea University of Technology Skelleftea campus	Johan Oja	Investigador	46-0910-585307	Skeria 3 Skelleftea, Sweden S-93187	Johan.oja@luth.se
Lulea University of Technology	Anders Grönlund	Investigador	46-0910-585307	Skeria 3 Skelleftea,	Anders.gronlund@tt.luth

Skelleftea Campus				Sweden S-93187	.se
University of Helsinki Department of Forest Ecology	Annikki Makela	Investigadora	358-9-191-58108	PO Box 27 (Latokartanonkaari 7) Finland	Annikki.makela@helsinki.fi
INRA Unité de Recherches Forestieres Equipe Croissance et Production	Celine Méredieu	Investigadora	33-5-57-122861	BP 45 Cestas Gazinet France 33611	Celine.meredieu@pierroton.inra.fr
VTT Technical Res. Centre of Finland	Arto Usenius	Director de Investigación	358-9-456-5540	PO Box 1806 VTT, Finland FIN-02044	Arto.usenius@vtt.fi
Equipe Qualite du Bois du Lerfob Centre Inra du Nancy	Gerard Nepveu	Director de investigación	33-3-83-394061	Cahmpenoux, France 54280	nepveu@nancy.inra.fr

9. **Detección de nuevas oportunidades y aspectos que quedan por abordar**: señalar aquellas iniciativas detectadas en la actividad de formación, que significan un aporte para el rubro en el marco de los objetivos de la propuesta, como por ejemplo la posibilidad de realizar nuevos cursos, participar en ferias y establecer posibles contactos o convenios. Indicar además, en función de los resultados obtenidos, los aspectos y vacíos tecnológicos que aún quedan por abordar para la modernización del rubro.

De todas las personas contactadas durante el seminario se nombraron las anteriores debido a que con todas ellas se discutieron posibilidades de cooperación, algunas de las cuales se están actualmente concretando:

- Sencer Alkan, Forintek, Vancouver, Canada: Trabajan en el uso de CT-Scanner para detección de defectos en la madera. Se ha propuesto un grupo de cooperación internacional con la Pontificia Universidad Católica para desarrollar en conjunto el tema de detección no destructiva y modelación de madera.

- Tony Zhang, Forintek, Quebec, Canada: Trabajan en el uso de CT-Scanner para detección no destructiva de defectos y modelación. Como forma de comenzar una cooperación concreta con Chile se ha solicitado se envíe un investigador joven a realizar su doctorado en uso de CT-Scanner para análisis de madera, a la Universidad de Laval, en un proyecto de Forintek-Universidad de Laval que dirige el Dr. Zhang. En este momento se está en proceso de búsqueda y selección.

- Robert Beauregard, Universidad de Laval, Quebec, Canada: Trabajan en conjunto con Forintek en tecnología CT-Scanner. Se espera establecer en el corto plazo acciones concretas de cooperación con su equipo de trabajo, quienes ya trabajan con la Universidad del Bio-Bio y manifestaron mucho interés en establecer además lazos con la Pontificia Universidad Católica. Ya existe un convenio de cooperación entre la Pontificia Universidad Católica y la Universidad de Laval que facilitará comenzar a trabajar en conjunto.

- Gero Becker, Decano Facultad de Ciencias Forestales, Albert Ludwig Universität, Freiburg, Alemania: el Dr. Becker propuso el establecimiento de canales de cooperación concretos con la Pontificia Universidad Católica. La Universidad de Freiburg mantiene contacto con la Universidad Austral y quisieran ampliar sus actividades con Chile a través de la Universidad Católica.

- Dave Cown, New Zealand Forest Research Institute, Nueva Zelandia: El Dr. Cown se ha dedicado desde hace 30 años a la investigación características y calidad de madera. En Chile ha realizado algunas asesorías a importantes industrias forestales. Propuso la posibilidad de establecer un proyecto de investigación con la Pontifica Universidad Católica.

- Richard Daniels, Warnell School of Forest Research, Universidad de Georgia, USA: tras el seminario se estrechó el contacto con el Dr. Daniels y su grupo de trabajo, en forma concreta a través de un proyecto de investigación que se establecerá en el corto plazo entre los investigadores de la PUC, del la Universidad de Georgia y Bioforest.

- Johan Oja y Anders Grönlund, Universidad de Lulea, Skelleftea, Suecia: Este grupo de investigación corresponde a uno de los grupos más destacados en investigación de CT-Scanner. Se ha mantenido el contacto tras el seminario, y han solicitado cooperación de nosotros en un proyecto que mantienen en este momento con el Instituto Forestal de Concepción.

- Annikki Mäkelä, Departamento de Ecología Forestal, Universidad de Helsinki, Finlandia: La Dr. Mäkelä es una de las más destacadas investigadoras en el área de modelos funcionales-estructurales de plantas. Ha solicitado a la PUC cooperación en análisis de madera en proyectos que están en curso. En forma concreta enviarán dentro de este mes un set de muestras de madera de *Pinus sylvestris* para que el equipo de la PUC las analice en el resonador. Con esto se explorarán también vías de cooperación futuras. Esta solicitud por parte de la Universidad de Helsinki valida aún más el uso y potencialidad de esta técnica como desarrollo industrial y para uso en investigación.

- Celine Meredieu, INRA Unité de Recherches Forestieres, Equipe Croissance et Production, Francia: La Dr. Meredieu ha trabajado desde hace años en modelación de arquitectura de plantas e integración de modelos a sistemas forestales. Tiene especial experiencia con coníferas. Se ha establecido un estrecho contacto para intercambio de información, dado que la que suscribe está en este momento trabajando en modelación de arquitectura y calidad de madera en Pino radiata.

- Arto Usenius, VTT Technical Res. Centre of Finland, Finlandia: El Dr. Arto Usenius ha liderado en su institución el desarrollo de un optimizador de debobinado y aserrío virtual, como herramienta de toma de decisiones en procesos productivos. Estos simuladores pueden recibir información proveniente de modelos o en el futuro proveniente de sist4emas de detección no destructiva tridimensional de características de la madera. El Dr. Usenius, interesado por los adelantos realizados en la Católica, ha ofrecido la licencia de sus softwares, para ser ocupados con los datos provenientes de los análisis hechos con el resonador. Con esto se explorará el desarrollo de salidas de información desde el resonador compatibles con este tipo de softwares, para futuras aplicaciones industriales. Se espera en un futuro cercano comenzar una cooperación formal.

10. Resultados adicionales: capacidades adquiridas por el grupo o entidad responsable, como por ejemplo, formación de una organización, incorporación (compra) de alguna maquinaria, desarrollo de un proyecto, firma de un convenio, etc.

Se puede concluir en forma global que la participación en el seminario ha abierto variados contactos desde donde se espera construir una plataforma más amplia para seguir desarrollando esta línea de investigación, así como otras nuevas. Se detectaron varios grupos de investigadores extranjeros ya trabajando con entidades chilenas, que solicitaron la posibilidad de incorporar a la PUC. Esto permitiría a nivel nacional acrecentar nuestras capacidades de desarrollos tecnológicos.

Como resultados adicionales se puede indicar que a raíz de comentarios que recibieron desde USA investigadores de Bioforest (Grupo Arauco), respecto a las investigaciones presentadas por la PUC, Bioforest ha solicitado establecer proyectos de investigación en el campo de análisis de calidad de madera con tecnologías nuevas. Estos proyectos ya están en etapa de desarrollo de los anteproyectos.

Se puede añadir que hubo un reconocimiento especial durante el seminario por el trabajo realizado en Chile, debido a que fue catalogado de alta tecnología y avanzada a nivel internacional. Debido a esto se generaron acercamientos por parte de entidades extranjeras solicitando posibilidades de cooperación con Chile. Como ejemplo de esto, en Marzo hay un congreso sobre productos forestales en Nueva Zelandia y el organizador, Thomas Maness, ha solicitado expresamente que la PUC presente sus adelantos en Resonancia Magnética. Lamentablemente no se tiene claro el poder participar por falta de disponibilidad de fondos.

A raíz de los positivos resultados obtenidos durante el seminario y las actividades de difusión en Santiago y Concepción, el grupo de la PUC está reestructurando su línea de investigación con nuevas estrategias y posibilidades de alianzas estratégicas.

11. Material Recopilado: junto con el informe técnico se debe entregar un set de todo el material recopilado durante la actividad de formación (escrito y audiovisual) ordenado de acuerdo al cuadro que se presenta a continuación (deben señalarse aquí las fotografías incorporadas en el punto 4):

Tipo de Material	N° Correlativo (si es necesario)	Caracterización (título)
Resúmenes de los trabajos presentados	1	IUFRO WP S5.01-04 Fourth Workshop Connection between forest resources and Word quality: Modelling approaches and simulation softwares"
Prospecto del Centro de Procesamiento Avanzado de la Madera, British Columbia	2	Centre for Advanced Word Processong. Research, technology transfer and education for Canada's Word processing industry
Prospecto visita a Forintek Canada Corp.	3	Forintek Canada Corp., Creating Technological solutions to meet members needs – adding value from forest to market
Prospecto Malcolm Knapp Research Forest	4	Malcolm Knapp Research Forest, The University of British Columbia

12. Aspectos Administrativos

12.1. Organización previa a la actividad de formación

a. Conformación del grupo
Fue una propuesta individual

____ muy dificultosa ____ sin problemas ____ algunas dificultades

(Indicar los motivos en caso de dificultades)

b. Apoyo de la Entidad Responsable

___ bueno X regular ____ malo

Habría sido deseable algo más de apoyo económico por parte de la entidad responsable.

(Justificar)

c. Información recibida durante la actividad de formación

____ amplia y detalladaX aceptable ____ deficiente

La información detallada (los Proceedings con los artículos y posters completos) llegará a fines de año, por lo que en definitiva se contará con muy buena información, aunque no inmediatamente.

d. Trámites de viaje (visa, pasajes, otros)

____ bueno ____ regular X malo

Por problemas de mala información en la agencia de viajes, no se tomó visa para USA (a pesar de ser tránsito en Los Angeles era necesario visa) por lo que se tuvo que incurrir en gastos extras durante el viaje, pagando un servicio especial para hacer tránsito sin visa en LA Airtport.

e. Recomendaciones (señalar aquellas recomendaciones que puedan aportar a mejorar los aspectos administrativos antes indicados)

12.2. Organización durante la actividad (indicar con cruces)

Ítem	Bueno	Regular	Malo
Recepción en país o región de destino	X		
Transporte aeropuerto/hotel y viceversa		X	
Reserva en hoteles	X		
Cumplimiento del programa y horarios	X		

En caso de existir un ítem Malo o Regular, señalar los problemas enfrentados durante el desarrollo de la actividad de formación, la forma como fueron abordados y las sugerencias que puedan aportar a mejorar los aspectos organizacionales de las actividades de formación a futuro.

A pesar de que los costos de inscripción incluían el viaje del aeropuerto en Vancouver a Harrison Hot Springs y viceversa, la hora muy temprana de mi vuelo respecto al de los otros participantes me obligó a tomar en forma particular un transfer desde el Hotel a Vancouver (alrededor de 100 km) debiendo pagar en forma particular.

13. Conclusiones Finales

Como conclusiones finales se puede indicar que la participación en el seminario técnico cumplió ampliamente con las expectativas y objetivos planteados.

Realmente el grupo de expositores que participaron corresponde a los que están haciendo investigación de avanzada en estos temas, por lo tanto se recibió información de muy buena calidad. Además el contacto personal con los investigadores permitirá mantener discusiones más fluidas por correo electrónico de distintos tópicos, cuando sea necesario.

Por otra parte, el trabajo presentado por la Pontificia Universidad Católica de Chile despertó mucho interés en la comunidad científica, lo que originó con facilidad el intercambio de información, acercamiento de distintos grupos de investigación y propuestas de cooperación. Sólo desde ese punto de vista se puede considerar la propuesta como exitosa, pues permitió posicionar nuestra investigación en el extranjero, y generar canales de comunicación y cooperación que nos permitirán potenciar aún más el trabajo logrado y generar nuevos proyectos en torno al tema. De hecho ya se están concretando algunas propuestas.

Fecha: 24 de Noviembre de 2002

Nombre y Firma coordinador de la ejecución: ______________________

ANEXO 1

IUFRO WP S5.01-04

FOURTH WORKSHOP

Connection between Forest Resources and Wood Quality: Modelling Approaches and Simulation Software

Harrison Hot Springs
British Columbia, Canada
September 8-15, 2002

THE WORKSHOP IS SPONSORED BY
BRITISH COLUMBIA MINISTRY OF FORESTS
US FOREST SERVICE, PACIFIC NORTHWEST RESEARCH STATION

CONTENTS

WELCOME LETTER

Dear Workshop Participant,

Welcome to Harrison!
Welcome to the Fourth Workshop
"Connection between Silviculture and Wood Quality through Modelling Approaches and Simulation Software"

Workshop information
In the following pages you will find most of the information (updated on August 30) you will need during the week:

- a summary of the scientific and social programme. You will be notified during the sessions if there are any changes in the programme or time schedule.
- the scientific programme and time schedule;
- one-page summaries of each of the 49 oral communications;
- one-page summaries of each of the 26 poster presentations;
- the name and address of each participant.

Assistance for participants and accompanying persons
If you need assistance during the week, Judy Mikowski and Mario Dilucca will be available to help you. In addition, Lana and Nathan Goudie will be available through Tuesday. Barb Young will assist with computer applications. All will be wearing green tree stickers on their name tags to help you recognize them.

Contacting participants during the workshop
Messages for workshop participants can be left at the following numbers:

1. Harrison Hot Springs Conference Centre: 604-796-2244, please identify person as a IUFRO conference participant.
2. Email: info@harrisonresort.com

Some important reminders:

- If you have not yet submitted a copy of your paper for the Proceedings, please do it as soon as possible. Barb is waiting impatiently for it. Please furnish a hard copy as well as an electronic version;
- A group photo will be taken on Monday at 1:15 pm. The meeting point will be announced. Please make sure that you are there, otherwise you will have no proof that you participated in the Fourth Workshop;
- Judy and Lana are coordinating the Program for Accompanying Persons.

We wish you an enjoyable stay at Harrison Hot Springs!
It will be a great pleasure for us to take care of you this entire week!

JIM GOUDIE and EINE LOWELL
IUFRO Working Party S5.01-.04
September 8-15, 2002

THE SOCIAL AND SCIENTIFIC PROGRAM (IN SHORT)

General arrangements:

Sunday registration: Cascade Foyer

Tickets: 2 Host drink tickets per person per day, voucher for Lakeside Café breakfast

Date	*Breakfast*	*Lunch*	*Dinner*
Sunday			**East Forum** 7:15
Monday	**East Forum** 7:00 – 7:45	**East Forum** 12:00 - 1:30	**East Forum** 6:30 (Bar open at 6:00)
Tuesday	**East Forum** 7:00 – 7:45	**East Forum** 12:00 - 1:30	**Copper Room** 6:30 (Bar open at 6:00)
Wednesday	**East Forum** 6:00 - 6:45	**Box**	**Cascade Rainbow** 8:00 (Bar at 7:00)
Thursday	**Lakeside Café** 7:00 – 7:45	**Copper** 12:30-2:00	**Cascade Rainbow** 6:30 (Bar open at 6:00)
Friday	**Lakeside Café** 7:00 – 7:45	**Copper** 12:00-1:30	**Cascade Rainbow** 6:30 (Bar open at 6:00)
Saturday	**East Forum** 6:00 - 7:15	**Box**	**Copper Room Patio (BBQ)** 7:00 (Bar open at 6:00)
Sunday	**East Forum** 6:00 - 8:00		

Date	*Description*
Sunday (8 September)	4:00-6:00 Registration in Cascade Foyer 4:00- 6:00 Reception in Cascade Rainbow 6:00 – 7:00 Self guided sand castles tour (on lake shore beach)
Monday (9 September)	8:15 – 12:00 Workshops Cascade Room 1:30 - 5:00 Workshops Cascade Room
Tuesday (10 September)	8:00 – 12:00 Workshops Cascade Room 1:30 - 2:50 Workshops Cascade Room 2:50 – 5:00 Afternoon break and Posters Rainbow Room
Wednesday (11 September)	7:00 – 3:00 Field trip UBC Research Forest, lunch at UBC, UBC Center for Advanced Wood Processing 3:00 – 5:15 FORINTEX Return to Harrison about 7:00 pm
Thursday (12 September)	8:00 – 11:00 Workshops Cascade Room 11:00 – 12:30 Posters Rainbow Room 1:30 - 5:00 Workshops Cascade Room
Friday (13 September)	8:00 – 12:00 Workshops Cascade Room 1:30 - 4:15 Workshops Cascade Room
Saturday (14 September)	White Water Rafting Excursion (7:30 am departure) Whale Watching Excursion (7:15 am departure) Return to Harrison about 5:00 pm
Sunday (15 September)	**Buses depart at 7:30 am for Vancouver airport**

(in case of change of the time schedule you will be informed during the sessions)

THE SCIENTIFIC PROGRAM AND TIME SCHEDULE

Duration of each oral communication: **15 minutes** – Comments and questions: **5 minutes**

Duration of each poster introduction in conference room: **4 minutes – No comment, no question allowed; no more than 2-3 overheads.**

Poster exhibitors will have more time to develop their ideas during poster session themselves on Tuesday 2:50-5:00 and on Thursday 11:00 to 12:30.

The name of the speaker is *underlined*

MONDAY, SEPTEMBER 9

- 8:00 – 8:10 Housekeeping
- 8:10 – 8:20 Welcome: Jim Goudie and Eini Lowell
- 8:20 – 8:30 Welcome: Gerard Nepveu
- 8:30 – 9:30

Posters
Moderator: Eini Lowell, United States

Charlie Cartwright	Genetic selection for wood and fibre traits in western Hemlock progenies
Anu Kantola	Impacts of size and competition on the distribution of aboveground biomass and wood quality characteristics in Norway spruce (*Picea abies*)
Alexander Clark	Modeling the effect of physiographic region on wood properties of planted Loblolly pine in the southern United States
Franka Brüchert	The spatial distribution of compression wood in Sitka spruce: preliminary results on the effect of wind exposure and silvicultural treatment on timber quality
Renaud Daquitaine	A new functionality of the Win-Epifn software: The simulation of the compression wood occurrence in the stems of standing trees
Holger Wernsdörfer	Statistical models to predict resin pockets in stems of Norway spruce

Shengquan Liu	Modeling wood properties in relation to cambium age and growth rate in Plantation Poplar in China
Henrik Heräjärvi	Modelling of internal knot characteristics of mature Finnish *Betula pendula* and *Betula pubescens*

- 9:30 – 10:10

Oral presentations
Moderator: Olav Høibø, Norway

Kevin Harding	Modelling juvenile wood quality in *Pinus* plantations: critical limits for wood properties needed to select clones with superior stiffness for structural timber
Charles Sorensson	Wood stiffness patterns in age-10 clones of New Zealand Radiata pine

- 10:10 – 10:40 Coffee break

- 10:40 – 12:00

Oral presentations
Moderator: Jim Goudie, Canada

Sven-Olaf Lundqvist	A system of models for fiber properties in Norway spruce and Scots pine and tools for simulation
Ute Seeling	Modelling red heartwood in Beech (*Fagus sylvatica* L.)
Miguel Badia	Modelling the presence of tension wood in a Poplar stem based on 3D growth ring distribution

- 12:00 – 1:30 Lunch

➢ 1:30 – 2:30

Posters
Moderator: Eric Turnblom, United States

Johan Oja	Detecting knots in logs using a simulated X-ray cone-beam scanner
Anders Grönlund	Modelling spiral grain in saw logs based on data from a simulated X-ray LogScanner
Sencer Alkan	Internal log defect model using CT-images
Karin Sandberg	Influences of growth site on different wood properties in Spruce sap-/heartwood using CT-scanner measurements
Mats Nylinder	Modelling compression wood in Norway spruce using data from a 3D-laser scanner
Robert Beauregard	Modelling of component recovery potential and analysis of incidence of defects in White birch (*Betula papyrifera*)
Kana Yamashita	Effects of microfibril angle and density on variation of MOE of Cryptomeria japonica logs among cultivars
Nico Mönnig	Modelling log yields by round wood product in one-centimetre diameter intervals as well as by log quality criteria

➢ 2:30 – 3:10

Oral presentations
Moderator: Richard Daniels, United States

Gero Becker	Growth stresses in Beech: occurrence, modeling and prediction on the base of stand and tree parameters - consequences for processing, log and product quality

	Leif Nutto	Growth rate and growth stresses in Brazilian eucalypts: preliminary results of growth and quality modeling on a individual tree basis

- 3:10 – 3:40 Coffee break
- 3:40 – 5:00

Oral presentations
Moderator: Dave Briggs, United States

Lars Wilhelmsson	A system of models for operative prediction of wood properties in Norway spruce and Scots pine
Richard Daniels	Predicting wood properties of planted Loblolly pine from pith to bark and stump to tip
Barry Gardiner	A timber quality model for Sitka spruce
Paulina Fernández	3D Internal tree structure modeling using Magnetic Resonance Imaging (MRI)

- 6:30 Dinner

TUESDAY, SEPTEMBER 10

- 8:00 – 8:10 Housekeeping
- 8:10 – 9:50 **Oral presentations**
  Moderator: Gerard Nepveu, France

Harri Mäkinen	Predicting branch properties of Silver birch (*Betula pendula* Roth.) from simple stand and tree properties
Olav Høibø	Vertical profile of branch and knot sizes in young coastal US Douglas-fir trees from plantations
Dave Briggs	Relationship between branch diameter growth and stem growth in young coastal US Douglas-fir
Meng Zhan Kang	Fast algorithm calculating trunk and branch ring widths in tree architecture
Annikki Mäkelä	Prediction of 3D stem structure from simple sample tree measurements using empirical models and the PipeQual simulator

- 9:50 – 10:20 Coffee break
- 10:20 – 11:00 **Oral presentations**
  Moderator: Annikki Mäkelä, Finland

C. Mario Di Lucca	Modelling crown morphology and wood characteristics of coastal western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) in British Columbia

Ryan Singleton	Predicting the effect of overstory density on crown structure and wood quality in multi-cohort Ponderosa pine stands

➢ 11:00 – 12:00

Posters
Moderator: Jim Funck, United States

Rolando Coro Gonzales	Influence of the stand parameters in the wood properties, modeling wood density and wood shrinkage through stand and tree parameters of *Quercus robur* L.
Marie Johansson	Distortion models based on variation in material properties
Erland Ystrom Haartveit	Mechanical properties of Norway spruce lumber from monocultures and mixed stands - modelling bending strength and stiffness using stand and tree characteristics
Reeta Stöd	Predicting the applicability of Scots pine (*Pinus sylvestris*) harvested in thinnings to the raw material of mechanical wood processing
Sebastian Hein	Tree growth and wood quality of valuable broadleaved species (*Acer pseudoplatanus*, *Fraxinus excelsior*) in Europe: construction of decision tools
Jean-Francois Dhôte	Improvement of growth and yield simulator Fagacées: quantifying various thinning options for silvicultural optimization
Celine Méredieu	Efforts for integration of models in France and benefits for the end-users
Jean-Francois Bouffard	Hardwood rough mill optimisation: comparison of various approaches and simulation software
Tom Maness	Evaluating ecosystem management scenarios using hierarchical planning

➢ 12:00 – 1:30 Lunch

➢ 1:30 – 2:50

Oral presentations
Moderator: Christine Todoroki, New Zealand

Celine Méredieu	Application of Finnish Scots pine branching models on French forest resource: preliminary results
Eric Turnblom	Cross-validation of alternative branch models for Douglas-fir using geographically disparate data sources from Europe and the Northwest USA
Kerrie Catchpoole	Development of branch and wood property models for use in a silvicultural decision support system
John Arlinger	Predictions of wood properties using bucking simulation software for harvesters

➢ 2:50 – 5:00 Coffee Break and View Posters

➢ 6:30 Dinner

WEDNESDAY, SEPTEMBER 11

- 6:45 Load Bus
- 7:00 Depart Harrison
- 8:30 Arrive at UBC Malcolm Knapp Research Forest
  Visit espacement trials in Douglas-fir, Western Hemlock, and Western Redcedar with Dr. John Barker
  Visit an on-site portable sawmill operation
- 10:30 Depart for UBC Campus
- 12:30 Arrive Campus—Have box picnic lunch somewhere on campus
- 1:15 UBC Centre for Advanced Wood Processing
- 3:00 Forintex, Canada Corp
- 4:30 Reception at Forintex
- 5:15 Load bus
- 5:30 Depart for Harrison
- 7:30 Arrive Harrison
- 8:00 Dinner

THURSDAY, SEPTEMBER 12

- 8:00 – 8:10 Housekeeping
- 8:10 – 9:50 **Oral presentations**
  Moderator: Tony Zhang, Canada

C. Sue Price	Using modelling and integrated forestry and sawmill software systems to value the pruned log resource
Isabela da Silva Pinto	Sawing simulation of *Pinus pinaster* Ait
Veli-Pekka Ikonen	Linking tree stem properties of tree stem in Scots pine to the properties of sawn timber through simulated sawing
Eini Lowell	Within and between log variation in lumber grade yield as demonstrated using AUTOSAW
Christine Todoroki	Models for predicting lumber grade yield using external log features, internal wood quality and sonics

- 9:50 – 10:20 Coffee break
- 10:20 – 11:00 **Oral presentations**
  Moderator: Alex Clark, United States

Jukka Malinen	Predicting the internal quality and value of Norway spruce trees using non-parametric nearest neighbor methods
Erkki Verkasalo	Modelling the end-use based value of Norway spruce trees and logs by using predictors of stand and tree levels

- 11:00 – 12:30 View posters

- 12:30 – 2:00 Lunch

- 2:00 – 3:20

Oral presentations
Moderator: Doug Maguire, United States

Jeff Welty	Predicting tensile and bending strength of dimension lumber defined by Weyerhaeuser's three-dimensional geometric GlassLogTM model
S.Y. (Tony) Zhang	A tree-level model for plantation-grown Black spruce lumber strength and stiffness
Dave Cown	Microfibril angle in plantation pine: distribution and influence on product performance

- 3:20 – 3:50 Coffee break

- 3:50 – 4:50

Oral presentations
Moderator: Ute Seeling, Germany

James Funck	Simulated sawing of real log images: linking wood quality and product potential
Eini Lowell	Linking simulation of primary and secondary products from small-diameter Western softwoods
Frederic Mothe	Simulating veneering and plywood manufacturing of virtual trees described by a growth-wood quality software

- 6:30 Dinner

FRIDAY, SEPTEMBER 13

- 8:00 – 8:20 Housekeeping
- 8:20 – 10:00

Oral presentations
Moderator: Dave Cown, New Zealand

Jim Goudie	The simulated impact of spacing and pruning on the wood characteristics of Coastal western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) in British Columbia
Geoff Smith	Modelling the impact of spacing and thinning on branching patterns of 36-year-old *Eucalyptus pilularis*
Renaud Daquitaine	Simulating the wood quality of a standing forest resource: how to adapt an existing tool to another species? The French experience gained in adapting to Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) the WinEPIFN software developed for Norway spruce (*Picea abies* Karst.)

- 10:00 – 10:30 Coffee break
- 10:30 – 11:50

Oral presentations
Moderator: Kerrie Catchpole, Australia

Shinya Koga	Wood properties of Japanese larch: modelling and integration with a stand level growth simulator
Thomas Seifert	Modelling growth and quality of Norway spruce (*Picea abies*) with the growth simulator SILVA

Dominique Pauwels	A multi-criteria approach to compare simulated silvicultural scenarios regarding growth, profitability, wood quality and biodiversity impact: application to Larch stands
Frederic Blaise	Connection between forest inventory data and geographic information systems for assessing timber value at the stand level. Case study: Norway spruce in Vosges mountains

- 12:00 – 1:30 Lunch

- 1:30 – 2:30

Oral presentations
Moderator: Kevin Harding, Australia

Jean Beaulieu	Using process-based approach for linking genetic origin and growth with environmental factors
Arto Usenius	Experiences from industrial implementations of forest - wood chain models
Laurent Saint-André	Integrative modelling approach to assess the sustainability of the eucalyptus plantations in Congo

- 2:30 – 3:00 Coffee break

3:00 – 3:40

Oral presentations
Moderator: Celine Méredieu, France

Gilles Le Moguédec	Using a chain of models to optimize the management of a forest resource: what about the precision of the results? Case study on carbon sequestration in a Sessile oak stand

	Gerard Nepveu	Optimizing the chain from the plant to the plank in Sessile oak by taking into account considerations related to sustainable management

- 3:40 – 4:15 Wrap Up—Gerard Nepveu, Jim Goudie, Eini Lowell
- 6:30 Dinner

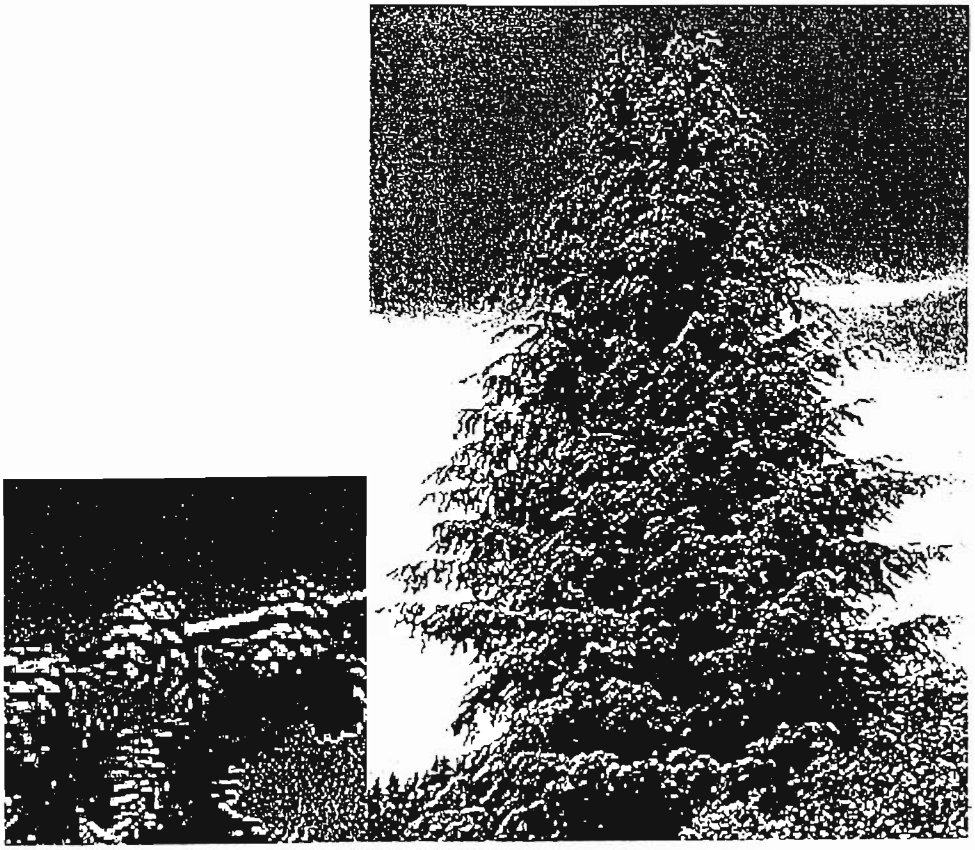
The one page summaries of oral communications and poster presentations

(in order of presentation)

Genetic selection for wood and fibre traits in Western Hemlock progenies

<u>*Charlie CARTWRIGHT*</u>

BC Ministry of Forests, Cowichan Lake Research Station, Mesachie Lake, BC Canada



Impacts of size and competition on the distribution of aboveground biomass and wood quality characteristics in Norway Spruce (*Picea abies*)

Anu KANTOLA

Finnish Forest Research Institute, Vantaa, Finland

This study analyses the aboveground biomass and wood quality improvement in terms of branchiness and stem taper, applying this information to parameterised PipeQual growth model for Norway spruce grown in southern Finland.

PipeQual is an eco-physiologically based dynamic growth model, which was developed to simulate the timber quality characters; branchiness and stem form in trees of different social position. It consists of a whole-tree growth model and modules for describing the whorl and branch structure of the tree. The whole-tree model is based on the carbon balance and it allocates carbon to maintain structural relationships (crown dimensions versus stem dimensions) in the tree. The structure of stems is formed in the process of tree growth, and it can hence be affected by factors influencing growth, such as weather and silvicultural measures. The model has been parameterised and tested for Scots pine in southern Finland but the causal structure of the PipeQual model is, to a large extent, suitable for Norway spruce as well.

For parameterising the PipeQual model for Norway spruce stand it is necessary to measure the structural relationships of individual trees with different competitive status. Tree characters, which are necessary for modifying the model, are: stem form, mass of sapwood, heartwood and bark, crown dimensions (length and width), branchiness (mass, size, quality and location in the crown) and foliage density. Allometric relationships are developed between biomass components and diameter. In order to determine allocation of growth, the dimensional relationships have to be converted into biomass ratios.

The primary aim of this study is to analyse biomass relations in the tree and biomass derivation in the crown. Crown structure is analysed in terms of pipe model relationships, sapwood diameter at crown base versus foliage density. Secondly, it is important to investigate the development of crown structure for the causal explanation of wood quality improvement but as well for predicting the growth or photosynthetic productivity of stands and trees.

The Finnish Forest Research Institute has collected a large biomass data set of individual trees over a wide age range from thinned and unthinned stands located in the boreal region. This material consists of 750 Norway spruce trees. In addition in the fall 2001 we have collected some more detailed measurements consisting of e.g. various sample disks from different heights of the stem and a large number of branch and needle samples per crown when the location, diameter and angle of every branch in the crown is registered. This material is collected from a sapling stage (20-year-old), a pole stage (67-year-old) and a mature (85-year-old) stage stand. We have measured in the young stand 5 sample trees grown in the same sample plot and in both older stands 12 sample trees grown in different sample plots. Sample plots represent different stages of thinning in the stand – hard thinned, normally thinned and unthinned sample plot. Sample trees represent different stages of crown layer in the sample plot – dominant, intermediate or suppressed tree. The biomass of the sample trees is divided into needles, branch wood, stem sapwood, heartwood and bark.

Using this material the distribution of the aboveground biomass of individual trees of different ages and of different competitive status will be investigated and PipeQual model will be parameterised. Using this information, it is possible to predict the stand growth over a wide age range and to use different thinning methods for creating model stands.

When the structural relationships of Norway spruce is analysed and PipeQual model is modified and tested the model is capable for further use. The effects of different stocking densities and thinning regimes on the quality and quantity of the timber produced in a model stand will be analysed. Impacts of different alternative management strategies on the size and quality distribution of trees at the time of harvest will be examined and possibilities of using the model as a management tool in Norway spruce stands will be discussed.

Modelling the effect of physiographic region on wood properties of planted Loblolly Pine in the Southern United States

Alexander CLARK[1], *Richard F. DANIELS*[2]

[1] *Wood Scientist, USDA Forest Service, Southern Research Station, Athens, Georgia USA*
[2] *Professor, Warnell School Forest Resources, University of Georgia, Athens, Georgia USA*

Specific gravity of planted loblolly pine (*Pinus Taeda L.*) 20 to 25 years old was determined using 12 mm increment cores collected from 84 stands across the Southern United States. Twenty-three stands in the lower Atlantic Coastal Plain, 19 stands in the Upper Coastal Plain, 24 stands in the Piedmont and 18 stands in Western Gulf Coastal Plain were sampled. Annual growth, proportion of late wood, and specific gravity of earlywood, latewood, annual ring, were determined using x-ray densitometry for 30 trees bored in each stand. Wood specific gravity and proportion of latewood was found to increase significantly from the northwest to the southeast. The relationship of physiographic region, latitude, longitude, summer precipitation and length of growing season on annual growth; earlywood, latewood and ring specific gravity; proportion of latewood and length of juvenility were examined. Regression equations will be presented to predict wood specific gravity at breast height based on tree DBH, age, latitude and longitude. Models will also be presented for predicting the diameter and specific gravity of the juvenile wood core at DBH.

The spatial distribution of compression wood in Sitka Spruce: preliminary results on the effect of wind exposure and silvicultural treatment on timber quality

Franka BRÜCHERT[1], *Barry GARDINER*[2]

[1]*Institute for Forest Utilization, Freiburg University, Freiburg, Germany*
[2]*Forestry Commission Research Agency, Northern Research Station, Scotland*

Objectives: The influence of wind loading on tree form effects fundamentally morphological, anatomical and chemical modifications in wood formation, modifying cell size and shape, cell wall thickness, microfibril angles and lignin content in the cell wall. These changes are manifest at a larger scale as changes in wood density and ring width, the presence of reaction wood and growth stresses. The overall objective of this project is to predict from stand characteristics and measurements on individual trees the wood quality of timber produced from a wind-exposed stand and to characterise the quality of potential end products. The high variability in properties of trees and wood indicates a great potential for optimisation of timber production and utilisation. This project links forest production and sawmill utilisation in order to deal with stands subjected to large mechanical impacts from wind.

Material and methods: In total 60 trees were sampled from four lines parallel with the stand edge and at different distances as within a stand the mean wind speed and mechanical impact decreases rapidly from the edge to the inner stand. 10m, 30m, 50m and 90m distance from the edge to the mid-forest were chosen representing the varying wind exposure to the trees. 15 trees were selected from each line. The trees were selected for a dbh range which allowed for the identified cutting scheme which required a top diameter of minimum 24.4 cm at the top of a 4m butt log. After the characterisation of the standing trees by their outer shape and size and their mechanical characterisation, the trees were felled. Saw logs and stem discs were sampled in a way to allow both an analysis of the internal structure for the entire tree and an analysis of sawn timber in construction dimensions. The logs were selected to represent two positions in the tree which differed in the impact of wind exposure. The butt log of each tree was taken at stock height and represents the wood formation at two stages: in the inner core we find the wood formation effected by higher wind exposure as the stand was more open, the outer wood cylinder was formed under a lower wind exposure with increasing stand closure. The top logs represent the wood formed under the constraints of higher wind exposure as wind speed increases with height from the ground. The logs were about 4m long and allowed for two thin discs to be taken at both ends of the log. The butt logs were all taken at the same absolute height, the top logs were taken at different absolute and relative stem height due to the restrictions of the stem dimension. The discs were investigated with respect to the differentiation of the annual increment and the presence of compression wood. The logs were converted into battens (final dimension after planing 4.8x9.8x400 cm), using a cutting scheme to seperate between windwards and leewards positioned battens in each individual log. After drying, the battens were visually assessed in terms of warp (twist, bow, spring, cup) and structural features such as grain angle and compression wood occurrence.

Results: Close to the edge, the trees grew shorter and thicker than the trees grown more sheltered. However, the classification of the logs showed no significant influence of the different levels of wind exposure on the log quality. The main factor for log quality was the size of branches (61%). Only for 10% of the logs the eccentricity of the pith was the relevant grading parameter. In contrast to the "homogenous" appeareance of the trees and logs grown under different wind exposure, we found a significant difference in the growth pattern of the stems and the variaton of wood structure in the cross section. The trees close to the edge grew increasingly more eccentric with age in comparison to the more sheltered trees. We also found a larger proportion of compression wood in trees growing close to the exposed edge than in more sheltered trees. The distribution of compression wood in the cross-section showed a more heterogeneous orientation in the exposed trees, in particular in the inner log parts. This is probably due to larger stem deflections in all directions at the stand edge. However, all trees showed a relatively high proportion of compression wood at this site indicating that overall it was very wind exposed. The internal variation of the wood structure (windwards, leewards, juvenile wood, mature wood, butt top) appeared to be important for the batten performance. These findings could have practical consequences for wood processing such as cutting schemes and automatic sorting based on the variation of the internal structure of the logs. The detailed analysis of all tested properties showed a much stronger influence of the position in the stem where the batten had been cut from than the influence of wind exposure to the tree. Whether the batten was cut from the butt log or top log or from the windwards or the leewards side or from the juvenile or the mature wood accounted for larger differences in wood structure and performance than did the wind exposure on the tree.

A new functionality of the Win-Epifn software: the simulation of the compression wood occurrence in the stems of standing trees

Jean-Michel LEBAN[1], Adrian HAPCA[1], Renaud DAQUITAINE[1], Laurent SAINT-ANDRÉ[2]

[1]Lerfob Inra ERQB, Champenoux, France
[2]CIRAD, Montpellier, France

Compression wood has been widely studied and analysed because of its consequences on the timber properties. It is formed during the tree growth and differs strongly from normal wood in its physical, mechanical, anatomical and chemical properties. It is formed by thick-walled round cells enclosing intercellular spaces. In comparison to normal wood compression wood has lower mechanical stiffness and strength. The lower loading capacity is mainly related to the low cellulose content and to the higher microfibril angle of the cellulose fibres in the secondary cell wall. As a consequence a higher longitudinal shrinkage affects strongly the board deformation during drying. Within the forest wood chain the objective of any end-users is then to detect as early as possible the occurrence of compression wood.

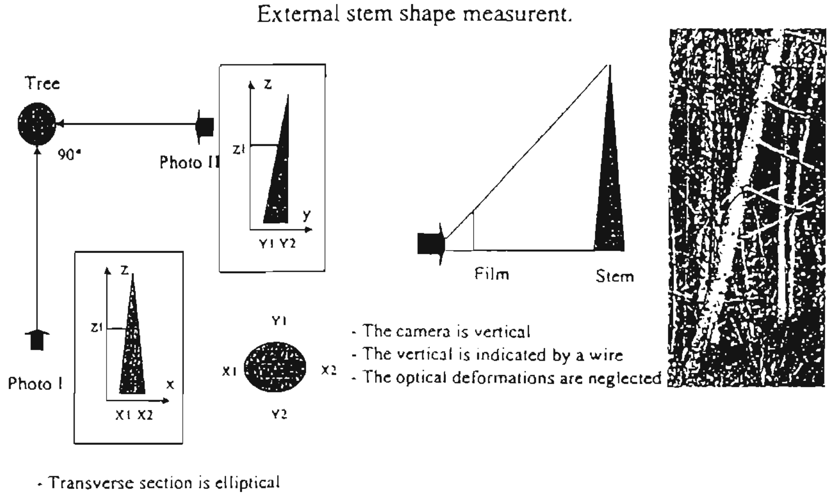
At the moment the importance of compression wood in the forest resource is not well studied and our objective is to analyse the relationships between the external stem shape and the intra stem cartography of compression.

In the field of modelling the timber properties of the actual forest resource we have previously developed models incorporated in one simulation software 'Win-Epifn'. The visual timber properties (knot pattern, ring width, wood density) were simulated by using as input the individual tree measurements (DBH, Height and Age). These simulations have been validated for both Norway spruce and Douglas fir.

The shrinkage is not taken into account and no information is available for compression wood. However, even if the vertical stem shape was considered straight, we have already incorporated in the software, models for the simulation of the stem transverse section asymmetry which is considered as elliptical and the pith is not always located in the gravity centre of the section.
The work presented here consist in the modelling of the intra stem compression distribution by using as predictive variable external stem shape measurements only. The experimental work conducted was based on the use of image analysis of tree stem pictures and on the intra stem distribution of compression wood was detected at different heights in the tree stems by using also image analysis procedures. The compression wood area is described by its location in the sections all along the stem.

The trees analysed were selected from 4 Norway spruce stands located in the Vosges mountains forests. The variation between stands is the slope which vary from 0 up to 40%. The simulation results will exhibit the visual board description including the location and proportion of compression wood.

External stem shape measurent.



Statistical models to predict resin pockets in stems of Norway Spruce

P. RECK, Holger WERNSDÖRFER

Institute of Forest Utilisation and Work Science, Freiburg, Germany

In modern silvicultural strategies[1] it is often foreseen to manage the growth and wood production of Norway spruce in wide-spaced stands. The wide spaces in these stands have been hypothesised to influence specifically the quality of the wood produced. In particular it is assumed that trees growing under these very wide spacings tend to have a high occurrence of resin pockets because of swinging and tilting by high wind stress[2]. Examining this hypothesis is of great importance because the occurrence and the intensity of resin pockets is an important criterion for roundwood classification of Norway spruce, e.g. EN 1927-1.

The objective of this study therefore was to provide a detailed data base about the occurrence and intra-tree distribution of resin pockets in stems of Norway spruce which are characterised by very wide spacing and to use this data base for developing statistical models to predict the formation of resin pockets in stems of Norway spruce, in order to evaluate the modern silvicultural strategies in terms of the quality of the wood produced.

For providing the data base, 34 sample trees were selected which were characterised by very wide spacing. From each sample tree, 9-10 discs were taken in stem heights of 0,7-25m; a total amount of 337 discs were included. On every disc, the amount of resin pockets, as well as the azimuth[3] and the year of formation of every resin pocket were determined by taking a digital picture of every disc and using computer based image analysis.

Firstly the occurrence, vertical and horizontal intra-tree distribution of resin pockets was analysed by descriptive statistics giving the amount of resin pockets per disc of vertical stem parts and also the amount of resin pockets per horizontal disc sections.

Furthermore, differences in the vertical and horizontal intra-tree distribution of resin pockets were statistically tested.

Secondly, as wind is hypothesised to be the most important factor influencing the formation of resin pockets, several parameters describing the influence of wind on a tree were correlated to the occurrence and intra-tree distribution of resin pockets:

- The vertical distribution of resin pockets was correlated to the relative wind speed, which is known to be increasing with stem height.
- The horizontal distribution of resin pockets was correlated to the main wind direction.
- The slope and exposition of the sampling stands was correlated to the amount of resin pockets occurring in the corresponding sample trees.
- Possible correlation was analysed between the date (year) of occurrence of heavy storms and the amount of resin pockets formed within the storm-year and during the following years.

The results of this study will be included into an integrated regression model to predict several important wood quality parameters in stems of Norway spruce which are characterised by very wide spacing. The model can be used as a tool for evaluating modern silvicultural strategies in terms of the quality of the wood produced.

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[1] E.g. WILHELM G.J., LETTER H.-A., EDER W. (1999): Konzeption einer naturnahen Erzeugung von starkem Wertholz (Conception of a Natural Production of Big Dimension High Quality Wood). AFZ/Der Wald 54, 232-240 *(German)*

[2] FREY-WYSSLING A. (1938): Über die Entstehung von Harztaschen (About the Formation of Resin Pockets). HRW 1, 329-332 *(German)*
CLIFTON N.C. (1969): Resin Pockets in Canterbury Radiata Pine. N.Z. Journal of Forestry 14, 38-49
HOLZMANN I. (1998): Harzgallen in Fichtenstämmen bei unterschiedlicher waldbaulicher Behandlung (Resin Pockets in Stems of Norway Spruce at Different Silvicultural Treatments). Diplomarbeit an der Forstwissenschaftlichen Fakultät der Universität München, 54 S. *(German)*

[3] Angle of deviation to the direction of north

Modeling wood properties in relation to cambium age and growth rate in Plantation Poplar in China

Shengquan LIU [1], *Fucheng BAO* [2], *Zehui JIANG* [2]

[1]*Anhui Agriculture University, Hefei, China*
[2]*Chinese Academy of Forestry, Beijing, China*

In this study, the wood of three poplar closes, poplar 72 (*Populus×euramericana* cv.I-72/58), poplar 63, (*P.deltoides* cv.I-63/51), poplar 69 (*P.deltoides* cv.I-69/55), grown in three different beaches of Yangtse river with three different planting densities were selected as the materials. Based on the relationships between wood properties, cambium age (CA) and ring width (RW), the fiber length (FL), the microfibillar angle (FA) and wood density (WD) were quantitatively modeled with regression analysis methods. It is revealed that the fiber length of plantation poplar can be well predicted using CA and RW (r=0.989) whilst the models of the microfibril angle and wood density using cambium age and growth rate is not good (r=0.141 for FA and r=0.143 for WD).

Keywords: plantation poplar, wood properties, cambium age, growth rate

Modelling of internal knot characteristics of mature Finnish *Betula pendula* and *Betula pubescens*

Henrik HERÄJÄRVI

Finnish Forest Research Institute, Joensuu Research Centre, Joensuu, Finland

The aim of this study was to examine the internal knottiness structure, and evaluate the possibilities of predicting the knottiness properties of boards sawn from mature Finnish silver birch (*Betula pendula*) and white birch (*B. pubescens*). The differences of the knottiness between the alternative growing conditions and trees representing different crown layers were also studied. The sample trees were sawn into unedged boards with a 25-millimetre green thickness and a 2-metre length. The boards were graded according to their knottiness into three categories (knot-free, only dead knots or both dead and sound knots, only sound knots). Polytomous logistic regression models were constructed to predict the grades for the boards on the basis of their location within the tree. Additionally, the diameters of the thickest sound and dead knot within a board were studied using linear regression. The results showed significant differences between the growing conditions studied. In all cases, the knot-free and the sound-knotted boards were separated in a satisfactory accuracy according to the models. The boards with only dead knots or with a mixed knottiness structure, on the other hand, were slightly more poorly classified. The diameter of the thickest sound knot within each board was linearly dependent on the location parameters of the board. The diameter of the thickest dead knot was, conversely, not predictable by the location parameters.

Modelling juvenile wood quality in *Pinus* plantations: critical limits for wood properties needed to select clones with superior stiffness for structural timber

K.J. HARDING[1], *B.M. GREAVES*[2], *C. GROSSER*[2], *T.R. COPLEY*[1]

Kevin

[1] *Queensland Forestry Research Institute, Queensland, Australia*

[2] *Co-operative Research Centre for Sustainable Production Forestry, University of Tasmania, Hobart, Tasmania*

A selection index tool developed as a key outcome of a breeding objectives and selection criteria project (described by Harding *et al.*, 3rd IUFRO Wood Quality Workshop, La Londe-Les-Maures, 1999) has been extended to link with a multi-trait, multi-stage selection tool called MaxDeploy. This tool allows tree breeders to optimise the assessment resources required to maximise the gains from selecting superior families or clones for routine deployment.

MaxDeploy targets the selection end of tree improvement programs. It allows a tree breeder to assess how the cost of sampling and assessment, and the intensity of selection applied to a suite of traits, can be manipulated to maximise the potential economic gains from a selection strategy. It accesses the selection index correlation matrix to use information about the degree of genetic correlation among traits to consider indirect effects of selection among correlated traits. Further, it has been developed to allow for multi-stage assessment, which is standard practise in most tree improvement programs. Traits with low sampling and assessment costs are sampled with a much higher sampling intensity than more expensive to measure traits. Hence, tree diameter, height and straightness class are usually assessed first on all or most trees in a test, whereas a subset of these might be assessed for wood density and then further sub-sets assessed for very high assessment cost traits such as spiral grain or microfibrillar angle. The combination of traits measured will depend on the breeding objectives defined for the target products.

To use MaxDeploy to maximum effect, estimates of the current breeding parent or clonal population means and variances for key traits, as well as co-variances among these traits, are required. The selection index and MaxDeploy tool are used to assess the impact of changing these population means on the profitability of the growing and/or processing enterprise. Co-variances among the key traits are also used to assess correlated responses to applying selection pressure to one or more traits. For example, the current goal in Queensland is to reduce the rotation age of *Pinus elliottii* var. *elliottii* and *P. caribaea* var. *hondurensis* and their interspecific F_1 hybrid from 28-30 years to around 20 years. This requires sawing studies and modelling of wood properties to establish critical selection cut-off values for early juvenile wood properties that will produce in-grade structural sawn wood recovery from these shorter rotation plantations. These critical values need to be defined so that screened population means are sufficiently high to ensure that all ramets in a clone, or individual trees in a family, will be acceptable for quality sawn wood processing. Structural timber recovery dominates the local product requirement from these plantations.

Work undertaken to evaluate within-clone variation in wood quality in routinely deployed clonal block plantings, including sawing study results, is described. Non-destructive evaluations (NDE) to assess basic density, spiral grain and microfibrillar angle in 6-year-old ramets are related to sawn board test results NDE tools used include Pilodyn, acoustic stress wave testing and increment cores. A stratified sample of 2.4m butt logs, representing a range of NDE results from 180 ramets sampled from two clonal blocks, have been sawn. The goal of this work is to establish an index of early juvenile wood property values required to obtain acceptable stiffness for the production of in-grade structural timber recovery from 20-year-old rotations. These values will be used to optimise selection strategies in MaxDeploy. This will achieve the selection of an elite pool of clones able to be harvested on a shorter rotation schedule but with equivalent or superior wood quality yield to the current 28-30 year old harvest.

Wood stiffness patterns in age-10 clones of New Zealand Radiata Pine

Charles SORENSSON[1], *Gérard NEPVEU*[2]

[1] *Trees and Technology Ltd, Whakatane, New Zealand*
[2] *INRA – Nancy, Equipe Qualité de Bois du LERFOB, Champenoux, France*

Wood stiffness is widely accepted as the No.1 target for tree breeding for improved wood at both family and clonal levels in NZ radiata pine. The "problem" (or, in our view, "opportunity") is worth well over $1 billion NZD. Young high-stiffness clones, which we have already begun producing commercially, offer many attractions including greater product flexibity in future markets, higher log conversions into "good wood" and greater flexibility in rotation age.

Until recently, the emphasis for breeding was on raising juvenile wood density. Recently it has become clear, though, that such efforts are inefficient because of the large role microfibril angle can play, as well as other factors like wood grain spirality. Many studies show that wood density accounts for 10 to 30% of stiffness of young radiata wood.

Our objective was to develop a model of wood stiffness that could be used for sensitivity analyses for early clonal selection. We have followed a Mixed Model approach developed in France, under kind guidance from Dr. Nepveu. The experimental design required us to survey a 400-genotype forest trial to identify at least 20 clones of similar size but divergent wood properties. At present, we are still completing this screening process.

We intend to harvest 3 stems of each of these 20 clones and extract clearwood samples from several fixed heights in the stem (bark-to-bark). Following the approach of Megraw and others in loblolly pine, we will orient sawn samples parallel to the fibre orientation to remove any biases from excessive spirality. We will then measure at least three critical properties: test density, longitudinal shrinkage (green to test), and clearwood stiffness. This will be used as the data to build a Mixed Model for use in simulating early clonal selection. To our knowledge, this effort will be the first ever modelling exercise of wood stiffness in young radiata clones in NZ.

A system of models for fiber properties in Norway Spruce and Scots Pine and tools for simulation

Sven-Olof LUNDQVIST [1], Fredrik EKENSTEDT [1], Thomas GRAHN [1], Lars WILHELMSSON [2], et. al.

[1] STFI, Swedish Pulp and Paper Research Institute, Stockholm, Sweden
[2] SkogForsk, The Forestry Research Institute of Sweden, Uppsala, Sweden

Studies of wood properties have been carried out with the objective to describe, model and utilise different sources of variation of Norway spruce and Scots pine. The main study material (Forest-Pulp-Paper project STFI/SkogForsk) comprised of sampled discs from different heights in trees of different ages, sizes, and site conditions distributed over Sweden. In total 252 trees from 42 stands of Norway spruce, and 120 trees from 20 stands of Scots pine were included. This material was used to develop models designed for prediction of basic wood properties in Swedish forestry, performed by SkogForsk, and fiber properties, performed by STFI.

Models have been developed for the fiber dimensions: fiber length, width and wall thickness. The models express strong influences of the number of annual rings in a cross-section or the diameter. Other variables of importance are latitude and height in stem. Coefficients of determination (r^2-values) in the range of 0,55 – 0,80 have been reached with a low number of input variables, which is high for this type of models. The values obtained for cross-sectorial averages are the following for Norway spruce and Scots pine respectively: fiber length (0,80;0,81), fiber width (0,69;0,61) and fiber wall thickness (0,54;0,72). The background of the different levels of the residuals will be discussed.

Tools have been developed to simulate property variability within and between trees and stands, to illustrate the results with "tree maps" and to compare with measurement data. With these tools properties of different alternative assortments of wood raw materials, which can be obtained from the trees and stands, may be estimated. Results will be illustrated.

Modelling red heartwood in Beech (*Fagus sylvatica* L.)

Ute SEELING

Institute of Forest Utilisation, Freiburg, Germany

With more than 20% of the forest area beech (*Fagus sylvatica* L.) is the most important broadleaf species in Germany. Following advanced silvicultural programs the area of beech stands shall even increase.

In many or even in most beech trees appears the so called "red heartwood" or "red core". Whereas light beech timber is highly appreciated in the veneer industry the occurrence of red heartwood leads to a severe devaluation of beech timber.

The objective of the presented research is to investigate if modem silvicultural concepts that were recently developed to manage beech stands might help to avoid or to reduce red heartwood in beech trees.

The new concepts can be characterised by a new spacing management: at an early tree age the stands will be managed in wide spacing so that in short rotation periods high dimension trees with a short stem in a good stem quality shall be produced.

To investigate the type, dimension and form of red heartwood seventy trees were selected in Germany and in France according to this typical tree architecture. This was done with support of the department for tree growth. The tree architecture was described by stem dimension (width and length), height of the first dead / living branch, height of the crown, crown projection area etc.

After felling the sampling trees on cross sections in different stem heights the occurrence of red heartwood was documented and the width of red heartwood was measured in eight directions.

The data give the characteristic form of the red heartwood within each tree (e.g. spindle, cylinder) and up to now the results have been visualised using PV WAVE.

In the following steps advanced statistical models will be developed to test the correlation between the tree architectural variables and the characteristic type, form and dimension of red heartwood within the trees.

To evaluate the new concepts in comparison to the past the results will be linked to existing databases conceming beech.

Modelling the presence of tension wood in a Poplar stem based on 3D growth ring distribution

Miguel BADIA, Thiery CONSTANT, Frederic MOTHE, Gerard NEPVEU, J.M. LEBAN

EQUIPE QUALITE DES BOIS: UMR INRA-ENGREF, Laboratoire d'Etude des Ressources Forêt-Bois LERFOB, Champenoux, France

The current shape of a trunk is determined by a complex process involving several internal and environmental factors and their mutual interactions during the life of the tree. The aim of the present study is focusing on the connection between tree shape and wood quality, especially with regard to the occurrence of tension wood.

A method for measurement of the three-dimensional (3D) shape of trees has been developed. This method which combines field and laboratory measurements was applied to nine poplars trees of 15-year-old and nearly 30-m-height. Three clones were studied, Luisa Avanzo, I- MC and I-214. For each clone, 3 trees were sampled with respect to the shape pattern: one straight tree, one leaning tree and one tree that after a curvature started growing vertically again.

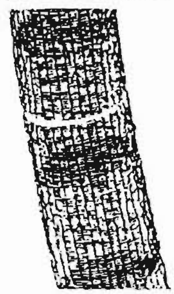
On the standing tree, several targets were placed using an aerial lift until 16-17-m-height. The Cartesian co-ordinates (x, y, z) of the target were measured using a total station (Leica 703). Then the tree was felled and bucked in logs.
The external shape of the logs were measured in laboratory using a 3D digitising device developed in our laboratory. The location of each target were also recorded and added to the set of data describing the log. At this stage, new targets were added to define the disks (three targets per disk) on which further analyses will be carried out.

Each disk was analysed by tracing off onto a transparent sheet several characteristics of the disks, the annual rings limits, the outline of the bark, the external limit of the black heartwood, the borders of tension wood areas and the projection points of the three targets nails.

This sheet was scanned and the image file was analysed with the image analysis software Visilog® 5.3. The main funtion of the software is to divide each element into small clusters defined by angular sectors centered on the pith intersecting the annual ring limits. Each cluster is characterised by its location, its age, its area and the surface percentages of to tension wood or black heartwood.

Two successive changes of co-ordinate system from the disk to the log then from the disk to the tree allow to compute the location of each cluster in the tree space.

Finally, a 3D view of the tree shape and the internal properties pattern may be synthesised. The visual comparison with a tree photograph shows that the reconstruction process is satisfactory.



The visualisation in situ of the internal properties of wood in the tree and particularly the data base collected with this method will be used to model the distribution and the quantity of tension wood in the stem. Specific models will be elaborated for each kind of shape, and the main inputs will be the local leaning, eccentricity, growth ring characteristics and their evolution during the life of the tree.

Simulation to investigate optimal resource use in selection strategies for multiple traits including expensive-to-measure wood property traits

John N. KING[1], *Jon K. HANSEN*[2], *Alvin D. YANCHUK*[3]

[1]*Research Branch, British Columbia Ministry of Forests, Forest Service, Victoria, B.C., Canada*

[2]*Department of Forestry, Danish Forest and Landscape Research Institute, Hoersholm, Denmark*

[3]*Research Branch, British Columbia Ministry of Forests, Forest Service, Victoria, B.C., Canada*

Population improvement schemes for recurrent selection for GCA have been very successful in improving growth and form quality traits in most conifers. In this scheme large populations are carried which is an expensive process, but we have efficiently managed quickly assessed growth and form traits. However wood quality issues are now becoming far more important and assessing these traits is expensive. This paper reviews multiple-trait improvement and suggests questions we may seek to ask in developing a multi-generational strategy for this improvement that is both cost efficient and genetically effective. The adverse correlation between diameter and wood density is used as an example to look at multi-trait improvement options, but it can also be used for most of the wood quality improvement scenarios. A series of simulations suggests that some of the multi-stage selection strategies would be most effective.

Modelling and experimental studies on wood quality parameters relating to stiffness, strength and shape stability

Hans PETERSSON[1]*, *S. ORMARSSON*[1], *O. DAHLBLOM*[2]

[1]*Department of Structural Mechanics, Chalmers University of Technology, Göteborg, Sweden*
* *presently guest professor at Växjö University, Sweden*
[2]*Division of Structural Mechanics, Lund Institute of Technology, Lund University, Lund, Sweden*

Structural timber should satisfy quality requirements regarding strength, stiffness and shape stability. Variations of the material properties and the fibre direction in the log have a strong influence both on stiffness and moisture induced deformations. To get a good prediction of the structural response due to mechanical loading and moisture influence, detailed information must be available about the variation of the material properties and the material orientation with respect to the main material directions.

Experimental data on the variation of important engineering properties are too limited both with respect to the variation from pith to bark and in the longitudinal direction of the log. Results from a recent experimental study on basic properties of Norway spruce will therefore be reviewed first. The distribution of properties in 274 spruce trees from 29 different stands in five countries of the European Union was investigated. The specimens were sawn at different distances from the pith, and at different heights in the stem. In all, about 7000 small specimens were tested. The parameters examined were: the longitudinal modulus of elasticity, the longitudinal shrinkage coefficient and the spiral grain angle. According to the results the variation in properties with the distance from the pith is considerable.

On the basis of the data obtained from measurements of small specimens, computer simulations were performed in order to predict stiffness and drying deformation. To obtain relevant results it is, in addition to information on parameters such as modulus of elasticity, shrinkage coefficient and spiral grain angle, important to have information of the pith location. The computational results have been compared with experimental results. The results obtained clearly indicate the potential of using computer simulations based on measured growth characteristics to predict strength, stiffness and drying deformations of timber and glued wood products.

On the basis of the experimental data obtained, also simplified numerical simulations have been carried out of the deformations that developed in sawn boards after changes in the moisture content. The theory behind such a simplified 3-D simulation is based on a finite element model where the number of degrees of freedom might be strongly reduced with respect to the cross section of the board. A special case of no variations of the properties in the longitudinal direction of the board has also been considered. The simplified 3-D model applied might in combination with advanced measuring technique be of great interest for the sawing industry in grading of timber with respect to strength, stiffness and shape stability.

Detecting knots in logs using a simulated X-ray cone-beam scanner

Johan OJA[1], *Stig GRUNDBERG*[2,3], *Anders GRÖNLUND*[2]

[1] *Forintek Canada Corp., Vancouver, B.C., Canada*
2. *Luleå University of Technology, Division of Wood Technology, Skellefteå, Sweden.*
3. *Swedish Institute for Wood Technology Research, Skellefteå, Sweden.*

Studies have shown that detailed information about the internal knot structure of saw logs would make it possible to increase the value recovery with 10%. Computed tomography (CT) is one method of measuring the internal knot structure of logs. The problem is that industrial applications require high speed (2-3 m/s) and that conventional CT-scanning is far to slow (< 0.1 m/s). One alternative that would make it possible to design a high-speed scanner is to use an X-ray cone-beam scanner. Such a scanner is based on fixed X-ray sources and several linear array detectors for each source. This scanner makes it possible to produce images of knots in cross-sections of logs. In order to control the sawing process it is necessary first to detect the knots in the images and to describe the position and shape of each individual knot. A natural first attempt would be to apply existing segmentation algorithms that were originally developed for analysis of CT-volumes.

Hence, the aim of this study was to make a preliminary test of the result when applying existing segmentation algorithms on volumes based on data from a simulated X-ray cone-beam scanner.

Two approximately 1 m long parts of two different Scots pine (*Pinus sylvestris* L.) saw logs were scanned in a medical CT-scanner (Siemens SOMATOM AR.T.). Then two volumes, covering one whorl from each log were chosen for the simulation. These volumes were used as input data when simulating a cone-beam scanner. Two different scanners were simulated; one with 33 detectors in each direction and one with 9 detectors in each direction.. The signals from the 9-detector scanner were filtered with a pre-processing method in order to exclude artefacts due to the low number of detectors. As an alternative, a more advanced pre-processing algorithm was applied on the 9-detector data. This resulted in three different types of volumes, one volume from a scanner with 33 detectors in each direction, and two types of volumes from a scanner with 9 detectors in each direction and with different pre-processing methods.

The segmentation algorithms originally developed for analysis of CT-volumes were then applied on both the original CT-data and the three different cone-beam volumes. The shape of the cross-section, the border between heartwood and sapwood and the position of the pith were measured in the original CT-data and this information was used also when the segmentation algorithms were applied on the cone-beam volumes. The segmentation algorithms produce an individual parameter description of every detected knot. Finally, the parameter description, together with information about the outer shape, the heartwood/sapwood border and the pith, was used for reconstruction of the log.

When comparing three slices from the different cone-beam volumes with the original CT-slice it is clear that all three cone-beam volumes give information about both size, shape and position of the individual knots. When comparing the segmentations based on the three different cone-beam volumes with the segmentation based on the original CT-volume it becomes clear that it is necessary to calibrate the threshold values in order to measure the accurate size of the knots.

The results were very promising and indicate that a cone-beam scanner makes it possible to detect size, shape and position of individual knots. The study also showed that the existing segmentation algorithms have to be adjusted to data from cone-beam scanners and that 9 detectors in each direction seem to be enough to detect most knots.

Modelling spiral grain in saw logs based on data from a simulated X-ray LogScanner

Paul SEPÚLVEDA[1], *Johan OJA*[1, 2], *Anders GRÖNLUND*[1]

[1] *Luleå University of Technology, Skellefteå Campus, Division of Wood Technology, Skellefteå, Sweden*
[2] *Swedish Institute for Wood Technology Research, Skellefteå, Sweden*

Spiral grain is a phenomenon studied by many scientists because of its effect on the twist of sawn wood. Boards sawn from logs with a large grain angle have a great tendency to twist when the moisture content changes. The objective of this study was to evaluate the possibility of predicting the spiral grain in of a log based on variables measured by a simulated industrial X-ray LogScanner.

The study was based on 80 Norway spruce (*Picea abies* L. Karst.) saw logs from three different stands in Sweden. The logs were scanned with a CT scanner every 10 mm along the log. From the stack of CT-images, concentric surfaces at different distances from the pith were reconstructed. In these concentric-surface images, the grain angle was measured. The spiral grain of a log was defined as the grain angle at 50 mm from the pith.

The CT images were then used to simulate the result when scanning logs with an industrial X-ray LogScanner. The result of the simulations was X-ray LogScanner measurements of variables such as heartwood density and knot volume.

A statistical model for prediction of spiral grain was then calibrated using partial least squares (PLS) regression. The PLS-model predicts the spiral grain of a log at based on the variables measured by the simulated industrial X-ray LogScanner.

The result was a PLS-model with R^2=0.61 for the training set and R^2=0.66 for the test set. The bias of the test set was 0,14°.

The conclusions were that:

- The study indicates that it should be possible to predict the spiral grain of a log based on variables measured by an industrial X-ray LogScanner.
- The most important variables for prediction of spiral grain were different measures of heartwood density and knot parameters.
- The accuracy when sorting the logs into two groups with grain angle >=2,0° and <2,0°, respectively was 85% correctly sorted logs.

Keywords: Spiral grain; stem-bank; PLS-regression; Jackknife; non-destructive measurement; X-ray; saw log.

Internal log defect model using CT-images

Sencer ALKAN

Forintek Canada Corp., Vancouver, B.C., Canada

Contrary to conceptually static, binary, and reproducible nature of the conventional computed tomography (CT)-image interpretation modelling primitives, biological features of wood are dynamic, patchy, irregular hygroscopic, uncertain, and unpredictable. Spatial structures of these features in-coupled with uncertainly within a CT-log image presents a high complexity that the current approaches cannot accurately handle.

A new hybrid model is developed for an automated interpretation of the complex log image features derived from CT-scanning. The proposed model is a consortium of synergetic concepts that intends to handle ambiguous and dynamic nature of CT-log-image-feature patterns. In this model, any log feature interpretation is achieved in two phases. The first phase called pre-attentive-fuzzy-object-shape-primitive formation describes the log features as fuzzy-adaptive-object-shape-prototypes. The modelling primitives are expressed as fuzzy-adaptive-inferring symmetric axes: the initial feature-building blocks, which are understood as the records of fuzzy-log feature formation-processes or are interpreted as the principle directions along which fuzzy-growth processes are most likely to act or have acted. The second phase called attentive-fuzzy-object-shape formation enables a recognition of the log-image features as the outcome of a proposed fuzzy-adaptive survival process among the fuzzy-object-modelling primitives and subsequent a fuzzy-fractal-warping of the survived pre-attentive object primitives.

The proposed new model will lead to new properties and descriptions for CT-log image interpretation. The concepts will be particularly suitable for a flexible and robust log feature interpretation to achieve maximum profitability from logs of different shapes, sizes and qualities that is still the central unsolved problem in machine perception of the lumber manufacturing industry.

Key words: log modelling, computed tomography, log quality, fuzzy set theory, fractal geometry, genetic algorithms, hybrid systems.

Influences of growth site on different wood properties in Spruce sap-/heartwood using CT-scanner measurements

Karin SANDBERG

AB Trätek, Skellefteå, Sweden

The object is to model parameters explaining the water absorption in Norway Spruce (*Picea abies* (L.) Karst). The parameters should be possible to measure in the chain from cutting the tree to the sawing operation on-line, and make it possible to separate appropriate raw material to products which requires low water absorption. The hypothesis is that differences in water absorption ability and desorption (drying time) in the end grain cause differences in durability for building products, since micro-organisms in wood need a moisture content (MC) over fibre saturation point (FSP) to live. In other words by choosing wood in a systematic way, related to a number of characteristics, be able to increase the length of the product life and decrease maintenance for spruce products used outdoors above ground.

20 logs, half of them suppressed and half of them dominant, were taken from two sites, one site with good supply of water and one without free ground water. The logs had approximately the same diameter. The logs were sawn and dried to 12% MC. The measurements were performed in room climate with a CT scanner, after 1, 3, 7 and 14 days absorption and during desorption for 7 days. Images from CT scanner show differences in water absorption in different parts of spruce especially between heart and sapwood (figure 1).

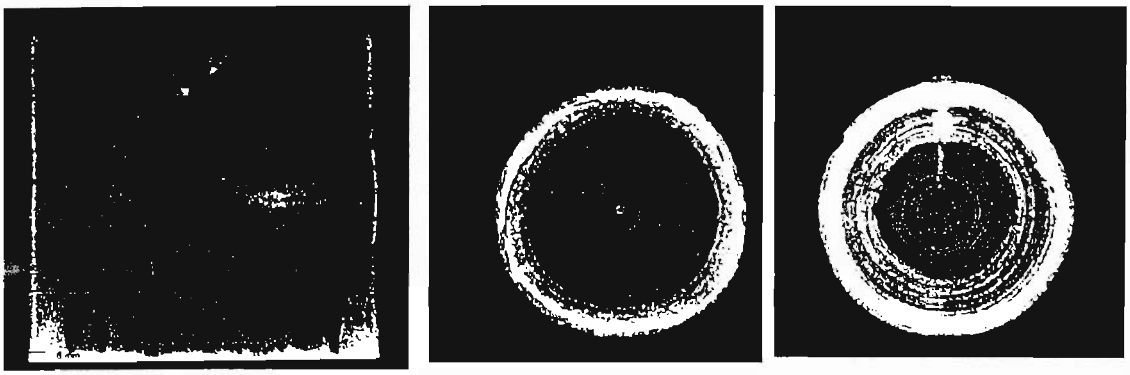


Figure 1. a) CT image showing water absorption after eleven days in end grain of spruce, starting on 12% MC . Light intensity corresponds to high amount of water. b) A crosscut of log from a dry site. The dark area is green heartwood and the light area sapwood. c). CT-image of a log from a wet site.

Results indicate:

- Trees growing with poor access to water have a larger share of heartwood and are more slow grown wood than the trees that have been growing with good supply of water.
- The water absorption is higher in the sapwood then in the heartwood.
- The wood samples from the wet site, especially dominant tree absorb more water then the wood samples from the dry site.
- Desorption is faster in the heartwood then in the sapwood. Time for heartwood to dry to 12% MC after 14 days of absorption is about 3 days compared to 6-7 days for sapwood.

It is desirable to find slow grown wood spruce with a large fraction of heartwood. The paper will discuss parameters to model water absorption in wood. Measured parameters are amount of heartwood, density, diameter of the log, age, annual growth ring density, and site conditions. Other parameters that will be observed are wood fibre properties, resin content, height of the tree, crown diameter, height to first living branch, crown length etc.

Modelling compression wood in Norway Spruce using data from a 3D-laser scanner

Mats WARENSJÖ [1], Mats NYLINDER [2], Fredrick WALTER [3]

[1] *Department of Forest Management and Products, Swedish University of Agricultural Sciences, Umeå, Sweden*
[2] *Department of Forest Management and Products, Swedish University of Agricultural Sciences, Uppsala, Sweden*
[3] *Dianthus, Boden, Sweden*

It is a well known fact that trees that are leaning or have pronounced curvature often contain compression wood. Cross sections from these trees also tend to be elliptical with an eccentric pith. With a 3D-laser scanner it is possible to obtain data that describe the spatial co-ordinates of the log surface with high resolution. From these data it is then possible to calculate geometric variables that could be used for automatic detection of logs with specific curvature during grading. One problem when using external geometry as a tool for grading is that trees tend to become more straight as they grow older, due to the concealment by radial growth. Therefore, logs that appear straight can still contain large amounts of compression wood. By using information obtained from the log ends the detection of compression wood logs could probably be improved.

The aim of the present study is to evaluate whether the external log shape variables obtained from a laser point triangulation 3D-scanner, data of compression wood content, and pith position received from the log ends could be used to model the distribution of compression wood in saw logs.

In total, 11 trees representing four different types of stem shapes, straight, but sweep, long sweep and multiple sweeps were selected in a thinning stand. After felling, each stem was crosscut within a straight section of the stem. At a commercial sawmill, a Rema laser point triangulation 3D-scanner was used for collection of external log data. In order to map the distribution of compression wood, 10-cm thick discs were cut at every 60 cm of the logs. From each disc, a 3mm thin disc with high measurement accuracy was sawn using a circular saw. The thin discs were placed on a light scattering table in order to be able to discriminate between mild and severe compression wood. In transmitted light, mild compression wood appears light orange to red in colour and severe compression wood appears dark brown to black. Images were registered with a digital camera and an image analysis software was used for classification and calculation of the compression wood content in the discs. The computer software uses supervised multivariate methods for classifying the discs into normal wood, mild compression wood and severe compression wood. The software also extracts shape parameters automatically, that can be used for calculation of geometric variables such as pith eccentricity and out of roundness. Out of roundness expresses the deviation from a perfect circular shape in percent of the diameter and pith eccentricity expresses the deviation of the pith from the geometric centre of the wood disc.

Another software application was developed for reconstruction of the original stem geometry by combining separate 3D log data sets to a complete stem. The computer software automatically calculates external geometry variables such as bow height and bow radius from the data set. One aim with this software and the crosscutting of stems was to create a simulation tool for crosscutting. By moving the position of the crosscut along the stem, it is possible to create new logs with known external log geometry as well as compression wood content. For example, it was possible to create 130 new 4-meter long unique logs from the original 11 stems.

A database with all data from the image analysis and the simulation of crosscutting was created. Compression wood content, out of roundness and eccentricity in logs were calculated as the mean value of all discs included in the log. The correlation between external geometry variables, compression wood content and geometric variables from log ends and internal compression wood content was calculated for all discs, log sections and logs.

Pith eccentricity in the discs was significantly correlated to the total amount of compression wood in the discs. However, the pith eccentricity in the log ends was not correlated to the total compression wood content of the logs. Out of roundness did not significantly correlate with the compression wood content. If logs from the two straight stems were excluded, bow radius was significantly correlated to the total compression wood content in the logs ($r=0.67$). The correlation between the compression wood content in the log ends and compression wood content within the log was also strongly significant ($r=0.67$). If stem no 3 was excluded, a stem with a very pronounced but sweep, the correlation between the severe amount of compression wood in the log end and the severe amount of compression wood within the log was also strongly significant ($r=0.93$). For the two straight stems the correlation between the severe compression wood content in the log ends with the severe compression wood content within the log was strongly significant ($r=0.97$). It seems likely that most of the compression wood content in saw logs could be modelled by using data from a 3D-laser scanner in combination with registration of compression wood content in the log ends.

Modelling of component recovery potential and analysis of incidence of defects in White Birch (*Betula Papyrifera*)

Charles CLÉMENT[1], *<u>Robert BEAUREGARD</u>*[2], *Rado GAZO*[3], *Torsten LIHRA*[4]

[1]*Ph.D. Candidate, Purdue University, West Lafayette, Indiana, USA*
[2]*Assistant Professor, Université Laval, Pavillon Abitibi-Price, Ste-Foy, Québec, Canada*
[3]*Assistant Professor, Purdue University, West Lafayette, Indiana, USA*
[4]*Group Leader, Department for the Development of Value-Added Wood Products, Forintek Canada Corp., Eastern Laboratory, Ste-Foy, Québec, Canada*

White birch (*Betula papyrifera*) is the last commercially sustainable species available for industry expansion in Québec. There are over 5,300,000 m^3 available per year, yet large quantities of this species are left standing because the stems are generally considered too small to be an economically viable source for conventional hardwood sawmills. In general, the log diameter is either too small or the length is too short for traditional machinery or the lumber produced is not covered by conventional grading rules.

A recently created white birch database was used to simulate crosscut-first and rip-first rough mills to determine the effects of the species physio-morphological characteristics on yield with respect to selected industry cutting-bills. A database of random width and length white birch boards containing information on all grade defects was developed for use in the simulation.

In first part of this study, the database allowed us to analyze the incidence of defects, which indicates that knots are the primary defect found in white birch of which short-length lumber has more of (in both quantity and average area) than conventional-length lumber. Short-length lumber had a greater surface area of wane/ void, but it also had less maximum average crook than conventional-length lumber.

Second part of this study analyzes the natural part distribution and the potential use of white birch lumber in the furniture and panel industries. For the purpose of this study, 5,574 board feet (BF) of lumber were used including conventional length, NHLA-graded lumber (1,156 BF of Select, 912 BF No.1 Common and 874 BF No.2A Common), and Custom graded short-length lumber (960 BF of Select, 970 BF of No.1 Common and 702 BF of No.2A Common). The effect of lumber length, grade, cutting bill and processing method on yield were analyzed. ROMI-RIP and ROMI-CROSS simulation software were used to model two traditional processing methods, rip-first and crosscut-first, respectively. Two cutting orders, Furniture, and Panel, from Canadian industry, were processed.

Two methods for processing this lumber are used. One is a conventional way of using standard-length logs to produce NHLA-grade lumber. The second involves the use of short-length logs (less than 8-foot-long) for custom-graded lumber. Because of the small diameter and crooked trunk shape, rough mills are only now beginning to use short-length rough lumber in order to increase lumber recovery, a common practice in the pallet industry.

Highly significant yield differences of 8.8% for Select and 10.3% for No 2A Common were observed between conventional and short-length lumber. These differences can be explained by: a) a shorter average length (i.e. the longer conventional-length lumber offers a greater number part combinations) and, b) the increased presence of wane and void. Results indicate, however, that there is little difference in yield, when comparing No.1 Common short-length to conventional-length lumber with appropriate cutting bills. Results also indicate that crosscut-first rough milling generates, on average, a 4.2% higher yield than rip-first rough milling. Analysis of the parts distribution indicates that high-grade lumber produces long wide components; scatter increases as grade quality decreases; and parts distribution for conventional and short-length lumber are similar.

Effects of microfibril angle and density on variation of MOE of *Cryptomeria japonica* logs among cultivars

Kana YAMASHITA[1], *Yasuhiko HIRAKAWA*[1], *Yoshitake FUJISAWA*[2], *Ryogo NAKADA*[3]

[1]*Forestry and Forest Products Research Institute, Ibaraki, Japan*
[2]*Forest Tree Breeding Center, Kumamoto, Japan*
[3]*Forest Tree Breeding Center, Ibaraki, Japan*

Sugi (*Cryptomeria japonica*) is used for structural timbers, often as poles or beams that include the pith. Its strength is graded according to its modulus of elasticity (MOE). It is important to study its variation and the parameters which effect MOE. There is large variation in MOE among cultivars, especially in the corewood.

The MOE of small Sugi clears has been explained by the two parameters, air-dry density and microfibril (Mf) angle using regression analysis. In this study, the cause of the MOE variation among cultivars was examined by measuring the density and Mf angle in the radial and height directions.

Three trees were selected from each of 18 cultivars planted in the same stand. The sample trees were 30 to 35 years old. The dynamic modulus of elasticity (Efr) was measured in each 2m log along the height by the tapping method. Discs were taken at 2m intervals and density measured by X-ray densitometry and by the floating method. The Mf angles of the S_2 layer in the latewood tracheids were measured at the 3th, 5th, 10th, 15th, 20th, 25th rings from the pith.

Variation patterns in the height direction: Efr: A) no change, B) increase with height and C) no change except smaller in the first log; air-dry density: A) no change and B) increase with height; Mf angle: A) no change both in the corewood and outerwood, B) decrease with height in the corewood, but no change in the outerwood, and C) decrease with height in both the corewood and outerwood. These patterns were almost the same among trees within cultivars, especially where the Mf angle decreases rapidly from pith to bark. The 18 cultivars were categorized into these variation patterns for Efr, air-dry density and Mf angle. We found the smaller Efrs in the lower parts of the stems were strongly affected by the of large Mf angles around the pith.

Variation among cultivars: Log values of Efr ranged from 3.6 to 9.9 GPa, the air-dry density from 0.30 to 0.47g/cm^3, the Mf angle in corewood from 20.5 to 49.8 degrees and the Mf angle in outerwood from 4.0 to 32.5 degrees. There were significant differences among cultivars in the Efr, Mf angle and density of logs at the same height. The differences were especially large in the first logs.

Effects of density and Mf angle: We examined the relationship of Efr with air-dry density and Mf angles in the corewood and outerwood. There were cultivars with high density and large Mf angles, high density and small Mf angles, low density and large Mf angles and low density and small Mf angles. The Efrs of the logs were less than 6.0GPa when the density was less than 0.35g/cm^3, or the mean Mf angles was greater than 25 degrees. The logs showed a relationship between Efr and Mf angle when the density was more than 0.35g/cm^3.

The cultivar characteristics of MOE were explained by density and Mf angle. Mf angle was as important as density, especially in explaining the patterns of MOE variation within the stems.

Modelling log yields by round wood product in one-centimetre diameter intervals as well as by log quality criteria

Nico MÖNNING

Global Forest Products, Sabie, South Africa

Global Forest Products is a grower/processor forestry organisation, permanently seeking ways to better utilise its softwood saw timber resource and to present the end product to the market in the most appropriate way.

In order to achieve this, whilst at the same time retaining flexibility in the market place, implies that the processors must have suitable and accurate data regarding the round log resource.

Over time a comprehensive growth and yield projection system has been developed which allows for the accurate estimation of the total timber yield of a compartment as well as breaking up this volume into merchantable log classes. Each individual log class can be presented in the form of a thin-end diameter size class distribution. Seeing that the majority of Global Forest Products' softwood saw timber resource has been pruned to at least 6.5 metres, it is also important to be able to estimate volumes for the pruned volume by log- and diameter class.

The above data has been available to our sawmills for two years, but we have been unable to predict the inherent quality of the logs in terms of accuracy of pruning (ie the actual expected yield of clear timber) and other internal defects. To this end a Pre Harvest Quality Assessment (PHQA) programme has been implemented. This process consists of two different sampling methods – destructive in-field sampling by cutting disks from the pruned section of selected trees or through sawing trials at the mill. Logistics determine which method is followed. After the PHQA has been completed, the data are analysed and each compartment is graded in terms of its expected clear wood recovery. Each compartment is also awarded a volume reduction grading factor based on the expected volume loss due to tree form abnormalities as well as internal timber defects. This factor is used during a more detailed phase of planning to adjust the previously empirically modelled data. By adapting one of the volume calculation parameters not only is the total volume adjusted to a more realistic level, but the log classes and diameters are also changed to reflect a more appropriate effective yield.

Still being a new system in an experimental phase it needs to be tested and adapted to provide the most accurate information to the mills. To close the gap between predicted and actual yields, an individual log bar coding system is being implemented so that all the logs can be traced back to source. This will enable one to send selected logs through the mill and establish whether the actual yield matches what was predicted. Individual bar coding will also make it possible to sort logs at the sawmill according to certain quality criteria so as to enable optimal sawing of the logs according to the requirements of the market.

Growth stresses in Beech: occurrence, modeling and prediction on the base of stand and tree parameters - consequences for processing, log and product quality

Gero BECKER, Thorsten BEIMGRABEN, Rüdiger MUTZ

Albert-Ludwigs-Universität of Freiburg, Freiberg, Germany

Growth stresses develop in the stem of trees as a result of static and dynamic forces induced by the weight of the stem itself and of the crown in interaction with the development of the wood tissue during growth. Some tree species, especially broad leaves like Eucalypts and Beech (*Fagus silvatica*) tend to develop significant internal stresses. This results in cracks, deformations and other negative quality features when the tree is felled and the wood is processed. Especially for high value utilization (sawn timber, veneer) growth stresses lead to significant losses in output, quality and consequently in economic terms. Several theories are discussed about the reasons why trees develop a higher or lower degree of growth stresses. Site (elevation, exposition, inclination), silvicultural management (competition), tree architecture (stem form, crown shape) and internal wood quality parameters (growth dynamic, reaction wood) are believed to be related with the development of growth stresses. There exist methods to assess the growth stress of standing trees and of logs by strain measurements. Also cracks which develop as a result of growth stresses after felling, can be used to quantify the level of internal stresses.

The objective of this European study focused on stresses in beech trees was

a) to asses the stress level and the stress distribution in horizontal and longitudinal direction of a stem by adequate field measurement methods
b) to find out correlation between selected parameters describing the site, the silvicultural management, the tree's architecture and the internal wood structure and the level of growth stresses, and to establish related models.
c) to analyze the effect of stresses within a log on the processing of high value beech wood and on the quality of the related products.
d) Based on these results, recommendations for a stress preventing silvicultural management and for a stress minimizing processing of stress containing beech logs should be given.

Basis of the empirical study were 500 beech trees, which were sampled in ten beech stands with different silvicultural history throughout Central Europe. The stress level of the trees was assessed by measuring the strain with the single hole drilling method. The results were correlated to various site, stand and tree parameters. Based on the results, models of stress occurrence and distribution could be established and recommendations for silviculturists could be given. 100 beech trees were felled and wood samples were taken for wood structural analysis in the laboratory. Full size logs were processed into high value sawn timber, rotary and sliced veneer and the effect of different stress levels within the logs on the production process and on the product quality was assessed. Recommendations for the design of stress minimizing production processes including drying and pre-treatment alternatives were given.

Growth rate and growth stresses in Brazilian Eucalypts: preliminary results of growth and quality modeling on a individual tree basis

Leif NUTTO

Institute for Forest Utilization and Ergonomics, University of Freiburg, Freiburg, Germany

Plantations of the genus Eucalyptus occupy approximately an area of 14 million hectares world wide, being more than 3 million hectares of this area in Brazil. The wood of eucalypts is mainly used for the production of fuel and pulp wood, but in the past few years there could be observed an increasing development of *Eucalyptus* based solidwood industry in the world. The reasons for this can be seen in a decreasing availability of hardwood timber from native forests in tropical countries, increasing demand for wood of higher quality and environmental concerns for the use of wood products of tropical rainforests and a movement towards the use of timber of certified and sustainable managed forests. Growth stresses probably constitute the most important growth phenomenon affecting quality and yield for Eucalyptus solidwood products. Defects associated with the release of growth stresses, like end-splitting and cracks, are considered the major problem while processing European Eucalyptus, resulting in end products of low quality with reduced mechanical properties and geometrical stability. Advances in genetics and innovative techniques for processing eucalyptus have reduced the problems of high growth stresses in the wood of eucalypts, but high quality lumber recovery still tends to be poor. A new approach for reducing growth stresses in individual trees is to adapt silvicultural management methods to the new requirements of the final wood products. In literature there can be found many hints that essential growth parameters are closely related to physical wood properties, including growth stresses.

In a first step diameter growth and self-pruning models for the important Brazilian Eucalyptus species *E. grandis* and *E. saligna* were developed. The material was collected from different Eucalyptus growing enterprises in Brazil, ranging between the latitudes of 17° to 30° South and between 39 to 53° East longitude. The data came from temporary sample plots each containing 35 Eucalypts. A crown projection map and a stem distribution map was constructed for each plot in addition to measuring various attributes of the individual trees. The results of the study showed that crown width is a good estimator of diameter growth and is closely related to stem diameter at 1.3m above ground (dbh). From this relationship a diameter growth model based on the growing space of the individual tree was developed, considering the impact of site quality. Beside this the prediction of the height above ground to the base of the crown using dbh, total tree height and age as predictors. With this model self-pruning dynamic of eucalypts can be predicted and influenced by the regulation of the individual tree competition. Prediction equations were also developed for maximal radial increment of stem at 1.3m. These prediction equations were used to model the development of the knotty core within Eucalyptus stems. Managers can use this model to guide silvicultural decisions needed to achieve a management goal of producing high quality wood.

In a second step the relation between growth rate and the distribution and strength of growth is intended to be analyzed. The working hypothesis is based on the fact that in the maturation process of wood cells the cell walls exhibit a natural tendency to develop axial contraction and tangential expansion. The reaction forces acting on the mature stem caused by the new cells in the growth layer yield residual stresses within the stem. The residual stresses within the stem accumulate as a superposition of the initial maturation stress state and the residual stresses generated by subsequent growth layers. The stresses developed by cell growth leads to tension stresses along the grain with the effect, that the stems can resist to strong mechanical impact like wind without compression failures. In circumferential direction compression stresses are found, enabling the tree to resist to frost or drought cracks. From a physical point of view it is evident that the growth rate of the tree influences the formation and strength of tension wood, leading to different cellular structures. To asses the impact of growth rate and growth stresses, data coming from two collectives of individual trees, subdivided in two variants with significantly different growth rates but same goal diameter were sampled. On 30 standing trees the tension wood was measured using the method of FOURNIER. After felling stem discs were taken at different heights and the most important parameters related to growth stresses like basic density, fiber properties and microfibril angle were analyzed at samples in direction from pith to bark and along the stem. The inter and intra-tree variations of this parameters were analyzed and compared to the tensions wood characteristics of the individual tree. This analysis forms the base of future wood quality modeling of eucalypts.

In a final step the results of step one and step two will be combined linked to a growth-quality model, considering the restricting factor for Eucalyptus solidwood production: defects associated with the release of growth stresses during processing. In a correlation analysis relations between growth parameters (age, dbh, height, crown projection area, crown length) and the above described anatomical and physical wood parameters are tested. The relationships are used to develop models and later on decision tools that form the base for new silvicultural strategies for managing eucalypts aimed at minimizing growth stresses and producing high quality timber.

A system of models for operative prediction of wood properties in Norway Spruce and Scots Pine

Lars WILHELMSSON [1], *John ARLINGER* [1], *Sven-Olof LUNDQVIST* [2] *et. al.*

[1] *SkogForsk, The Forestry Research Institute of Sweden, Uppsala, Sweden*
[2] *STFI, Stockholm, Sweden*

Studies of wood properties have been carried out with the objective to describe, model and utilise different sources of variation of Norway spruce and Scots pine. The main study material (Forest-Pulp-Paper project SkogForsk/STFI) comprised of sampled discs from different heights in trees of different ages, sizes, and site conditions distributed over Sweden. In total 252 trees from 42 stands of Norway spruce, and 120 trees from 20 stands of Scots pine were included. This material was used to develop models designed for prediction of basic wood properties in Swedish forestry. Diameter and the number of annual rings in a cross-section and temperature sum explain the following proportions of measured variation in wood properties of spruce and pine respectively: Basic density (50%, 59%), latewood% (52%, 54%), heartwood diameter (94%, 92%), juvenile wood diameter (85%, 79%) and bark thickness (76%, 85%). Random among-tree-variance dominated the remaining variation of density, and was considerable for latewood as well. This was in agreement with the importance of genetic variation indicated by the study of basic density for Scots pine. In general, only a minor part of the random variation was related to variance between stands. The number of annual rings was the most important variable for prediction of many properties. One study provides models for such predictions. The models were validated with data from two earlier studies of basic density, heartwood and juvenile wood. Within the range of expected prediction errors, the measured values were generally in agreement with the predicted. The models could be used in forest planning or by means of diameter measurements, tree age information and a bucking computer in a harvester. The differences in prediction accuracy for the various wood properties as a function of the accuracy of input data will be simulated by comparisons of measured and modelled input data.

Predicting wood properties of planted Loblolly Pine from pith to bark and stump to tip

Richard F. DANIELS[1], *Alexander CLARK*[2], *Ray A. SOUTER*[3]

[1]*Professor, Warnell School Forest Resources, University of Georgia, Athens, Georgia, USA*
[2]*Wood Scientist, USDA Forest Service, Southern Research Station, Athens, Georgia, USA*
[3] *Information Analyst, Rork Associates, Athens, GA*

Variation in wood properties follows identifiable patterns within individual trees of loblolly pine (*Pinus taeda* L.). Wood properties were sampled from disks cut at 1.8 m intervals from over 200 mature trees across the natural range of the species. Wood property and mensurational data will be used to develop predictive models describing the distribution of key wood properties in three dimensions. Patterns of wood properties such as wood density, moisture content, microfibril angle, and fiber dimensions will be described ring-by-ring from the pith to bark and vertically from stump to tip using mathematical models derived from wood sheath increment. Changes in patterns resulting from geographic and environmental variability will be discussed. Identifying and predicting properties of the juvenile core and the transition to mature wood will be examined. The availability of such models can lead to improved merchandizing decisions for trees and logs. The utility of these models will be demonstrated for determining wood properties for various portions of the tree that might result from different utilization patterns.

A timber quality model for Sitka Spruce

Barry GARDINER, Elspeth MACDONALD, Joanna FORBES

Forest Research, Northern Research Station, Roslin Midloth, Scotland

A model to predict the key wood properties controlling timber performance in Sitka spruce is being developed. This model will be used to guide potential timber utilisation from future supplies of spruce in Great Britain. The model, which will be coupled to an existing tree growth model, follows the methodology established by Leban et al. (1996) who have already successfully developed such a model for Norway spruce in France.

Data to support the development of the timber quality model have been obtained from a number of destructive sampling studies. To obtain information on wood density and grain angle we selected 9 trees at each of four spacings from two sites (Glengarry Forest and Kershope Forest). The Glengarry Forest plots were planted in 1935 at 0.9, 1.4, 1.8 and 2.4m spacings and the Kershope Forest plots planted at 1.8m in 1967 and subsequently respaced to 1.8, 2.4, 3.5 and 5.0m. At every spacing 3 trees were selected from the sub-dominant, co-dominant and dominant classes in order to cover the full diameter range. Discs of 2-4 cm were cut at 1.5m intervals from the entire length of the tree. The discs were air dried to 12% moisture content and scanned using a computer tomography (CT) system to obtain the density distribution across the disc. The CT scan data were analysed using an image analysis programme to obtain information on the mean, maximum and minimum densities for each ring along East-West and North-South slices, together with the ring width, distance of the ring from the pith and the overall mean disc density. The data have been used to create mathematical relationships for density as a function of ring width and age of the ring relative to the pith. These relationships are being validated against an independent set of density data obtained from Clocaenog Forest in Wales (Simpson and Denne, 1997). Additional thicker discs were cut at 3m intervals up the tree. The discs were split along an East-West axis and the grain angle measured every 5 growth rings by placing the split disc on a level base-plate and using an indicator arm attached to a protractor. Analysis of the data has shown a strong correlation between grain angle and inter-tree tree spacing.

Information on the knot distribution within the tree stem was obtained using the methodology developed by Colin and Houllier (1992). A total of 60 trees with ages from 13-65 years were sampled with once again the trees from each forest stand selected across the diameter classes. Measurements were made on every second growth unit from the tip of the tree. These included the branch location relative to the top of the growth unit, the horizontal and vertical branch diameters, branch azimuth, branch insertion angle, whether the branch was alive or dead and whether the branch was from the whorl or interwhorl. Currently the data are being analysed to form predictive equations for use in the Sitka spruce timber quality model.

The model itself is being developed as a set of Delphi objects within dynamic link libraries. This enables easy integration with other models, in particular existing Sitka spruce stand growth models (Matthews and Methley, 1999) as part of the Forest Research integrated Core Model programme.

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3D Internal tree structure modeling using Magnetic Resonance Imaging (MRI)

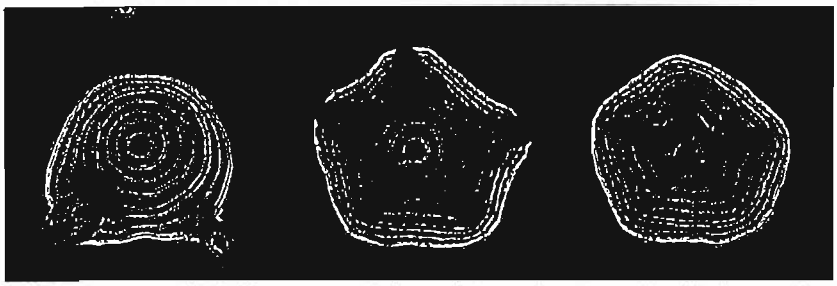
Paulina FERNÁNDEZ[1], *Sebastián MORALES*[2], *Andrés GUESALAGA*[2]

[1]*Department of Forestry, Catholic University of Chile, Santiago, Chile*
[2]*Department of Electric Engineering, Catholic University of Chile, Santiago, Chile*

This work is part of a research activity devoted to the optimum exploitation of the Chilean main forest resource: radiata pine (*Pinus radiata* D. Don). The overall objective is to model the effect of site, silviculture and genetic material on wood quality, considering variables such as knot distribution, size and shape, and annual ring width and shape (eccentricity and irregularities). To accomplish the latter, the modeling has been split in three parts. Model I is based on an architectural analysis of the tree, which includes: a) whorl (and knot) distribution along the trunk; b) number of branches per whorl; c) branch dimensions according to whorl's position in the annual growth of the trunk; d) internode length and, e) diametric incremental growth in annual units in the main axis, subject to site characteristics and forest handling. This model is based on Markov series and stochastic models.

The second part in the modeling, Model II, is aimed to describe the internal structure of wood in three dimensions, i.e. the geometrical relationships found inside the wood. Here, the variables are: a) knot phyllotaxis within the whorl; b) size relationships among knots in the whorl; c) knot profile as a function of their position and size in the whorl; d) shape of annual rings; e) size of rings, and f) ring irregularities due to branching.

Combining Models I and II, a 3D representation of the wood (Model III) is obtained, which takes account of the internal structure of the trunk and tree architecture. This final model is developed using Lindenmayer Systems. In this paper, the development of Model II is described, i.e. internal wood structure. Here, MRI (Magnetic Resonance Imaging) is used as an experimental tool. Radiata pine logs are analyzed using a Phillips 0.5T scanner. MRI has been preferred over other techniques such as X-ray tomography, due to the potential ability to identify wood constituents. Modeling is based on the data obtained from image contrasts (Hydrogen relaxation times T_1 and T_2 and density). Spacial resolution is 128x128 pixels.



Pixel intensity will be a function of water content and other hydrogen bondings (lignin and cellulose) at every location inside the wood. Elements such as annual rings are clearly noticeable due to density changes between spring and summer seasons. Knots are also detectable since their water content and molecular structure are different from that of clear wood.
Transversal scans are gathered together to form a sequence of images. Novel Finite Impulse Response (FIR) filters are applied to each image in order to identify rings and knot borders. The techniques take advantage of the *a priori* knowledge of wood (concentric structures of rings and radial knot progressing) to define rings and knots more precisely. Filters are designed to search for the known patterns of rings and knots, so the result is a clearly segmented image ready to be processed with the rest of scans in order to reconstruct the 3D picture.

Once all images have been processed and segmented in two binary levels, an integration of the whole longitudinal sequence is performed. This processing performs correlations between adjacent images using standard *thin-plate* techniques, obtaining 3D surfaces, which represent concentric rings and well defined knots. From this 3D information, the wood structural parameters listed above can be readily measured and analyzed.

Preliminary results obtained via this technique are feeding a model based in Lindenmayer Grammar, where the main variables extracted from the architectural analysis are internodal length, number of branches in whorl, characteristics of whorl (with or without cones, according to its position in the yearly growth unit) and diametric incremental growth of trunk. Information obtained from the scanner such as knot and ring shapes and sizes as a function of their relative position to the whorls are injected in the Lindenmayer model. Initial analysis of data, have shown the existence of interesting geometric relationships around knot locations, that will eventually facilitate modeling considerably. The method proposed in the paper provides a fast, simple and non-destructive tool for wood data acquisition. It also allows for cut planes, different from the transversal one.

Finally, Nuclear Magnetic Resonance is a powerful tool in spectroscopy analysis that could impact MRI by providing 3D information on material distribution (like cellulose and lignin) inside wood. Although it is not covered in the paper, this unique characteristic will be explored in future work.

Predicting branch properties of Silver Birch (*Betula pendula* Roth.) from simple stand and tree properties

Harri MÄKINEN[1], Risto OJANSUU[1], Pentti NIEMISTÖ[2], Jari HYNYNEN[1]

[1]*Finnish Forest Research Institute, Vantaa Research Centre, Vantaa, Finland*
[2]*Finnish Forest Research Institute, Parkano Research Station, Parkano, Finland*

The aim of this study was to develop simple and logical models that could be applied as a part of growth simulation system. Data were collected from planted pure silver birch (*Betula pendula* Roth.) trees growing on abandoned agricultural land and forest sites of different fertility, stand densities, ages and canopy positions. They were used to develop multivariate generalised linear variance component models for (1) crown ratio, (2) dead crown ratio, i.e. height of the lowest dead branch divided by the height of crown base, (3) number of living branches along the stem, (4) total number of branches, (5) diameter of the thickest branch, (6) diameters of smaller branches, and (7) branch angle. The independent variables of the models were restricted to those measured in forest inventories and for forest management planning purposes. In Finland, models describing the branch properties of Scots pine (Mäkinen and Colin 1998, 1999) and Norway spruce (*Picea abies* (L.) Karst.) (Mäkinen et al. 2001) have recently been developed. The models of this study were developed according to the same principles than those for Scots pine and Norway spruce to ensure comparability of the predictions for different tree species.

Random variation of the dependent variables was divided into variance components at stand, plot, tree, stem section and branch level. In addition, the traditional linear models are not appropriate for binomial variables as branch status (living, dead). Such data can be modelled using the generalised linear models (GLM). GLM consists of a linear function and of a non-linear link function that describes how the expected value is related to the linear predictors. GLM also allows the probability distribution of the response variable to be any member of the exponential family of distributions. Because different branch characteristics are correlated, the models also have correlated errors. The efficiency of the estimates was improved by taking these correlations into account. Multivariate models provide techniques to produce consistent and asymptotically efficient estimates for systems of regression equations by estimating the parameters of the equations simultaneously

In the independent evaluation data set, the models were in most cases unbiased, but they overestimated self-pruning rate and diameters of the thickest branches at the lowermost part of the stem. No major additional bias was found, when the models were applied for the other native birch species, downy birch (*Betula pubescens* Ehrh.). Even though bias in predicting some branch properties, the behaviour of the models was logical and they provide a framework for predicting branch properties along the stem from usual stand and tree measurements.

The models of silver birch were connected to a statistical growth simulation system MOTTI (Salminen and Hynynen 2001). The combined system can be used for assessing the development of wood quality and possibilities of silvicultural treatments to control branch properties. Effects of different thinning regimes during the stand rotation on wood quality were compared based on the simulated stand development. Four different thinning programmes were defined. The yields and quality distributions were calculated and simple economic calculations made in order to compare the profits of the different thinning programmes.

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Vertical profile of branch and knot sizes in young coastal U.S. Douglas-fir trees from plantations

Olav HØIBØ[1], *Eric TURNBLOM*[2], *David BRIGGS*[2]

[1]*Agricultural University of Norway, Department of Forest Sciences, Ås, Norway*
[2]*University of Washington, College of Forest Resources, Seattle, Washington, USA*

Several studies describing different aspects around crown recession and branch distribution have been carried out on Douglas fir. Models describing basal diameter and vertical distribution of primary branches have also been developed. But the studies have mainly been done on young stands before crown closure. Models describing vertical profiles of knot diameter and sound knot lengths for trees where the crown recession, and therefore the quality of the lower part of the tree is given, have not yet been developed for Douglas fir.

The aim of this study was to describe vertical profiles of knot diameters and sound knot lengths for young coastal US Douglas fir trees, and to examine the possibility of developing models similar to those developed in Scandinavia on Norway spruce and Scots pine.

28 trees from four plots, two from a fairly high site index and two from a fairly low site index were sampled. The average tree age was 21 years in breast height, and the mean crown height was 10 m.

The vertical profiles of knot diameters and sound knot lengths were first modelled for each tree. The vertical profiles were calculated as random coefficient models, where the parameters were described with one fixed part common to all trees and a random part varying from tree to tree. In a second step the parameters in the vertical models were modelled by tree-level and stand-level variables.

The study showed that models similar to those for Norway spruce and Scots pine are possible to develop. A variable describing stem diameter increment, for instance in breast height, is the most important independent variable describing knot structure differences between trees in a stand. In addition variables describing differences between stands are important to include, for instance site index.

Relationship between branch diameter growth and stem growth in young, coastal US Douglas-fir

David BRIGGS[1], *Eric TURNBLOM*[1], *Olav HOIBO*[2]

[1]*University of Washington, College of Forest Resources, Seattle, Washington, USA*
[2]*Agricultural University of Norway, Department of forest Sciences, Ås, Norway*

Essentially all of the crown profile models in the literature for predicting the size and distribution of branches in a tree, which become knots affecting the quality and value of logs and products, can be characterized as static, descriptive models. That is, branch characteristics of a tree are predicted from other measures of the tree geometry, perhaps augmented by stand-level measures such as stand density and site quality. These static modeling efforts have provided valuable insights concerning which variables are important predictors in providing a "snapshot" view of a tree at some point in time and have been incorporated in some individual tree growth models as a basis for estimating new branch characteristics of trees after they have grown through time, perhaps in response to some combination of treatments such as thinning, fertilization, and pruning. It is known that such treatments can alter the distribution of growth along the stem as well as mortality in the stand. It is very likely that these treatments similarly alter the pattern of branch diameter growth and mortality within trees. In such cases, applying static, descriptive branch profile models may be inaccurate and misleading. While it may be possible to incorporate one or more measures of growth as well as treatment indices into the static models, an alternative is to develop growth models for branches in trees. In this paper, we present preliminary results of empirical regression and differential equation approaches for modeling diameter growth of branches in coastal US Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) trees.

Fast algorithm calculating trunk and branch ring widths in tree architecture

MengZhen KANG[1], *HongPing YAN*[1], *Philippe DE REFFYE*[2],
Marc JAEGER[2], *Jean-François BARCZI*[2], *BaoGang HU*[1]

[1] *National Laboratory of Pattern Recognition. Institute of Automation, Chinese Academy of Sciences, Beijing, People's Republic of CHINA*
[2] *LIAMA - Sino-French Laboratory of Computer Science, Applied Mathematics and Automation*

Stem ring width is one of the major parameters used to characterise and model wood quality. Our research focuses on tree growth modeling and simulation using architectural and functioning approaches. Ring width computation is then a resulting output from simulation process. In this paper, we describe a new method that allows very fast biomass repartition computing in the stem.

In fact, the growth of the tree includes two aspects: organogenesis and photosynthesis. The first one provides the number of organs in tree architecture, i.e. the sources and the sinks. The second aspect provides the biomass of the plant, i.e. the volume and the weight of the organs. Organogenesis is under the control of a genetic program that generates the architectural model, simulated in our model by an automaton, and photosynthesis is simulated from plant water transpiration, using the water use efficiency (W.U.E.). 3D Plant simulation, based on discrete events methods, has to control all buds; in a single tree, hundred of thousands of buds may be processed. So these simulations have heavy costs in terms of CPU time and memory space.

In our new approach, the use of substructure instantiation, which means that a same pattern (in sense of organogenesis and functional behavior) may be repeated many times in tree architecture, can save a lot off simulation time and memory.

In this article, we briefly present the substructure approach. It is based on a hierarchical tree analysis that includes functioning process. We explain then how we apply this model to compute the stack of rings in the tree trunk (and branches) according to the Pressler law and Shinozaki assumption. This corresponds to a uniform distribution of the assimilates along the path defined from the leaves to the root system. The algorithm enables to calculate the biomass repartition in the internal wood of the whole tree structure, including effects of environment variations during the plant growth (temperature and water supply especially). Simulations, and more precisely resulting ring widths at any trunk internode, define a useful output for a wide range of applications, from forestry resource evaluation to wood quality purposes.

Tests performed on Cedar-like architectural models gave very interesting results. Computation time drop down from more than an hour to less than one second for same results for a single tree. So, that makes complete exhaustive plantation and natural forest growth and functioning simulation be a realistic goal.

Further works will be focused on model calibration for real tree data fitting on one side, and introduction to stochastic substructure instantiations on the other side.

Prediction of 3D stem structure from simple sample tree measurements using empirical models and the PipeQual simulator

Annikki MÄKELÄ[1], *Harri MÄKINEN*[2], *Arto USENIUS*[3]

[1]*Department of Forest Ecology, University of Helsinki, Helsinki, Finland*
[2]*Finnish Forest Research Institute*
[3]*VTT Building Technology*

PipeQual is a wood-quality application of an eco-physiologically based dynamic growth model. It was developed to simulate the branchiness and other timber quality characteristics in trees of different sizes, and parameterised for Scots pine in.Finland. The model grows trees on the basis of resource capture and allocation of growth within and between trees in the model stand, producing 3D stems in different size classes at any point of the stand history. The model consists of a hierarchy of modules for tree, whorl, and branch level growth. The tree and whorl level follow a causal structure, but the branch level utilises empirical submodels. The model has been applied to the prediction of the development of internal stem structure and quality distributions as a function of silvicultural treatments in stands that have been simulated from regeneration onwards, and the method has been thoroughly tested for size distributions, stem taper, and branchiness.

This paper is concerned with another application of the model, where the quality distribution of an existing stand is predicted from indicator data measured from the stand, possibly amended by information about the silvicultural history of the stand. This is done by improving the initialisation routine of the model, and by conducting a preliminary test of the procedure. Initialising the model generally requires information about the diameter (or height) distribution of individual trees and data about tree height, crown base, DBH, and height of the lowest dead branch by size class. These data are used to generate the stems with the aid of empirical functions concerning the regularities in tree structure, including the pipe model and several empirical functions for the size distribution of individual branches in a whorl when total branch basal area per whorl is known, branch compass and insertion angle, and pruning of branches below the live crown. In addition to these equations, backward simulation is applied to generate the internal structure of the stem below crown. The backward simulation can take into account the silvicultural history of the stand, if available.

The method is tested using data collected and analysed by VTT Building Technology from Scots pine stands. The stem distribution is generated by the model using sample tree data collected from these stands as input. The same stems are sawn into 2 cm flitches that are scanned for branchiness and used for producing a computerised representation of the measured stems. Both measured and modelled stems are sawn in the WoodCim sawing simulator developed by VTT Building Technology, and the resulting quality distributions of modelled and measured stems are compared. The results of the comparison will be used for further development of the model.

Modelling crown morphology and wood characteristics of coastal Western Hemlock (*Tsuga heterophylla* [Raf.] Sarg.) in British Columbia

James W. GOUDIE, C. Mario DI LUCCA

Growth and Yield Applications Specialist, Research Branch, British Columbia Ministry of Forests, Victoria, BC, Canada

Coastal western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) is one of the three most important tree species in BC. It accounted for 8.09 million m^3 or 31% of the volume harvested on the coast in 1999/2000 (Ministry of Forests, 2000). Most came from old-growth forests although the resource is gradually shifting to managed second-growth forests. In the future, industry will derive most of its hemlock from second-growth stands. This transition must be supported by improved understanding of the technical characteristics and wood attributes of western hemlock to ensure the success of silvicultural investments and marketing strategies.

The impact of silvicultural activities on wood quality of coastal western hemlock in BC has been documented by Jozsa et al. (1998), Ellis (1998), Goudie (1999), and Middleton and Munro (2001). For instance, stands with wider spacing resulting from lower initial establishment densities, or intensive thinnings, will generate wider and longer crowns that will produce a greater proportion of earlywood, lower relative wood density, and more juvenile wood. The relationships between the morphology and variation of hemlock crowns and their effect on wood quality need to be better documented.

This report is one component of a large western hemlock project initiated in 1997 by J. Goudie (1999). The main objective of the project is to upgrade the decision making system SYLVER (Mitchell et al., 1989; and Kellogg, 1989), to help foresters better manage second-growth hemlock stands for both volume and value. A total of 86 forest-grown trees from four age classes (i.e., ranging from 20 to 90 years) were sampled at four geographic locations in coastal British Columbia. We intensively sampled each tree to characterize its foliage (i.e., leaf area and biomass), branches (i.e., distribution, size, and growth), and bole attributes (i.e., height growth, annual rings - width, area, proportion of earlywood, relative density of earlywood and latewood).

The proposed paper will report on the modelling of the distribution of crown characteristics (biomass or leaf area) and four annual ring characteristics: a) total area increment, b) percent of earlywood, c) earlywood relative density, and d) latewood relative density. These relationships will upgrade the Tree and Stand Simulator (TASS) (Mitchell, 1975), a component of SYLVER (Mitchell et al. 1989), to simulate hemlock crown characteristics and wood quality resulting from different silvicultural treatments.

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Predicting the effect of overstory density on crown structure and wood quality in multi-cohort Ponderosa Pine stands

Ryan SINGLETON, Douglas A. MAQUIRE

Department of Wood Science and Engineering, Department of Forest Resources, Oregon State University Corvallis, Oregon, USA 97331

Ponderosa pine generally produces a single whorl of branches near the tip of each annual shoot comprising the main stem and crown segments. Under full sunlight, annual height growth and corresponding interwhorl distances can reach 1m, but increasing shade and poorer site quality can result in very short interwhorl distances. As interwhorl distances shorten, the number of buds that are set and the number that flush and grow into branches diminish. Under this condition, the crown changes from having a structure dominated by distinct whorls to a structure in which branches appear distributed individually in a spiral pattern around the stem. These responses raise two major issues about the management of multi-cohort ponderosa pinein eastern Oregon. First, the need to lower fire hazard by reducing stand density is widely recognized in the western U.S.; yet, the economic feasibility of removing small diameter trees forming dense understories in pure, multi-cohort ponderosa pine stands relies on an uncertain ability to utilize material grown under low light conditions. If the suppressed crown structure characterizing these trees results in wood of inferior quality, the economic feasibility of removing small diameter trees over large areas becomes problematical. Second, management of ponderosa pine in multi-cohort stands has been advocated as an alternative to even-age management, yet the potential influence on wood quality has not been fully explored. The primary branching structure of ponderosa pine grown under various multi-cohort structures was simulated with a growth model. The structures included two-tiered stands with three different overstory densities, three-cohort stands with two overstory and two midstory densities, and four-cohort stands with two overstory, twoupper midstory, and two lower midstory densities. Inferences drawn from the the stand simulations suggest the scarcity of clearwood on undestory stems with a suppressed crown structure, and the difficulty of maintaining uniform ring width as understory stems are released.

Influence of the stand parameters in the wood properties, modeling wood density and wood shrinkage through stand and tree parameters of *Quercus robur* L.

Rolando Coro GONZALEZ, Marcos Barrio ANTA, Ignacio Javier DÍAZ-MAROTO

Departamento de Ingeniería Agroforestal Universidad de Santiago de Compostela, Lugo, Spain

Wood density (WD) and wood shrinkage (WS) are high wood quality indicators, which are an important index of the dimensional stability of wood and wood products, their influence both wood processing and end use is relevant. The problems in the processing and drying could be caused by many factors because the logs processed tend to have diverse moisture content resulting in a different dimensional performance.

Trying to get a future visual classification of the wood, according to its dimensional stability and establishing different drying and transformation process, this study tended to estimate these properties by collecting forest information (Stand parameters) and Tree data (Tree parameters).

Different trees of *Quercur robur* L. were sampled in the Norwest of Spain and separated in different groups according to (Plot, Tree and height). The discs were taken at different height levels of the stem from 0.30m with an interval of 1m, the disc were cut in different cubes (20mmx20mmx40mm and 4mm0x40mmx20mm) to determinate the wood density and wood shrinkage. The cubes were preliminarily classified in three classes: H. Heartwood, S. Sapwood and SH. SH is a medium classification, to analyze the differences between heartwood and sapwood.

The collection of data may vary with different situation, for example collecting inventory data when planning a sylvicultural activities, the measures of the different parameters for each group were:

Plot (bisymmetric area, dominant height, medium height, number of tree per hectares, site index), Tree (Competence index "BAL", volume outside and inside bark, diameter at 1.30 meters, diameter at the beginning the first branch, height, taper function), Height (Relative height and diameter).

In all situations, the knowledge of the structural variation of each properties (estimate variance components, correlation between properties etc.), is essential. The experimental project consists in three blocks, the difference in both regarded properties is significant.

Generally stand and tree parameters are not directly related with any wood properties. Mathematical transformations were developed to improve its correlation. Individual regression equations were established for estimating de WD and WS with those transformed variables. About half of the variation of the wood properties could be explained through those models.

The second phase of this work analyzes the variability along the stem of WD and WS, they are not consistently distributed in the stem. In this study we will show how the WD and WS are distributed in the stem and how they vary from tree to tree and to plot to plot related to the stand and tree parameters examined.

Our objective are to develop a model useful for wood harvesters to estimate this properties in standing trees.

Distortion models based on variation in material properties

Marie JOHANSSON, Magnus BÄCKSTRÖM

Department of Structural Engineering – Steel and Timber Structures
Chalmers University of Technology, Göteborg, Sweden

Massive research energy has been devoted to the subject of distortion during the last ten years. Distortion causes problem for the building industry to utilize distorted timber in a mechanised process. This has lead to an increased use of steel sheet products and other substitute materials in the structure of newly built houses. The understanding of the phenomena of distortion, methods to predict distortion and, in the next stage, process the timber material in a way that minimize the distortion is an important step to take back and increase market shares for timber products. This paper will show models how to predict and model distortion based on measured material properties. The main focus in our research has been on studying which material properties affect the shape stability of Norway spruce timber. The results presented in this paper concern the propensity of the wood material to distort. All changes in moisture content of the material included in this study are carried out without restraint. This is made to avoid influence of gravity and restraint and only study the effect of the properties of the wood material.

For this project 8 studs (4 with dimensions of 45 x 95 x 2500 mm and 4 with dimensions of 45 x 120 x 3000 mm) were chosen. The distorted geometry of these studs was measured every 5 centimetre along the length of the stud at two different moisture contents, 17% and 11% respectively. In this way it was possible to register the actual shape and the change in shape due to moisture content changes. After measurement of the shape, the whole studs were sawn into sections (45 x 95 (120) x 200 mm). These sections were then sawn into 3 by 8 (10) sticks (10 x 10 x 200 mm) from each section. The longitudinal shrinkage of these sticks was measured for a change in moisture content from 17.5% to 7.5%. For a portion of the sticks also tangential and radial shrinkage were measured. Spiral grain angle was measured along the whole length of the studs and was also registered at three depth levels in the stud. This resulted in a very detailed knowledge about the variation in material properties and was also a good foundation for detailed models of the shape of the studs.

This paper will show a successful modelling of bow and spring based on the variation in longitudinal shrinkage along the length, thus showing that variation in longitudinal shrinkage is the main cause of bow and spring. The longitudinal shrinkage variation over each section was used to model the distorted geometry of the sections. The sections were then connected with their end planes against each other and in this manner the distorted stud was built up. The modelled bow and spring are in good agreement with the measured change in bow and spring. The results showed that the variation in longitudinal shrinkage within each section and between sections can explain the change in bow and spring between these moisture contents.

For twist, it has been shown that the main reasons for a high magnitude of twist in studs are grain angle in combination with annual ring curvature. The most twisted studs were sawn close to the pith (large annual ring curvature) with large grain angle. These two parameters explain up to 70% of the variation in twist with a multiple linear regression model. A detailed model for twist in studs has been made based on the theory of twisting of thin cylindrical shells. In this model the deformation of each annual ring was calculated due to its geometry, grain angle, tangential and longitudinal shrinkage. The deformed annual rings are then coupled together to form the geometry of the distorted stud. In this way it was possible to calculate the twist of the stud based on the variation in material properties for each annual ring layer. The calculated twist was compared to the measured twist variation over the length of the stud and good agreement was obtained

Mechanical properties of Norway Spruce lumber from monocultures and mixed stands - modelling bending strength and stiffness using stand and tree characteristics

Erlend Ystrøm HAARTVEIT, *Per Otto FLOTE*

Norwegian Forest Research Institute, Ås, Norway

Mixed stands of Norway spruce (*Picea abies* (L.) Karst.) and one or more species of broadleaves are getting increasingly common in Scandinavian forests. This is partly because clear-cutting is the predominant method for harvesting. Silver birch (*Betula pendula* Roth) and downy birch (*Betula pubescens* Ehrh.), that rapidly colonise clear-cut areas, were earlier considered an obstacle to regeneration of Norway spruce. Birch was often entirely removed using chemical or repeated mechanical methods to enhance spruce regeneration. In recent years, the use of chemical methods has decreased, and methods for partial removal of birch are increasingly applied.

From the perspectives of biodiversity and landscape aesthetics, the increasing proportion of birch occurring in stands of conifers has been considered positive. Positive effects of birch, when grown in mixtures with Norway spruce have also been proposed concerning wood properties and volume production of sawlogs. Knowledge about wood properties of Norway spruce grown in mixed stands is sparse. The present study analyses differences in wood properties of Norway spruce structural lumber from mixed stands and monocultures. The material is sampled from stands in Finland, Sweden and Norway.

Structural lumber is the main group of solid wood products produced from Norway spruce. Different sorting systems are applied at different points along the chain from forest to sawmill. However, these systems have restricted abilities to take into account the mechanical properties of the lumber. If non-destructive input data can be used to successfully predict strength properties of structural lumber, sawlogs can be sorted according to the predicted bending strength and stiffness of the lumber. A second objective of this paper is, therefore, to evaluate the potential for predicting bending strength and stiffness of structural lumber using stand and tree characteristics, measurable prior to harvesting.

The results from the analysed material show that bending strength and stiffness do not differ significantly for lumber originating from mixed stands and monocultures. Other wood characteristics, that are correlated with strength properties, such as wood density, annual ring width and knot size were also analysed, however, no significant differences between mixed stands and monocultures were detected. When modelling relationships between measurable tree characteristics and strength properties, using simple regression models, similar relationships were found for spruce grown under both conditions.

Various stand and tree characteristics were analysed by using multivariate statistical methods to identify characteristics that contribute significantly in models predicting bending strength and stiffness of structural lumber. Important variables when modelling bending strength and stiffness of the lumber were vertical position in the tree, distance from ground to the base of the living crown, and age of the stand. Although the explanatory power of the models are limited, evaluated by the coefficient of determination, their ability to classify logs according to bending strength and stiffness of the lumber is high.

It is concluded that for Norway spruce the wood properties with respect to bending strength and stiffness do not seem to be significantly different when comparing monocultures with mixed stands. Hence, the presence of birch does not seem to affect the wood properties of Norway spruce *per se*. Competition resulting from the distribution of trees and their relative sizes are likely of higher importance than the presence, or non-presence, of particular tree species. This simplifies the situation when modelling wood properties, and potentially increases the opportunities to generalise the models.

When modelling bending strength and stiffness using information available prior to lumber manufacturing, the low explanatory power found for the models was expected. The coefficient of determination for models of bending strength are considerably lower when using stand and tree characteristics than for models using lumber properties, such as the modulus of elasticity. However, when applying the models for classification of logs according to predicted strength properties of the lumber, the models manage to detect a high percentage of logs yielding lumber with high bending strength and stiffness. The models are also able to identify logs yielding lumber with poor strength properties, implying that such logs can be excluded from best log-classes. Hence, differentiation of the raw material is possible, which, in turn, may increase the abilities of the log producer to deliver logs according to customer specifications.

Predicting the applicability of Scots Pine (*Pinus sylvestris*) harvested in thinnings to the raw material of mechanical wood processing

Reeta STÖD

Finnish Forest Research Institute, Joensuu Research Centre, Joensuu, Finland

In Finland, the first commercial thinning should be carried out on an area of more than 200 000 hectares every year. However, only half of this area is actually thinned, mainly because of the high costs and small yields, even though default on a thinning causes loss of growth and decreases average stem size and future's felling quantities. Besides the first commercial thinning, 1-2 intermediate fellings are normally done during the forest rotation period. So far, timber harvested in the first or the second thinning has not been widely used in the mechanical wood processing. One of the reasons for this is that for the wood product industries, there has been enough timber available from the final fellings. Additionally, the great percentages of juvenile wood and compression wood in young trees decrease profitability in upgrading. In a normal thinning trees of the poorest quality are removed, and among those the stems that meet the requirements set by the wood product industry must be found; this is a major problem in the utilisation of thinning wood.

The aim of this study is to determine how much timber suitable for mechanical processing is available from thinnings, and which are the factors that affect on its yield. Most of the data was collected in the year 2000 and it consists of 200 pine stands in which the 1st or the 2nd commercial thinning could be done. The stands were situated in the procurement areas of five Finnish sawmills in the Eastern, Western and Northern Finland. More than 8000 sample trees were measured in the forests, at least 40 sample trees from every stand. In addition, the data was completed with the applicable parts of two research data which were collected 1-3 years earlier from 104 pine stands in Southern, Eastern and Western Finland using similar measurement methods.

From the standing trees, the breast-height diameter, height, crown height, height of the lowest dead branch and diameter of the thickest dead and living branch were measured. All the defects noticed in the trees were taken into account as well as their starting points and ends. In addition, the starting points and the ends of the stem parts that filled the quality requirements set by the sawmills were written down. Besides stem properties, the data includes stand properties e.g. basal area, site type and regeneration method.

A real thinning will not be put into practise in this study. The trees that should be harvested in an ordinary 1st or 2nd thinning are chosen from the data using a computer software, specially made for the projects dealing with the thinning wood, that utilises thinning models presented by Niemistö (1992). The criteria for selecting the trees that should be removed are the breast height diameter, the height and the defects observed in the trees. Taper curves of the removed trees were calculated using the taper curve functions based on the breast-height diameter and height (Laasasenaho 1982). The computer software utilised in the laying-off takes into account the taper curve of the stem, the defects and the proportional values of different timber assortments. Laying-off is based on the proportional values of timber assortments, as the objective is to get the most valuable assortments as much as possible.

As a result, one will have the removal and its structure, the distributions of the size and the quality of the logs and the factors affecting on those, i.e. the stand and stem properties. The preliminary results show that when cross-cutting is carried out according to the common definition of the timber assortments, in which a log is considered to be 3,7-6,1 metres in length and at least 14 centimetres in diameter, the proportion of the removal suitable for mechanical processing will be low. Calculated from the data of this study its yield was 2 m^3/ha at the most in the 1st thinning and 12 m^3/ha in the 2nd thinning. When smaller dimensions, for example small logs that were 3,1 metres in length and 9-12 centimetres in diameter, were allowed, the maximum yield was 8,5 m^3/ha in the 1st thinning and 17 m^3/ha in the 2nd thinning.

Defects, especially crooks and sweep had a strong effect on the proportion of the timber that can be utilised by wood product industries. However, especially when the first thinning is concerned, dimensions of the trees set limits to the use of thinning wood. In sawmills, for example, separate machinery is demanded when thinning wood is used as a raw material in sawing. Besides the defibration, new targets of usage must be developed for the thinning wood. Sawn timber with sound knots is excellent raw material for e.g. furniture industry and visible gluelam wood compositions. When the knots are dead, thinning wood can be utilised e.g. in packing systems and invisible gluelam wood compositions.

Tree growth and wood quality of valuable broadleaved species (*Acer pseudoplatanus*, Fraxinus excelsior) in Europe: construction of decision tools

Sebastian HEIN

Institute for Forest Growth, Alberts-Ludwigs-University Freiburg, Freiburg, Germany

Some years ago forest management in Europe became aware of the high growth and value potential of the indigenous valuable broadleaved species European Ash and Sycamore Maple. This led to a considerable increase in regenerated area for these species. Despite of the rising interest in these species few quantitative information on growth dynamics is available.

The main questions associated with management of Ash and Maple have their origin in their growing situation which are mostly mixed stands with European Beech. Reaching the targeted wood quality, high final stem diameter and mixtures are often not possible due to insufficient knowledge or disregard of their typical growth pattern in comparison with Beech. To get better quantitative estimates for growth of European Ash and Sycamore Maple and therefore to enable single-tree growth control in mixed stands data sampling on a broad regional base in Europe has been conducted.

Data related to height growth and crown expansion dynamics, branchiness and diameter growth have been collected in 13 European countries. Data from stem analysis and height shoot measurement were used to describe height growth. To assess inter-tree competition on radial growth the radial increment from stem discs of several heights and stem and crown distribution maps for each sample have been analysed. Using these data three models have been developed to set up a valid growth model for both species at a single-tree base, flexible for a broad range of ages and various management practices. First a nonlinear model on height growth has been fitted with special emphasis on early height development, second a model describing wood quality such as internal branchiness and length of the branch free bole and finally a third model on diameter growth dynamics.

From these models decision tools for producing high valuable timber depending on site quality, diameter growth and aspects of wood quality have been elaborated. In contrast to Beech management of Ash and Maple should pay more attention to early stages of tree development due to the fact that reactivity of height growth and crown expansion is declining at an early time. High stem diameter targets within a short rotation time can only be reached if high diameter increment potential at young ages is taken into account. The decision tools are also integrating interactions between diameter growth and branch free wood which is considered as one of the most important criteria for high value wood production. Because of the fast natural pruning dynamics and the enormous height increment in young ages a certain length of the branch free bole is reached at an very early time. Results on the base of these growth models are summarized in form of graphs and tables in order to give easy usable decision tools to forest management for mixed stands with European Ash and Sycamore Maple.

Improvement of growth and yield simulator Fagacées: quantifying various thinning options for silvicultural optimization.

Jean-François DHÔTE, *Gilles LE MOGUÉDEC*

Laboratoire d'étude des Ressources Forêt-Bois, Champenoux Cedex, France

Optimizing silvicultural schedules in broadleaved high forests requires to take into account the specific features of such stands and thinning practices. In French Oak and Beech management, individual tree quality is a major criterion for marking thinnings ; furthermore, crown thinning has proven the best way to achieve selection for quality and efficiently promote growth of elite trees.

In these species, a large part of the commercial value for the whole rotation lies in the first basal meters of the final harvest trees' logs. In addition, wood quality is strongly influenced by silviculture, although in opposite directions for the two species (much better quality for fast-growing Beech trees, due to reduced growth stresses ; highest quality in slow-grown Oaks, due to narrow, homogeneous rings, bright colour and better physical properties). Hence, silvicultural optimization requires that (i) a sufficient degree of individual-tree information be provided by growth models (diameter, crown base, stem taper, history of radial growth) ; (ii) the impact of thinnings of various types (incl. crown thinnings) on stand structure be taken into account.

Growth models designed to evaluate, compare and optimize thinning strategies for these situations are distance-independent individual-tree models. *Fagacées* is the generic name of the 2 models built for *Fagus sylvatica* L. and *Quercus petraea* Liebl. in our team.

Past work on silvicultural optimization mainly addressed fast-growing conifers tended for structural timber, and used stand level models. In the frame of a larger programme on Sessile Oak (see Nepveu *et al.*, 2002), *Fagacées* will be used and needs to be adapted. In previous software releases, silviculture was simulated "by hand", through graphical handling of diameter histogrammes at each time of thinning. In order to allow hundreds of simulation runs, specific routines were created to simulate automatically all possible types of thinnings : thinning weight and rotation defined by schedules of stand density before and after thinning ; crown and low thinning, self-thinning, or any mixture of these basic types, the degree of mixture being flexible along stand's life (*eg* crown thinning at pole stage *vs* low thinning at maturity, etc...).

In the communication, the present state of the silvicultural simulator is presented, and a series of preliminary simulations is commented with regard to current questions on broadleaved forest management.

Efforts for integration of models in France and benefits for the end users

C. ORAZIO[1], F. DE COLIGNY[2], Celine MÉREDIEU[3], Laurent SAINT ANDRÉ[4]

[1]*European Institute for Cultivated Forest (IEFC) – Site de recherche Forêt Bois, France*
[2]*BotAnique et BioinforMatique de l'Architecture des Plantes Montpellier Cedes, France*
[3]*Institut National de Recherche Agronomique (INRA) - Site de recherche Forêt Bois, Gazinet, France*
[4]*Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), Montpellier, France*

As a consequence of the development of modelling activities within the scientific community, there is a large number of available models which need to be integrated and to be adapted in order to facilitate access for forest managers. We will illustrate two french initiatives to improve this transfer through a forestry models database and a software aimed at studying the stands growth and dynamics called Capsis.

A database «models for forest» is hosted by the European Institute for Cultivated Forest (www.iefc.net) which is a consortium of european research institutes working on forestry science. An Internet online form allows every volunteer modeller to reference his own models in this international information system. Some keywords can be associated to each model, according to its kind (growth, dynamics, wood quality...), species, inputs and outputs, authors country and organisations. Open fields can reference websites, bibliography elements and contacts.

In the paper's second section, we will discuss the Capsis platform's architecture. Capsis - Computer-Aided Projections of Strategies In Sylviculture - was designed by some french forestry modellers to share their expertise and resources, and ease knowledge transfer towards forestry managers. This open software can host different kinds of models (stand models, distance-independent or dependent tree models...). Many tools can be added to simulate interventions (thinning, fertilization...) and view the effects of the simulation. We will describe two Capsis models to illustrate the system's flexibility.

First example is a Maritime Pine growth model. It is a distance-independent tree model based on the original models by Bernard Lemoine and Philippe Dreyfus. During a simulation, this model can be associated to a capsis project, with an given set of parameters and an initial stand inventory. Scenarios can be built from the root step, by performing successive evolution and intervention actions. Many outputs can be prepared by the model's author (distribution histograms, variables evolution curves along time, reports...), possibly showing results from different projects.

The second example is Eucalypt (CIRAD-Forêt).This distance-independent tree model aims at assessing the productivity, the quality and the sustainability of Eucalyptus plantations in Congo. This model is developed in close collaboration with ECO SA that is in charge of the 43000 ha of plantations near Pointe-Noire (Congo).

Prospective for the development of specific tools for end-users will be described. Indeed, all scientists' efforts to incorporate their models into a common software can be valued if the expectations of the end users are taken into account. That requires a better knowledge of their practices, of their needs expressed or not, and also the incorporation of basic management references like cost, thinning, stand units, past management. Such a development also means a good knowledge of other wood related software tools to provide bridges and connections with them. Only this work will allow a continuous transfer from the research area to management and decision support systems.

Link to the database "models for forest":
http://www.pierroton.inra.fr/IEFC/index.php3?page=bdd/models/modeles_liste.php3

Hardwood rough mill optimisation: comparison of various approaches and simulation software

Torsten LIHRA, Jean-François BOUFFARD, Robert BEAUREGARD

Universite Laval, Dept. des Sciences du Bois et de la Foret Pavillon Abitibi-Price, Ste-Foy, Québec, Canada

After kiln drying lumber, the rough mill is the first department where further processing is performed in typical furniture, wood flooring, cabinetry or components plants. The rough mill consists in a series of saws and related equipment intended to convert kiln dried lumber into dimension stock. The industry may choose between two main approaches to process lumber in a rough mill: the cross cut first or the rip first method. In a conventional rough mill producing parts for the furniture industry, the lumber defects are cut out by a cross cutting operation. The fixed length boards obtained are than ripped into components. This approach is especially suited for production of solid wood panels. An alternative approach may be the ripping of boards to fixed width followed by a cross cut operation to cut defects out in order to obtain the dimension stock. This method is mainly applied by wood flooring manufacturers because it is more likely to produce longer parts. However, according to the literature, rip-first results in higher yield than crosscut first in a majority of studies. An alternative to those two methods is the use of a flexible cell including two parallel production lines, one using a crosscut-first technology, the other using a rip-first technology. As a function of parameters, such as lumber grade or cutting bill requirements, the lumber is then processed on either of the production line yielding the highest value or raw material recovery for every single board. This can be refered to as two-axis optimization. Significant yield differences can be obtained by using one or another of the rough mill processing methods mentioned. An increasing yield of 1%, in a typical furniture or component plant consuming 5 MBF/year, can represent an economy of 80 000$ on the production costs. For a flooring mill, consuming 20 MBF/year, it can represent 240 000$. With decreasing lumber quality and considering the number of parameters to consider, an operator may be unable to decide under time restrictions which component of the cutting bill fits best among clear wood areas of the lumber. Longer components are particularly difficult to obtain. To improve value or raw material recovery, scanning devices allied with an optimization software are available to the industry. The scanning device detects specified character marks on each board and sends the data to the optimization software which determines the optimum cutting pattern as a function of cutting bill requirements, given rough mill technology, and equipment settings. The objective of the present study is to compare three processing methods in a rough mill (cross cut first, rip first and 2-axis optimization) by computer simulations and determine potential yield improvements by proper processing as a function of raw material quality and cutting bill requirements.

The ROMI-RIP and ROMI-CROSS rough mill simulators, developed by the USDA Forest service, are used to simulate rip-first and crosscut-first approaches respectively. The two-axis simulator, developed by the Centre de recherche industriel du Québec (CRIQ), is used to simulate a rough mill processing lumber on two parallel lines with either of the previously mentioned cutting options. Sugar maple and black cherry lumber is digitized with a crayon mark scanning device developed by the CRIQ to create a databank necessary to run the computer simulations. Following the Northern Hardwood Lumber Association (NHLA) rules, each species is graded in No. 1 Common, No. 2 Common and No. 3 Common lumber. Boards of those grades are divided in two width groups (under 127 mm (5 inches) and 127 mm and more). Previously to rough mill simulations the CRIQ optimization software is run in a cross cut first and a rip first mode only. Results are compared to ROMI-RIP and ROMI-CROSS simulations using the same parameter setting (kerf, saw blade set up, cutting bill, salvaged parts and others) in order to calibrate the three softwares. The following rough mill simulations are run using four cutting bills from local component manufactures, each representing a different level of difficulty (predominance of short/narrow parts, short/wide parts, long/narrow parts and long/wide parts). The interaction between cutting bill, lumber grade, and board width, in regard to the obtained yield, is analysed statistically to determine the optimal rough mill processing method as a function of the chosen parameters.

It is expected that higher yield can be obtained when using the 2-axis optimization approach because the best solution between rip first and cross cut first is chosen for each board. Overall yield should be higher when a cutting order showing predominance of short/narrow parts is sought after because these parts need less clear board area between defects. The impact of board width, in combination with lumber grade on yield using a given rough mill technology, is not well known and results of the present study may indicate appropriate cutting approaches to the industry dealing with a decreasing lumber quality.

The study is ongoing and realised with financial support from both Forintek Canada Corp. and the Natural Sciences and Engineering Research Council (NSERC) of Canada. Final analysis of the results shall be completed by June 2002.

Evaluating eosystem management scenarios using hierarchical planning

Thomas C. MANESS

Associate Professor, Faculty of Forestry, University of British Columbia, Vancouver BC

This paper presents a procedure for evaluating ecosystem management scenarios using a model based on hierarchical planning. The model is segregated into three planning levels, each with different time horizons and optimization strategies. The strategic level is concerned with long term sustainability of the management plan. The tactical level is concerned with allocation of scarce resources, community stability, and maximization of social and biological indicators. The operational level develops optimal manufacturing production strategies given the constraints imposed by the top two levels. The levels are tied together in a decomposition approach using Lagrangian multipliers to connect the optimization between the various levels. The model has be a wide variety of uses including determining the opportunity costs of alternative management scenarios.

Application of Finnish Scots Pine branching models on French forest resource: preliminary results

Celine MÉREDIEU[1], *Sandrine PERRET*[2], *F. COLIN, C. BASTIEN, C. GINISTY*[2]

[1]*INRA Unité de Recherches Forestières, Équipe Croissance et Production, Gazinet, France*
[2]*Cemagref Division Ressources génétiques et Plants forestiers Domaine des Barres, Nogent sur Vernisson, France*

In France, since 1999, development of French Scots pine growth and yield models at the tree level has been initiated. In order to link growth and yield models and models describing wood quality, models describing branch attributes are needed. Branch angle (from vertical) and diameter models were already developed for pure Scots pine stands in southern and central Finland ("Finnish" models; Mäkinen and Colin, 1998; Mäkinen et al., 1999).

The objective of this study is to answer two questions:

- Is it possible to use the "Finnish" models of diameter and angle on French Scots pines?
- Is it possible to reduce the number of branch measurements if the development of new models for the French resource is necessary ?

The Finnish branch data were recorded on a 229-tree-sample (age range 22-76 years with 45 trees between 22 and 31 years) in experimental stands installed by sowing or naturally regenerated in fairly infertile to medium fertile sites; only thinnings from below were made one to four times after installation. Angle and diameter models were constructed in such a way that the angle was included in the diameter model to take account of the intra-whorl variability (thicker branches in a whorl are branches having rather more acute angles). Three phases were followed: simultaneous fit of individual profiles of angle and diameter versus whorl number counted from tree top to explain intra-tree variability; adjustements of relationships between profiles parameters and usual tree measurements (explanation of the inter-tree variability) or competition indices; separate final construction of angle and branch models with previous relationships included. DBH only was finally incorporated in the angle model in addition to the whorl number while the diameter model included relative crown length and DBH, in addition to branch angle and whorl number.

In order to rapidly assess the relevance of using directly the "Finnish" models in France, 27 trees were sampled in 3 planted experiments: 1 progeny test in Alsace (North-east of France) and 2 thinning experiments in Region Centre; stand ages were 23, 24 and 30 years; current stand density ranged from 980 to 3615 stems/ha. Branch measurements were made following same methods as Mäkinen and Colin (1998). The observed data were compared to the predictions obtained with the "Finnish" angle and diameter models. The predicted branch angles were always higher than the observed branch angles, Finnish Scots pines having larger angle (almost right angles) than French Scots pines. The differences were interprated mainly in terms of genetic determinism. The predicting branch diameters were underestimated; this underestimation increases with tree dimensions. So, the parameter estimates were not accurate for the stem diameter and the relative crown length for the French data set.

The re-estimation of the "Finnish" models on the reduced French sample appeared quite encouraging especially for diameter; the mathematical form of the model seemed to be preserved. Conversely, the branch angle model seemed less relevant; a complete reconstruction of the model appeared necessary.

In order to optimise the collection of new data sets, it can be interesting to reduce branch measurements on each tree. The "Finnish" models were re-estimated on our initial data set and sucessively on reduced data sets in which all branch measurements for x whorls were removed: for example, 1 whorl on three. The results showed that the loss of accuracy was low if the measured whorls were well distributed along the stem from the apex to the ground and if the selected whorls corresponded to specific crown regions. The implementation of this lighter measurement procedure will allow to collect a wider data set and so more trees and stands. Our sampling strategy in our new data set will take into account the full range of the regressor variables identified by the "Finnish" models.

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Cross-validation of alternative branch models for Douglas-fir using geographically disparate data sources from Europe and the Northwest USA

Eric TURNBLOM[1], *Gero BECKER*[2]

[1]*University of Washington, College of Forest Resources, Seattle, Washington, USA*
[2]*Albert-Ludwigs-Universität of Freiburg, Freiburg, Germany*

Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) has been planted globally, including areas of western Europe and other continents. This gives rise to some fundamental questions regarding the potential dependence of Douglas-fir wood quality on the geographic zone in which it develops. A somewhat coarse, but meaningful measure of wood quality is the size of knots appearing in manufactured lumber. An estimate of the size of knots in lumber that can be expected on a log from any position in the bole of the tree can be made by estimating expected branch sizes along the bole using a branch diameter profile model.

The primary objective of this study is to compare branch diameter profile characteristics between two geographically disparate (Germany / Northwest US) Douglas-fir data sets. A secondary objective is to gain insight into the "best" modeling approach for future branch diameter modeling.

The first objective is accomplished by benchmarking a branch profile model developed for Douglas-fir grown in Germany on data from Douglas-fir stands grown in northwest US. Further, in the cross-validation step, we benchmark a branch profile model developed for Douglas-fir grown in northwest US on data from Douglas-fir stands grown in Germany. Ordinary residuals from each benchmarking test are presented, compared, and discussed to better illuminate the difference between branch profile characteristics on Douglas-fir grown in Germany and the Northwest US. The second objective is accomplished by re-fitting each model tested in the benchmarking procedure to its benchmarking data set, and comparing the predicted and fitted residuals. Indicators that seem to favor a particular model form in this case are examined and discussed.

Development of branch and wood property models for use in a silvicultural decision support system

Kerrie CATCHPOOLE[1], Marks R. NESTER[2], Kevin HARDING[1]

[1] *Queensland Forestry Research Institute, Agency for Food and Fibre Sciences, Department of Primary Industries, Indooroopilly, Queensland, Australia*

[2] *Queensland Forestry Research Institute, Agency for Food and Fibre Sciences, Department of Primary Industries, Gympie, Queensland, Australia*

Modelling branch architecture and wood properties has been undertaken to develop a predictive grading model for slash pine (*Pinus elliottii*), Caribbean pine (*P. caribaea* var. *hondurensis*) and their F_1 interspecific hybrid. These are the main plantation taxa grown in Queensland, with the F_1 hybrid now deployed across the main plantation estate in south-east Queensland. To evaluate the internal rate of return from a plantation based on product mix, a linkage between silviculture, wood quality and grading of structural timber is needed.

This requirement is being addressed in a decision support system project that will allow the grower of these plantations, Queensland Department of Primary Industries – Forestry, to test a range of silvicultural scenarios through a computer software interface. The key to the decision support project is linking silvicultural scenarios with a conversion model that will simulate the sawing of logs into specific products, based on a range of sawing patterns. The Win-EPIFN software is being evaluated for its suitability in the conversion modelling component of the project.

The conversion model requires tree distribution information such as log length, small end diameter and large end diameter. These parameters will be combined with the description of branch architecture and wood properties to generate a profile of the structural properties both within the tree and within each board. Based on a series of user-specified grading rules the conversion model will assign a stress grade to the boards according to the criteria defined for each machine grade pine class, or visual grading system. Provision will be made to allow for changes to the timber grading rules and to facilitate the adoption of these changes throughout the development of the described software tool.

The decision support system will bring together the graded sawn timber outputs from the conversion model, assign revenues, link to costs associated with a specific silvicultural scenario, and finally generate internal rates of return and net present values. This type of decision support system will pass on significant benefits to plantation managers, as they will be able to test a range of silvicultural scenarios and evaluate economic returns prior to implementation. Further, it will capture several decades of research history to maximise the benefits to forest growers and processors by linking silviculture, wood quality and grading of structural timber.

Predictions of wood properties using bucking simulation software for harvesters

John ARLINGER

The Forestry Research Institute of Sweden, Uppsala, Sweden

If models for predicting wood and fibre properties are to be of practical use we need methods and tools adapted to the information systems available in practical forestry today[1]. Increased knowledge about wood and fibre properties will give us the possibility to utilize the wood raw material in a more efficient way. We might for example be able to:

- Use the knowledge as a basis for pricing, that is making it possible to give different priorities to different types of stands/species/regions
- Supply industry with a description of the wood that will be delivered from a certain site, thus making it possible for the industry to adapt their process in advance
- Direct the wood from certain stands to certain industries

The focus in this presentation is on pulpwood, but there are no fundamental differences between pulp logs and saw logs.

Today, bucking simulation software is used on a quite large scale in Sweden, giving us the possibility to predict the harvested yield from a site, both in volume and value. These software programs can simulate the results of the bucking computers found in modern harvesters with a very high precision. In at least one of these programs (Timan, developed at SkogForsk) predictions can be made of the qualities, dimensions, volumes and values of each log in each tree. Combining these results with knowledge about the age of the stands gives us the possibility to predict the properties of all logs as well as the average properties for different assortments of saw logs and pulpwood.

The basic data needed for this kind of calculation is: diameter distribution, tree height, age, geographical location, pricelist and possibly the average quality of the trees. The analysis is done in four steps: generation of stand data (1), bucking simulation (2), calculation of properties for each log (3) and calculations of mean values for different assortments/groups of logs (4).

Results from bucking simulations using data from real stands in southern Sweden will be presented. These results are partly based on results from a study where we tried to evaluate a method for selecting pulpwood with well-specified strength characteristics (properties of the pulp). Comparisons between simulations and measurements of some wood properties will be presented for different assortments.

Conclusions:

- We have all data we need to implement the models on a large scale but we do need to improve the methods for estimating age of individual trees
- From a Swedish perspective there are two important variables effecting wood properties of pulpwood that are not included in the models at present. These are root rot and sawmill chips.
- Models, well integrated with each other, are available today, making it possible to fully implement these in simulation software as well as in bucking computers of modern harvesters

Using modelling and integrated forestry and sawmill software systems to value the pruned log resource

C. Sue PRICE, C. B. WESSELS, P. TURNER

Forestry & Forest Products Research Centre, Congella, South Africa

Over the past few years in South Africa, there has been strong market pressure to increase the price of pruned softwood logs. However, there has been no equitable basis on which to price pruned logs, as their value can vary enormously, depending upon a number of issues which are not fully accommodated in the South African log grade specifications.

In earlier work (Turner and Price, 1996[1]), an approach to pruned log grading was considered, which took into account the inherent value of the log. The aim of this work was also to offer a meaningful framework for price negotiations between growers and processors. The work involved extensive sawmill simulation studies using a modified version of SIMSAW 5, with log grade curves being modelled from the results.

The sawmilling industry supported this work, although they thought the grade curves might be too generic. The forestry industry thought that the predictions were too conservative, and feared that they would not be able to get the full value from the forest resource.

An alternative approach of valuing the pruned log resource was then taken. It involved the development of integrated software tools to enable sawmillers to determine what a particular mill could do with a specific log resource supplying a specific market. Using these tools, the sawmiller could assess what logs (in terms of volume and quality) he should be sourcing and their market value within his business. The tools help the forester to understand the appropriate market value of the resource, and what markets they should be supplying in order to obtain maximum value.

This paper discusses these approaches to valuing the pruned log resource, and describes the software tools used to determine its value.

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[1] Turner, P., Price, C. S., "Maximising value of the plantation resource: Part I – Development of a log grading proposal for pruned softwood logs", *South African Forestry Journal*, No. 176, July 1996

Sawing simulation of *Pinus pinaster* Ait.

Isabel PINTO[1], *Helena PEREIRA*[2], *Arto USENIUS*[3]

[1]*Centro de Estudos Florestais, Instituto Superior de Agronomia, Lisboa, Portugal.*
Visiting Researcher at VTT Bulding and Transport, VTT, Finland
[2]*Centro de Estudos Florestais, Instituto Superior de Agronomia, Lisboa, Portugal,*
[3]*VTT Bulding and Transport, VTT Finland*

In Portugal, Maritime pine is the most important species with more than 1 million ha (ca. 30% of the total Portuguese forest area) and pinewood is the primary raw material for the sawmilling. The presentation deals with the sawing optimisation of Maritime pine (*Pinus pinaster* Ait.). The effect of some parameters on the recovery of Maritime pine sawn timber is studied. Parameters include the final products dimensions and quality requirements, log dimensions, its position within the stem and saw kerf. The conversion is executed by an integrated optimising software system, WOODCIM® developed at VTT - Technical Research Centre of Finland. The software system describes the whole conversion chain and comprises software modules to model the way from forest to end products. For this work it is used the WOODCIM® simulation program for predicting the value yield in sawmilling. Mathematically reconstructed logs based on scanning provide input data set for simulation converting logs into end products.

The study is based on a sample of 45 Maritime pine stems random sampled from 4 different sites in Portugal. The sampled trees were 83 years old in one sampled site and between 30 and 40 years old on the other 3 sampled sites. The trees were cross cut into 133 logs and live sawed into 25-mm flitches. The top diameter of the logs varied from 10 to 52 cm. In Finland the flitches were scanned using VTT's - WOODCIM® camera system providing RGB (colour component) information stored in the computer files for further processing and analyses. The measured data was computed by VTT's PuuPilot software showing the image of the flitch on the screen. The data concerning the geometrical and quality features of the flitch is processed with special software producing a mathematical reconstruction of a sawlog and stem in xyz-co-ordinate system. Therefore 3D and 2D representations were obtained for logs and stems allowing the visualisation of external shape as well as of the internal knot architecture. For all logs the exact position on the tree as well as the compass orientation is known.

The reconstructed logs are converted into final sawn timber products through the sawing simulation software. Input data concerning final products and process variables was obtained directly from the Portuguese wood based industry. The simulation tests different set-ups for each log choosing the best combination of saw pattern, dimensions and qualities of the sawned products. Quality definitions are based only on knot characteristics.

The simulation programme gives, for each individual log and for the total of the logs, the following outputs:

- number of sawned products for each dimensions and quality
- yield of sawned products in quantity and value per log cubic meter

Results are obtained for a set of simulations using different input variables on log lengths and positions in the stem, product specifications and sawkerf. These will contribute to increase the knowledge on the variations of Maritime pine sawing yield outputs with different factors and to connect these results with raw material main characteristics. In this way its possible to generate bucking instruction as well as limit definitions for log diameter classes and process instructions which allows Portuguese sawmill industry to optimise their raw material utilisation.

Key words: *Pinus pinaster* Ait, sawmill, simulation, optimisation, process parameters

Linking tree stem properties of tree stem in Scots Pine to the properites of sawn timber through simulated sawing

Veli-Pekka IKONEN, Seppo KELLOMÄKI, Heli PELTOLA

[1]*University of Joensuu, Faculty of Forestry, Joensuu, Finland*

We demonstrate how tree stem properties may be linked to the properties of sawn timber through simulation of the structural growth of the tree and of the sawing of the stem into pieces subjected to quality grading. In this context, the growth and development of individual Scots pines (*Pinus sylvestris*) is presented in terms of the three-dimensional structure of the tree crown as determined by the influence of local light conditions on branch growth, with implications for the distribution of the properties of the stem and wood such as stem form and knots. The three-dimensional distribution of these properties allows one to saw the stem into logs and further into sawn pieces which can be graded based on quality.

The part of the stem to be cut into logs is defined by the height of the stump (felling height) and the diameter of a stem fulfilling the minimum top diameter for a log acceptable for sawing. The stems are characterised by means of the number of logs obtainable for sawing, the length of the logs, the top and butt diameters of the logs, their volume and their taper. The wood is characterised for sawing mainly in terms of the occurrence of knots and their size and quality (sound, dead). The sawing algorithm checks the knots in terms of diameter and quality and calculates the grade and value of each piece. This procedure is repeated log by log, and a summary of the sawing is made covering the whole stand, with a report on the total yield and value of the sawn timber obtained from each stand. The performance of the sawing simulator will also be demonstrated in this paper with the example computations on sawing for Scots pine trees grown in unthinned and thinned stands, respectively.

Keywords: sawn timber properties; sawing simulator; stem properties; three-dimensional modelling; Scots pine; forest management.

Within and between log variation in lumber grade yield as demonstrated using AUTOSAW

Jamie BARBOUR[1], *Dean PARRY*[1], *Christine TODOROKI*[2], *Eini LOWELL*[1]

[1]*USDA Forest Service, PNW Research Station, Portland, Oregon, USA*
[2]*Forest Research, Rotorua, New Zealand*

Empirical wood product recovery studies have the disadvantage of only allowing evaluation of one set of products, one sawing position, and one cutting pattern for each log. This makes it difficult to explore the sources of the variation observed in these studies. We report on the use of the AUTOSAW sawing simulator in a systematic examination of the sources of variation in both the lumber volume recovery and lumber grade yield typically encountered in empirical lumber recovery studies. We explored log position (rotation) and shape (sweep and roundness) as possible sources of variation. Several studies have already looked at these characteristics in terms of lumber volume recovery and algorithms developed from these studies are commonly used in process control software for sawing of logs, cants, and flitches in commercial sawmills. The use of sawing simulation to understand the potential variation in lumber grade yield, however, is not as well explored. We diagrammed the location and size of all branches plus the stem diameter at each branch whorl for a set of 22 western hemlock (*Tsuga heterophylla* (raf.)sarg.). trees. The trees came from a variety of forest conditions representing the range of young-growth hemlock in the U.S Pacific Northwest. The bucking of these trees into 65 4.9 m logs was simulated and the diameter, branch location, and knot size data were converted into AUTOSAW input files and "sawn" using AUTOSAW. Each straight log was sawn repeatedly by rotating it in five-degree increments, which resulted in 72 repetitions per log, each with a unique knot configuration. Sweep was then added to each log and the sawing process repeated. The sawing simulation results suggest that sweep reduces the overall lumber grade yield. The variation in lumber grade yield with log diameter is, however, about the same for straight and swept logs (see table). The levels of variation observed for simulated sawing are similar to those observed in several empirical studies for the same species.

Lumber Grade Groupings	Percent Lumber Volume All Logs		R^2 for Regression with Log Diameter	
	Straight Logs	Swept Logs	Straight Logs	Swept Logs
Select Structural	40	29	0.11	0.14
No. 2 & Btr., 3 Common & Btr.	49	54	0.04	0.04
No. 3, Utility & 4 Common	7	10	0.30	0.41
Economy, 5 Common	4	7	NS	0.04

Models for predicting lumber grade yield using external log features, internal wood quality and sonics

Christine TODOROKI, R.L. KNOWLES, M. BUDIANTO, A.B. BARR

Forest Research, Rotorua, New Zealand

Recent research based on the simulated sawing of virtual logs suggests that we can develop improved models for predicting internal log quality and lumber grade yield. This is particularly important for fertile ex-farm sites that have shown evidence of consistently poorer lumber quality than would be expected from comparative logs extracted from plantation forests.

Using AUTOSAW in combination with external log features, models for predicting New Zealand visual framing grades and clear cuttings grades were developed for a plantation forest (Kaingaroa Forest) and an ex-farm site (Tikitere Agroforestry Research Area). A new model based on the sum of branches within a whorl, WGB, provided significant improvements over the traditional Branch Index (BIX) model for predicting visual structural grades. Prediction of clear cuttings grades from ex-farm logs was improved using a model that incorporated a new measure of internodal lengths.

In this study those new models developed from the simulated yield obtained from AUTOSAW are applied to actual lumber.

The lumber, external and internal log features and wood quality measurements were obtained from a sample of 30 *Pinus radiata* second logs extracted from the Tikitere ex-farm site. The lumber was dried and manually graded using three grading criteria: NZ visual framing grades, cuttings grades, and machines stress grades. The effectiveness of the above models was evaluated through statistical regression models. Further models incorporating sound velocity, wood density, resin pocket incidence, branch insertion angle, and ring counts were developed and evaluated.

The model incorporating WGB provided consistently better correlations with visual structural grade outturn than models incorporating BIX. A newly developed measure of internodal length that ignores whorls with three or fewer branches (FIL), provided better correlations with clear cuttings yield than either Mean Internode Length, MIL, or Internode Index, IIX. Sound velocity, SVEL demonstrated strong correlations with machine stress grades.

These results are promising as the new models show improvements over traditional methods for both actual and simulated results.

Grading Criteria	Model Variables	r^2 for linear regressions with model variables and lumber yield
Visual framing	BIX, SED	0.18
	WGB, SED	0.31
Cuttings	IIX, SED	0.45
	MIL, SED	0.57
	FIL, SED	0.62
Machine stress	SVEL	0.58
	SVEL, SED, density	0.74

Predicting the internal quality and value of Norway Spruce trees using non-parametric nearest neighbor methods

Jukka MALINEN[1], *Matti MALTAMO*[1], *Erkki VERKASALO*[2]

[1]*University of Joensuu, Faculty of Forestry, Joensuu, Finland*
[2]*Finnish Forest Research Institute, Joensuu Research Centre, Joensuu, Finland*

End-use oriented sawing, which has become more and more popular for Norway spruce, demands more accurate evaluation of the properties, quality and grades of trees, logs and lumber id demanded to predict their potential for different end-uses of mechanical processing. This is needed to select the right stands, trees and logs for the right production plants and end products.

The description of internal quality includes characteristics such as wood density, decay, amount of heartwood and knottiness. The prediction of these variables using commonly measured tree- and standwise variables has been found very difficult. Regression models have been constructed but correlation between tree variables (DBH, height etc.) and these characteristics has been found weak and complex. Moreover, the separate prediction of these variables does not quarantee logical dependent estimates between these variables.

Due to the complex correlation of internal variables the use of non-parametric regression methods in the prediction of properties of spruce trees is one alternative. These methods predict the value of the variable of interest as the weighted average of the values on neighboring observations, the neighbors being defined with the predicting. All variables of interest can be predicted simultaneously and the original covariance structure of variables remains. Furthermore, unrealistic estimates cannot be produced because they are based on measured observations.

At the Finnish Forest Research Institute, a large research project on predicting and controlling the properties and quality of spruce trees and logs for mechanical wood processing was performed in 1994-98. For the project, 240 saw timber trees were sampled from 48 spruce-dominated mature or nearly mature stands in Southern Finland. Extensive field measurements were performed on the external quality of trees and laboratory measurements were performed on sample discs. Field and laboratory data were used to generate external and internal structure of trees by computer calculations. The predicted stems were theoretically bucked to logs according to bucking rules by simulating computer programs. The logs were theoretically sawn by simulating computer programs, by using sawing patterns of a traditionally operating sawmill The simulated sawn goods were graded and priced according the Nordic Timber Grading Rules. Volumetric yield, grade and gross value of sawn mill products, i.e. lumber, chips, saw dust, and bark were calculated for each log and tree (incl. pulpwood).

The emphasis of this study was to test possibilities to predict the yield and internal quality spruce trees and value of lumber and by-products by stand and tree factors for traditionally oriented sawing with two non-parametric nearest neighbor method: k-nearest-neighbor MSN and locally adaptable neighborhood (LAN) MSN method. The methods are compared by using two different level predictor models. Standwise predictors include variables such as site variables and average tree information and treewise predictors include information additionally from tree and its surroundings, such as spatial information and external quality variables.

According to the results of this study the non-parametric nearest neighbor methods seems to provide one interesting option to estimate internal quality and value of Norway spruce trees. The LAN MSN method was found to be slightly better than k-nn MSN method in most cases, when using relative root mean square error as criteria to compare results. Treewise information improved accuracy of the methods compared to the results of standwise input information.

Modelling the end-use based value of Norway Spruce trees and logs by using predictors of stand and tree levels

Erkki VERKASALO [1], *Pentti SAIRANEN* [2], *Harri KILPELÄINEN* [1], *Matti MALTAMO* [3]

[1] *Finnish Forest Research Institute, Joensuu Research Centre, Joensuu, Finland*
[2] *Finnish Forest Research Institute, Vantaa Research Centre, Vantaa, Finland*
[3] *University of Joensuu, Faculty of Forestry, Joensuu, Finland*

End-use oriented sawing for further processing has become more and more popular for Norway spruce in Nordic countries along with the traditional sawing aiming for maximum volumetric recovery. Accordingly, proper evaluation of the properties, quality and grades of spruce trees, logs and lumber is demanded to predict their potential for different end-uses of mechanical processing.

At the Finnish Forest Research Institute, a large research project on predicting and controlling the properties, quality and value of spruce trees, logs and wood for mechanical wood processing was performed in 1994-2000. For the project, 240 saw timber trees were sampled from 48 spruce-dominated mature or nearly mature stands in Southern Finland. Extensive field measurements were performed on the external quality of trees, including dimensions, stem form, knots and other visible defects. Laboratory measurements were performed on sample discs for bark thickness, cross-sectional geometry, pith eccentricity, and extent of heartwood and compression wood, and on sample whorls for the diameters and quality of branches at fixed radial locations. The extent and quality of adventive branches were measured from rotary-cut veneers, peeled from 1-meter logs from selected sample trees.

Field and laboratory data were used to generate external shape and internal structure of trees by computer calculations. Internal knots were created for all trees by multivariate polynomial regression models based on the whorl measurements, and the zones of compression wood and heartwood were placed by linear smoothing from the disc measurements. Stems were theoretically bucked to logs according to six different bucking rules by simulating computer programs. Logs were theoretically sawn by simulating computer programs, by using alternative sawing patterns of a traditionally operating saw mill with the emphasis on bulk production and an end-use oriented saw mill with the emphasis on special products and intensive sorting of lumber. The simulated sawn goods were graded and priced according to the rules of the two before-mentioned types of saw mills, respectively. Volumetric yield, grade distribution and gross value of sawn mill products, i.e. lumber, chips, saw dust and bark, as well as plywood logs and pulpwood were calculated for each log and tree, and for all combinations of bucking rules, sawing patterns, and grading and pricing principles. Final values of individual trees, tree-sections and logs were obtained by summing the values of respective tree sections.

This paper reports selected results on modelling the value of individual trees and saw logs by using miscellaneous predictors of stand and tree levels. Here, the standpoint is sawmilling for value-added further products of building industry and interior furnishing. The principles and structure of the statistical and simulation models to construct the geometric shape and internal structure of trees for knottiness, compression wood and heartwood are shown, as well. Some demonstrations are also presented on the application of the models for evaluating different policies of wood procurement and saw milling regarding the recovery of different timber assortments and the gross revenue of products.

Predicting tensile and bending strength of dimension lumber defined by Weyerhaeuser's three-dimensional geometric *GlassLog*™ model

David M. HYINK, Jeffrey J. WELTY

Weyerhaeuser Co., Federal Way, Washington, USA

Following a brief description of Weyerhaeuser's three-dimensional geometric *GlassLog*™ model, the development of a sub-system to estimate performance characteristics – namely tensile (f_t) and bending (f_b) strength – of a "glass lumber" will be discussed. The loblolly Pine Lumber Strength Model was developed from data gathered from an empirical study which involved the four-face surface-mapping of knots on several hundred individual pieces of lumber, measuring the clearwood specific gravity on each board, estimating distance from the lumber to the point of failure. Characteristics of the subsequent "digital scanning algorithm" will be reviewed, and its performance evaluated.

A tree-level model for plantation-grown Black Spruce lumber strength and stiffness

S.Y. (Tony) ZHANG

Research Scientist & Group Leader, Resource Assessment & Utilization Group, Forintek Canada Corp., Sainte-Foy, Québec, Canada

One hundred thirty-nine trees were selected from a 48-year-old initial spacing trial. The trees selected cover 4 spacings and different DBH classes ranging from 10 to 24-cm. For each tree, various tree (e.g., DBH, tree height, taper, live crown size, clear log length) and wood characteristics (e.g., ring width, wood density, juvenile wood%) were measured. Each tree was bucked to 8-foot long logs and each log position in the tree was marked. The logs were sawn into 2-inch thick lumber. Following the ASTM standard, each piece of lumber was tested to determine its bending strength (MOR) and stiffness (MOE). Mean lumber strength and stiffness were calculated for individual logs and individual trees. After the lumber in-grade tests, various wood characteristics (e.g., ring width, wood density, juvenile wood%, grain deviation) and knottiness (e.g., knot diameter, knot frequency) were measured for each piece of lumber tested.

The lumber strength and stiffness in relation to various potential variables were analyzed at different levels (e.g., lumber, log, tree). Preliminary analyses indicate that the lumber strength and stiffness are closely related to wood density and knottiness at the lumber level. Since wood density is not closely related to ring width (growth rate), average ring width of individual lumber pieces is not a good indicator of their strength and stiffness. Both lumber strength and stiffness vary greatly with log position, but much of the variation can be explained by wood density and knottiness. At the tree level, a model which includes tree characteristics explains very limited amount of the variances in lumber strength and stiffness. However, a high percentage of the variances can be explained when selected wood characteristics are added to the tree-level model.

Microfibril angle in plantation pine: distribution and influence on product performance

Dave COWN, Rod BALL, Mark RIDDELL, Phil WILCOX

Forest Research, Rotorua, New Zealand

In recent years, the role of microfibril angle in product performance has been highlighted. Many studies have examined its relationship with compression wood and its influemce of wood shrinkage and distortion. Some authors have concluded that it is one of the most important fundamental wood properties. Recent work in radiata pine has documented its relative importance in juvenile wood and mature wood clearwood in terms of material stiffness.

The present study involved intensive sampling of 10 mature (27-year-old) radiata pine clones. Stems and logs from four replicates of each clone were assessed for external branching characteristics before felling. Discs were removed at 5m intervals up the stems of 2 replicates/clone and measured by Silviscan for wood density and microfibril angle. The logs were processed into a range of products including, structural lumber and clearwood components suitable for furniture, doors and windows.

The paper will discuss:

1. Patterns of wood density and microfibril angle variation within and between clones.
2. Relationship between density, microfibril angle and clearwood stiffness.
3. Indications of heritability of intrinsic properties, based on repeatability of the 10 clones.
4. Relative impact of branching characteristics and intrinsic properties in relation to "in-grade" performance of structural lumber. *

On the basis of the results, conclusions will be drawn regarding the impact of intrinsic properties on end product performance, and the desirability and feasibility of including microfibril angle in tree breeding programmes.

- Not completed at time of writing the Summary.

. spiral grain as ? factor affecting twist
. Alta H² para densidad y spiral grain y twist
. No strong evidence for [illegible] of MFA
. Stiffness determined by dens. KAR y ring orientation

Simulated sawing of real log images: linking wood quality and product potential

James FUNCK[1], C.C. BRUNNER[1], J.W. PUNCHES[1], J.B. FORRER[2]

[1]Associate Professor, Forest Products Department, Oregon State University, Corvallis, Oregon, USA
[2]Faculty Research Associate, Forest Products Department, Oregon State University, Corvallis, Oregon, USA

Past forest management practices in the Western United States have resulted in significant acreages containing dense stands of small-diameter timber. With current valuation procedures, much of this material has insufficient value to offset harvesting costs, which limits economical stand management. The goal of the project presented in this paper was to evaluate the potential for using small-diameter timber from over-stocked stands as a raw material source for the secondary wood products manufacturing industry. This was accomplished by using a different approach to assign stem value by analyzing the market value of alternative end-products and then determining whether those products could be produced from the available raw material.

To do that, 48 Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*) trees were selected, measured, felled, bucked, live-sawn, and optically scanned. The resulting digital images were reconstructed into logs and finally tree stems. This technique allowed full knowledge of internal features and external shapes to be used when bucking and sawing alternatives were investigated.

One important consideration in this approach was the use of alternative products to assign value when optimizing log sawing. Log breakdown optimizing systems in the lumber industry will eventually be greatly enhanced through the addition of scanning systems that provide information about both the geometry of a log and its internal defects. Concurrent with that development is the need for log breakdown optimization models that take advantage of such detailed information. Current models for softwood species can be separated by level of sophistication as shown by the use of such factors as true exterior shape versus truncated cones or cylinders, sawing variables, breakdown patterns, and individual internal defects versus defect zones. However, all breakdown patterns generated by any of the models are driven either by maximizing the volume or estimated value of lumber. In contrast, the secondary wood products manufacturing industry, specifically the cut-stock industry, has raw material requirements that can differ significantly from the characteristics that are defined by standard lumber grades. As a result, optimization of the lumber cut-up operation has been constrained by those lumber grades. With the descriptive log and board data developed in this research, both cut-stock yields and operational parameters were investigated by determining the log-sawing patterns that produced the greatest cutting yield values rather than board grades. To do that, CORY, a lumber cut-up optimization algorithm, was used as the determinate of value by embedding it in SAW3D, a log breakdown optimization algorithm.

The small diameter material examined in this study is normally not considered for use in value-added products because wider boards are more efficient to process and narrower boards are less likely to meet minimum appearance grade criteria. Consequently, dimension lumber is the typical lumber product. However, as larger and higher quality appearance grade lumber becomes increasingly scarce, this resource could become an attractive alternative raw material. This transition will only take place when wood quality factors are understood well enough to allow prediction of alternative products and their yields, thus allowing the standing timber's value to be more accurately estimated.

Linking simulation of primary and secondary products from small-diameter western softwoods

Eini C. LOWELL[1], *Ed THOMAS*[2]

[1]*USDA, Pacific Northwest Research Station, Portland, Oregon, USA*
[2]*USDA, Northeast Research Station, Princeton, West Virginia, USA*

Densely stocked stands of small diameter softwoods present an important utilization challenge in the western United States. Producing primary products from material removed from these stands is often not cost effective. Evaluation of the suitability of this resource for higher value products, with an attempt to minimize the amount of unusable material, may increase opportunities for offsetting costs of active management in these stands.

A sample of Douglas-fir and ponderosa pine was obtained in northern California, USA. The Douglas-fir came from suppressed stands (about 70 years old) and the ponderosa came from 45 years old natural stands and plantations. Trees averaged 19 cm diameter breast height. Log small end diameter averaged 13 cm. All knots were diagrammed (size and location) on peeled, short logs (2.4 meters) for use in the sawing simulator AUTOSAW to determine primary product recovery. Logs were then sawn on an Economizer® portable sawmill with dimension lumber (38mm surfaced dry) produced from Douglas-fir and 5/4 boards (29 mm surfaced dry) produced from ponderosa pine. The Economizer is not designed to maximize grade or volume recovery. Alternate sawing patterns are being evaluated with AUTOSAW to determine if knot defects can be minimized by sawing pattern and if a subsequent increase in yield of secondary products obtained. A CCD camera was used to capture board images to calculate defect data. The majority of Douglas-fir defect was from checks and splits. Ingrown needles accounted for 66% of the total defect area in ponderosa pine.

ROMI-RIP and ROMI-CROSS, computer simulation programs for lumber cutting solutions, were developed as a rough-mill analysis tool for use with eastern hardwoods. Material removed from small diameter stands in the western U.S. provided an opportunity to evaluate their use for softwood lumber. Both simulators operate by attempting to maximize the potential yield or value in rough sized parts for panels, moulding, finger-joint, and/or solid part stock. ROMI-RIP simulated using a fixed-blade-best-feed gang ripsaw followed by an optimizing chopsaw. ROMI-CROSS simulated using an optimized chopsaw followed by a straightline ripsaw.

Image data was input to ROMI-RIP and ROMI-CROSS to examine potential yield of parts given specific defect size and position allowances. Various cutting bills and character mark specifications for products typical for this resource were evaluated. These included yields for parquet flooring blanks, random lengths, trestle table parts, and stair tread blanks for glue-up.

Rip first processing was capable of producing higher yields. The Douglas fir lumber was fairly high quality containing few knots, very little warp, and few splits. Higher clear part yields were obtained from the Douglas-fir. On average, the ponderosa pine had more defect area per board but a greater percentage of the pine defects were acceptable character marks.

Simulating veneering and plywood manufacturing of virtual trees described by a growth-wood quality software

Frédéric MOTHE, Thiéry CONSTANT, Jean-Michel LEBAN

Laboratoire d'Etude des Ressources Forêt – Bois, UMR INRA-ENGREF LERFOB, Champenoux, France

Starting from virtual trees built with WinEpifn software including tree growth and wood quality models, the aim of the present work is to simulate the veneering process and to assess the quality of the products (veneers or plywood). The relevant inputs are the minute spatial distributions of wood properties within the log (ring shape pattern, wood density variations, branchiness...) delivered by WinEpifn

The development of two main tools is currently in progress to reach this objective:

A first software allows to visualise each tree and to choose interactively the size of the bolt, the location of the lathe spindles, the veneer thickness and the number and length of the sheets. The veneering simulation basically consists in translating the tree based data into the sheet co-ordinates. The veneer quality may then be assessed through the inner wood properties. Optionally, the software may simulate the radial wood displacements during the cutting process to estimate the thickness changes, which are considered usually as an important quality criterion for a veneer sheet.

The next stage consists in selecting a subset of sheets to compose a plywood panel and choosing the ordering and the orientation of each layer. The data describing each plywood panel may then be processed by a second software able to compute the technological properties of the whole panel. Particularly, this software uses the finite elements method to predict the structural warping of the panel due to given moisture changes.

It must be noticed that the quality of the prediction of the plywood properties, as well as of the veneer thickness changes, depends strongly on the knowledge of numerous wood properties (mechanical properties, shrinkage, grain angle...) and of its distribution inside the tree. In the present demonstration case several of the models needed to assess these properties from the few available data (basically ring width and location inside the tree) are still missing and are coarsely assessed.

Nevertheless, this paper presents a first theoretic application of the proposed tools, starting from two typical trees constructed by WinEpifn and wood properties model, to simulate the veneering process, visualise the aspect of the veneer deliveries and compare the properties of plywood panels.

The simulated impact of spacing and pruning on the wood characteristics of coastal Western Hemlock (*Tsuga heterophylla* [Raf.] Sarg.) in British Columbia

James W. GOUDIE

Biometrician, Growth and Yield Research Branch
British Columbia Ministry of Forests, Victoria, BC Canada

Silvicultural activities usually impact the quality of wood fibre produced. Jozsa et al. (1998) demonstrated that 39-year-old western hemlock (*Tsuga heterophylla* [Raf.] Sarg.) planted at close spacing (0.9m) has significantly higher density wood at breast height than at wider spacing (2.7m and 3.7m). Ellis 1998 found that except for the wood in close proximity to the pith, the strength and stiffness of hemlock wood correlates well with relative density. Goudie (1999) reported preliminary simulation results that generally supports the findings found in the field - the widest spacings produces lower basic densities that may reduce lumber strength by up to 15 percent at a reasonable rotation age.

Hemlock is the third leading species harvested in BC but recently, the price of hemlock lumber declined due to sagging overseas markets and difficulties in drying. Improved drying schedules will certainly help. However, informed management actions are needed to maximise the value of the second-growth stands. Treatments such as precommercial thinning and pruning are likely to become more important as the forest products industry moves from visual grading machine stress rating. In addition, the new government in BC proposes to dramatically change the way BC forests are to be managed in that the forest industry will be much more directly responsible. The importance of efficient economic decision will increase because costs will be minimised and value will be maintained or improved. The ability to predict wood quality is integral to maximising value.

The morphology and variation of hemlock crowns and their relation to wood quality is not well known. In 1997, a large study was initiated to produce decision tools that will help foresters manage hemlock stands for both quantity and quality. Western hemlock trees from natural stands of four age classes (approximately 20, 40, 60 and 90 years) at four geographic locations in coastal British Columbia were destructively sampled. Detailed samples of foliage (leaf area and biomass), branches (distribution, size, and growth), and bole characteristics (height growth, ring characteristics - width, proportion of earlywood, relative density of earlywood and latewood) were taken on 86 forest-grown trees. Over 5200 branches were mapped on the stem and measured for diameter and length; almost 1500 branches were sampled for growth and foliage biomass (560 of these also sampled for leaf area); and 1100 bole radii scanned for ring characteristics. Relationships have been developed to predict amount of foliage biomass and leaf area on individual branches and in complete internodes, the vertical distribution of foliage in the crown, the location of new branches along internodes, and the terminal growth and basal diameter of branches. Work nearing completion will quantify the relationship between crown condition and wood characteristics. These components are incorporated into a growth and yield computer model and linked to a sawmill simulator to allow investigations of silvicultural decisions.

The proposed paper for the 2002 workshop will report the design of the system and predict the impact of various combinations of precommercial thinning and pruning on wood quality. Economic analysis may also be presented. The framework for such a system (SYLVER, Mitchell et. al 1989) was developed in B.C. as part of the Douglas-fir Task Force (Kellogg 1989) and has since been expanded to incorporate additional crown and bole information for coastal Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco). The linked components of SYLVER include a tree growth model (TASS) (Mitchell, 1975), bucking simulator (BUCK), a two-dimensional sawmill simulator (SAWSIM), lumber grading routine (GRADE) and financial analysis system (FAN$Y). Financial and economic analyses have already shown the positive effects of pruning and commercial thinning of coastal Douglas-fir on many sites (Mitchell et al. 1989, Stone 1993). We hope to link TASS to a three-dimensional sawmill simulator and upgrade SYLVER to evaluate knots and other internal log defects so that more dynamic distributions of board grades can be produced.

Modelling the impact of spacing and thinning on branching patterns of 36-year-old *Eucalyptus pilularis*

Geoff SMITH[1], *Graeme PALMER*[2,3], *Allie MUNERI*[2]

[1]*State forest of New South Wales Research and Development Division. Cnr Hood and High Sts. Coffs Harbour, New South Wales, Australia*
[2]*QFRI, Agency for Food and Fibre Sciences, Department of Primary Industries, Queensland, Australia*
[3]Current Address: *Bil Technologies Pty. Ltd,, Lismore Heights, New South Wales*

Eucalypts are increasingly being grown in plantations for the production of solid wood in tropical and subtropical eastern Australia. However, there is little knowledge of the wood properties and solid wood quality of commonly grown species and the effect that stand management has on these properties. Knots have been found to be the most common grade limiting factor. Because of eucalypt branching characteristics, knots are a characteristic that is strongly influenced by spacing and thinning. The pattern of branching is also important for the development of pruning schedules.

This study is part of a larger project that aims to model the influence of spacing and thinning on the following characteristics of 36-year-old *E. pilularis*:

1. branching patterns and branch occlusion processes.
2. sawing characteristics and the feasibility of processing this plantation resource into sawn timber.
3. wood quality characteristics: wood density; longitudinal growth strain (LGS); sapwood proportion; juvenile wood proportion; chemical composition; shrinkage; gluability; hardness; stiffness and bending strength.

The study examined a total of 8 treatments: 3 initial spacings (500, 1000, 1500 trees/ha) with no subsequent thinning and 5 treatments that were thinned from an initial spacing of 1500 down to 700, 450, 250, 125 and 87 trees/ha. The trees came from two research trials (a spacing trial and a 'correlated curve trend' design thinning trial) for which complete growth data were available. One hundred and sixteen trees were sampled across the treatments and throughout the diameter range of each stand. After felling, the trees were processed into sawlogs and discs were taken from the end of all logs for analysis of wood properties. All logs were sawn into 100 by 25mm boards and were visually graded before drying. For the lowest two logs in each tree, the position and size of all knots were recorded. A method was developed to track the original position of each sawn board within the log by labelling the log ends. This allows sawing through normal mill processing and there is no need to reassemble logs after sawing. Wood quality parameters and branching (knot) patterns can then be modelled from the relationship between growth data and position within logs. .

Preliminary results show a high percentage of select grade boards. A range of treatments, including unthinned, spacing treatments gave similar total recoveries but with different mixes of timber grades. This information will allow stand management to be matched to end-product use. Knots were the most common reason limiting the grade of boards in all treatments. The knot positional data will be used to model branching patterns in response to spacing and thinning. The wood quality data will be used to model the effect of growth and silvicultural treatments. The positional data allows the examination of relationships between board distortion, sawing pattern and tree growth. All data will be used in the development of conversion simulation software. Results on branching patterns and an outline of the conversion simulation project will be presented.

Modelling the impact of site and age on the quality of plantation eucalypts

Philip TURNER, D. DREW

Forestry & Forest Products Research Centre, CSIR, Congella, South Africa

This paper describes work carried out to quantify the impact of tree age and site index on fiber quality, pulp and pulping properties of *E. grandis*. Material of different ages, grown on a range of different site types was evaluated in a laboratory scale kraft pulping process. Data on pulp yield, pulp strength properties and a number of other important wood and pulp characteristics were generated. Age and site index were found to significantly impact on many of the wood and pulp and paper characteristics measured. Of particular importance is the positive improvement in pulp quality observed as site index increases. Based on this work, the potential to model the impact of site and age on wood, pulp and pulping characteristics such as wood density, active alkali consumption, burst, tear and tensile strength, benzene alcohol and hot water extractives, freeness and pulp brightness was evaluated. The paper discusses how factors such as climate could be driving the large variation in wood quality and how tools such as bio-climatic modeling could be used to help us in predicting wood quality. The paper concludes with an outline of how the models developed in the project can be used in information systems to manage the variation in quality to support more consistent quality and higher value extraction within the manufacturing environment.

The work forms part of the output generated from the research cooperative on Eucalypt pulp quality, sponsored by Mondi, Sappi and the Council for Scientific and Industrial Research (CSIR) in South Africa.

Simulating the wood quality of a standing forest resource: how to adapt an existing tool to another species ? The French experience gained in adapting to Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) the WinEPIFN software developed for Norway Spruce (*Picea abies* Karst.)

Renaud DAQUITAINE[1], *M. El AYDAM*[2], *Jean-Michel LEBAN*[1], *Laurent SAINT-ANDRÉ*[3]

[1] *Wood Quality Research Team, LERFOB, Champenoux, France*
[2] *Control Engineering and System Analysis Department, ULB, Bruxelles, Belgium*
[3] *CIRAD, Montpellier, France*

Douglas fir is one of the main species used for planting in France, together with Norway spruce. There were about 336000 hectares of Douglas-fir forests in France in 1999, with a standing volume of 45 million cubic meters (french National Forest Inventory service: IFN, 2001). The harvesting in 1996 was about 850000 cubic meters of stems and rough estimations predict a harvesting of 3 million cubic meters in 2005 and 6 million in 2030 (De Champs, 1997).

About 95% of these stands are today younger than 40 years (IFN, 2001) so the proportion of juvenile wood is very important. In consequence, the evaluation of the wood quality of this resource is extremely important for forest managers and end users.

Considering the good results gained on Norway spruce (Daquitaine et al ,1999), a collaboration work was initiated in order to provide a wood quality simulation tool adapted for the Douglas-fir forest resource in Belgium (El Aydam et al, 1999). For this, the existing WinEPIFN software which was developed to assess the timber quality of existing Norway spruce plantations in north-eastern France, was planed to be adapted. Based upon simple forest inventory data namely the diameter at breast height, total height and age of trees, this software contains (i) a chain of models which reconstructs the past growth of trees, simulates branchiness and wood properties, (ii) a sawing simulator which provides logs and boards volumes versus quality, at a stand or a region level.

A state of the art of the scientific knowledge concerning Douglas fir and especially on models was done in order both to define our needs in terms of supplementary data and to built the appropriate models for Douglas fir.

The available models were tested on a first data set collected in Belgian young stands (33 years old). Characteristics such as height growth, stem taper, number and diameter of branches, wood density, were tested. On the base of this diagnostic, new models were developed and adjusted.

These new models were then tested on a second and independent data set (age of trees from 21 to 46 years) and simulations of board's visual grading were compared to the actual value.

The good results obtained allows the use of the adapted software in order to simulate the timber properties and timber value of Belgian trees harvested during early thinnings.

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Wood properties of Japanese larch: modelling and integration with a stand level growth simulator

Shinya KOGA, Yasushi MITSUDA, Shigejiro YOSHIDA, Morio IMADA, Tetsuo OKANO

Division of Forestry and Forest Products Sciences, Graduate School of Agriculture, Kyushu University, Hakozaki, Fukuoka, Japan

Japanese larch (*Larix kaempferi*) is a fast-growing species and is one of the most valuable reforestation species in Japan, especially in Hokkaido, the northernmost main island of Japan. Recently a stand level growth and yield model for even-aged, pure Japanese larch plantation in Hokkaido using some environmental factors derived from GIS was developed as a decision-making tool for forest managers. It has furthermore been developing a growth model based on crown structure. In these models, however, wood and stem properties are not taken in account so far. To establish a forest management system for meeting end-user requirements for timber products, wood quality prediction models for this species should be developed and integrated with the recent growth and yield model.

The objective of this study was (1) to evaluate effects of several factors such as site index, silvicultural treatments, crown size, tree age (or cambial age), and growth rate on basic wood properties such as heartwood content, moisture content, basic density, tracheid length, microfibril angle, (2) to develop wood quality models, and (3) to integrate those with the recent stand level growth model. The data based on several studies on forest inventory and wood properties of Japanese larch carried out in Kyushu University forests was used in this study.

It was possible to predict stem taper, and size and content of defect core containing knots or branches through the developed growth simulator based on crown structure. Sapwood content at breast height was highly correlated with crown structure, distance from crown, and tree age. Thus, size and content of heartwood (or sapwood) at breast height could be predicted through the developed growth simulator based on crown structure. The intra- and inter-tree variations in green moisture content of heartwood and sapwood for this species were appreciably small. Thus, green moisture content of heartwood and sapwood could take a fixed value in stand level wood quality models. At the stand level, basic density, tracheid length, and microfibril angle were strongly correlated with cambial age, while those were not significantly influenced by site index, silviculture treatment and crown volume. Therefore, wood quality model for each characteristics based on tree age, which was independent on the stand level growth simulator based on crown structure, was developed. Juvenile wood content could be predicted through the growth simulator based on crown structure as the same as defect core content.

Modelling growth and quality of Norway Spruce (*Picea abies*) with the growth simulator SILVA

Thomas SEIFERT, Hans PRETZSCH

Chair of Forest Yield Science of the Technische Universität München, Department of Ecosystem and Landscape Management, Freising, Germany

The connection between forest growth and wood quality models has been identified as a main challenge for both forest and wood scientists to provide a continuous simulation of the wood conversion chain by an analogue model chain (e.g. LEBAN ET AL. 1999, WILHELMSSON ET AL. 1999). Forest growth simulators make predictions for the initial raw material, the round timber, and can be regarded as the beginning of such a model chain. They are proven tools to estimate quantity and growth of the forest resource but often neglect the quality aspect.

The presented forest growth simulator SILVA (PRETZSCH 1997, 2001) is designed not only to interlink an existing growth simulator with a wood quality prediction model but rather to integrate both simulation aspects in one system where interactions and feedback processes between wood quality and growth models can be simulated. The aim of the integration is to create a tool for both scientific and applied purposes. The description of SILVA is focused on the integration of growth and quality models especially the recent advances since the presentation at the last workshop in La Londe-Les-Maures, 1999, when the wood quality part was outlined methodologically but not integrated (SEIFERT 1999).

SILVA is designed to estimate the growth of stands on different sites in Central Europe. It permits to simulate even aged and uneven aged, pure and mixed stands with a big variety of silvicultural treatments and allows the calculation of the financial revenue. Recent advances in the integration of wood quality for Norway spruce *(Picea abies* KARST.) in SILVA imply among other things the implementation of models for branchiness and the internal spread of the red rot fungus Heterobasidion annosum FR. (BREF.) in the stem as well as a bucking and grading model taking in account wood quality.

One of the main characteristics of the model is an explicit simulation of branchiness as a competition process in spruce stands. Competition is calculated from the stand structure and used to control crown development and hence branch growth. The possibility of simulating vertical and horizontal asymmetrical crown structures with plastic behaviour is an essential feature of the model and leads to more plausible branch distributions along the stem depending on the competition situation of each single tree. This spatial approach of modelling branchiness makes it possible to test different silvicultural treatments, which differ not only in thinning intensity but also in the spatial application of thinning. This is for example necessary for comparing geometric and selection thinning systems.

Another model covers the spread of decay in tree stems of Norway spruce caused by red rot, one of the most serious fungal pathogens for the quality of spruce timber in Europe. The model estimates the extent of the decayed wood in diameter, length and form and is able to predict the degree of decay which is an important criterion for grading.

The integration of these wood quality models is exemplified by a practical application in forestry: A case study of the effects of different thinning systems and intensities on timber quality of Norway spruce on a site in Southern Germany. The different thinning regimes alter both tree growth and wood quality. This scenario study gives a good overview on the simulator and the possibilities of the integrated modelling of growth and quality in a simulation tool. Furthermore the application potential of such an integrated simulation system is demonstrated.

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A multi-criteria approach to compare simulated silvicultural scenarios regarding growth, profitability, wood quality and biodiversity impact: application to Larch stands

Dominique PAUWELS, P. LEJEUNE, J. RONDEUX

Forest Management and Economics – Gembloux Agricultural University, Gembloux - Belgium

A silvicultural decision support system (DSS) is developed within the context of a FAIR European project (FAIR-CT98-3354 "Towards a European larch wood chain"). Its main objectives are: (i) to help in predicting the influence of silvicultural treatments on stand evolution and (ii) to guide the forest manager in the comparison of different scenarios relatively to predetermined goals.

This DSS concerns more particularly the silviculture of pure even-aged larch stands (European, Japanese or hybrid larches) in lowland areas where growth conditions are similar to South Belgium ones.

The DSS is made of three modules respectively devoted to (i) the growth prediction in relation to initial plantation spacings, thinning regime and site index (scenarios building), (ii) the assessment of a set of indicators characterising the scenarios and (iii) the comparison of scenarios' scores regarding calculated indicators (Multi-Criteria Decision Making or MCDM techniques).

The growth model deals with dominant height growth (site index curves) and individual trees diameter growth (distance independent tree-based model). A simulation model allows to take into account the installation conditions (initial spacing), an auto-thinning process and different thinning regimes (intensity, type, cycle).

Indicators are of different categories: financial, technical, and ecological. They characterise wood production both qualitatively and quantitatively. A risk assessment (windfall) is also performed.

Indicator assessment module is based upon such different prognosis tools as a heartwood prediction model and stem profile equations that allow to connect assortment optimisation to silviculture. By lack of suitable data, knots have not been characterised. An irradiance model, developed by CEMAGREF (Clermont-Ferrand, France) makes possible to connect available light and thus ground vegetation to such global stand parameters as basal area and dominant height.

A MCDM method based on partial aggregation (Electre III) is used to compare the built scenarios regarding the indicators.

This DSS is integrated in a user friendly designed software called MGC-Larch (Make Good Choice for larch) that allows the user to formulate, evaluate and compare different larch silviculture scenarios.

Connection between forest inventory data and geographic information systems for assessing timber value at the stand level.
Case study: Norway Spruce in Vosges mountains

Frederic BLAISE[1], *J.C. GÉGOUT*[2], *Laurent SAINT-ANDRÉ*[3], *J.C. HERVÉ*[2], *Jean-Michel LEBAN*[2]

[1] *Loria, Nancy, France*
[2] *Lerfob, Engref-INRA Nancy Champenox, France*
[3] *Cirad, Montpellier, France*

Recent developments in the modelling of tree growth and wood quality has produced new models and software packages that enable the simulation of timber properties, usually at the stand level. Separately foresters are now deeply involved in the development and implementation of GIS concerning forest yield, vegetation, soil properties and climatic variables etc. To our knowledge there no wood quality information available in such data base.

The objective of this work is to demonstrate that it is possible to establish a linkage between these Growth and Wood Quality models and the available forest geographic information.

We intend to present a method which enable to produce for the French Vosges mountain area (i) a map of forest ecological conditions (which combine climatic, trophic and hydric characteristics of sites) (ii) a map of the saw timber properties for Norway spruce stands and (iii) a realistic 3D representation of trees for one or more selected stands.

The software involved for this work are (i) AMAP that permits to simulate and to stage 3D shapes of plants including trees species (ii) ARCINFO a commercial GIS (iii) IMAGIS which interfaces AMAP and GIS in order to represent GIS information in photo realistic way (iv) Win-EPIFN which simulates the board visual properties from one stand described by it's usual forest inventory measurements.

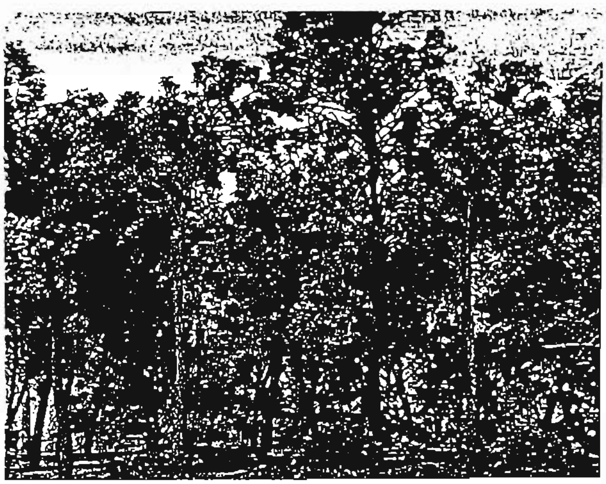

Fig 1: AMAP simulation

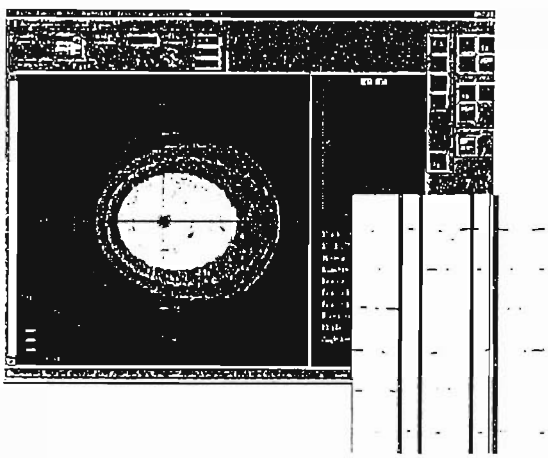

Fig 2: Wood quality simulated with Win-EPIFN

Using process-based approach for linking genetic origin and growth with environmental factors

Jean BEAULIEU[1], François HOULLIER[2], Jean-Michel LEBAN[2], Gérard NEPVEU[2], Frédéric RAULIER[1], Chhun-Huor UNG[1]

[1]Research Scientist, Laurentian Forestry Centre, Canadian Forest Service, Sainte Foy, Québec, Canada
[2] Head, Department of Forests, Institut National de la Recherche Agronomique, France

Forest geneticists have spent a great deal of time with provenance trials to delineate seed zones and recommend seed sources for a specific region to optimize stem growth or wood quality. Meanwhile, biometricians have also spent a great deal of time in Canada building growth models applicable on wide regions for natural forests but they never accounted for the species provenance. In one word, they either assume that the population for which they want to model its growth is totally homogeneous or that the provenance effect on growth is confounded with the effect of site fertility. Provenance trials, when they are dispersed on an extensive territory, represent an ideal way to separate the effects of the environmental factors on growth or wood quality with those caused by the genotypic variability. This work addresses (1) the null hypothesis that genetic effects on growth of black spruce (*Picea mariana* (Mill.) B.S.P.) are mostly confounded with environmental effects and (2) the consequences of upscaling these relationships with growth models when ignoring the genetic effects for the operational application (i.e. climatic and edaphic maps, and remote sensing spectral signal).

The work uses the paradigm that both tree growth (net primary productivity) and wood quality (i.e. branchiness and wood density) are determined by site environmental factors (degree-day, vapour pressure deficit, precipitation, soil water holding capacity) and by biomass allocation (distribution of the biomass between stand storeys and tree compartments, i.e. leaf, branch, stem, fine and coarse roots). The paradigm relies on the fact that tree growth is driven by the interception of radiant energy and its conversion into carbohydrates through photosynthesis. The work is based on the crucial data on the growth pattern and allometric relationships of different genotypes. The data are collected on the existing field experiments of the range-wide black spruce provenance study. These experiments were established between 1973 and 1977 through the co-operation United States – Canada from the Atlantic Coast to Alberta.

Experiences from industrial implementations of forest - wood chain models

Arto USENIUS

VTT Building and Transport, VTT, Finland

Since early 1970 VTT (Technical Research Centre of Finland), Wood and Composite Materials, has developed scientific models to describe the dependencies between properties of wood products, processing parameters and characteristiscs of wood raw material. The models are essential parts of simulation and integrated optimization software systems describing the whole conversion chain from the forest to the end products. The aim has been to increase value yield and profitability of wood converting companies by developing software tools for supporting short term operational planning as well as long term strategical planning.

Simulation and optimisation software system consists of the following modules, which can be integrated according to the needs of system users in the sawmills and plywood factories:

- selection of stands
- bucking and cross cutting of stems
- grading and sorting of logs
- sawing of sawn timber products and components
- peeling of veneer
- grading of sawn timber products and plywood
- designing of new business concepts.

In the development of the models and software special emphasise has been paid on the description of quality features of products and wood materials. Software system or a part of it has been implemented in many companies. The size of the companies varies from very small to very big companies. The configuration of the software system is always made according to the needs of the company.

In the presentation the following topics will be discussed:

- description of the software system
- determination of companies' needs
- designing of software configuration
- implementation of software at the company's business environment
- collection of input data
- evaluation of the software's functionality and predictability
- training of companies' personal.

Business life in forest industry is becoming more and more dynamic, flexible and customer oriented. Due to huge number of operation alternatives it is not possible to manage business without computer aided planning. Practical experiences of industrial use of simulation and optimisation software have yielded good results. It has been possible to increase the sales value of the production by several per cent compared to planning produced manually or by simpler computer programs.

Integrative modelling approach to assess the sustainability of the eucalyptus plantations in Congo

Laurent SAINT-ANDRÉ [1], Jean-Paul LACLAU [2], Jean-Pierre BOUILLET [1], Philippe DELEPORTE[3], André MIABALA[3], Nina OGNOUABI[3], Henri BAILLÈRES[4], Yann NOUVELLON[3], Regis MOUKINI [5]

[1]*CIRAD, Campus de Baillarguet, Montpellier Cedex, France*
[2]*USP/ESALQ-LCF, Piracicaba, Brazil*
[3]*CIRAD-UR2PI, Pointe-Noire, Congo*
[4]*CIRAD, Maison de la technologie, Montpellier Cedex, France*
[5]*ECOsa, Pointe-Noire, Congo*

Since 1978, 42000 ha of clonal eucalyptus plantations have been established in the littoral savannas of Congo, mainly for pulpwood production. These plantations were established on sandy soils, characterised by low reserves of available nutrients and a low water retention capacity. An intensive silviculture is carried out, resulting in the removal of high amounts of biomass and nutrients every 7 years. Therefore, a decision-making tool is needed (i) to assess stand productions under different silvicultural options, (ii) to evaluate the risks of nutrient deficiencies and non sustainable production, and (iii) to estimate the economic return of different harvesting strategies. For many years, field trials have been established focusing on clonal selection, silvicultural practices, stand growth and quantification of the biogeochemical cycles of nutrients. This high amount of data was used (or will be used) to elaborate a chain of models named "EUCALYPT-Dendro" that includes three main modules.

The growth module: A single tree distance-independent model was elaborated. The dominant height growth model is similar to the one developed by Dhôte (1996). However, two main differences can be reported: (i) the model was segmented in order to take into account a change in height growth rate that occurs during stand rotation, (ii) tree spacing affected the dominant height growth and was introduced as regressor in the equation. The stand basal area increment is function of the dominant height increment. Individual tree basal area is function of a potential (given by the stand basal area increment) and a reductor (given by the size of the tree). The height of the trees is obtained from a height – girth relationship. Tree mortality is not yet taken into account (but in our case, tree mortality is limited owing to the short rotation length).

The wood properties module: a generic stem taper equation was constructed. It explicitly takes into account the global taper of the bole (when the trunk is assumed to be a cone), the but swell and the decrease in diameter within the crown. The equation allows accurate estimations of diameters and volumes along the bole. The wood density model was based upon a non-parametrical modelling approach but is not yet introduced within the chain of models. Allometric relationships were also fitted for evaluating the biomass of roots, branches, stem, bark and leaves throughout the whole rotation.

The biogeochemical module: a model was built to assess the distribution of nutrient concentrations (N, P, K) in individual rings within the bole and their changes with the ring ageing. Furthermore, different allometric relationships estimated the nutrient contents within the branches, roots, leaves and bark. Input-output budgets of nutrients at the plot level were simulated during the whole planted crop rotation from (i) measurements of nutrient fluxes in a clonal stand between ages 6 and 9 years, (ii) a chronosequence approach to quantify the main fluxes of the biological cycle throughout stand rotation, and (iii) hypotheses concerning nutrient losses by deep drainage during the juvenile stand growth.

Work is in progress. All these models are embedded within Capsis (for the growth modelling part). Key points concerning the building of the models are presented. Input-output budgets of nutrients during the planted crop rotation are simulated to assess the influence of various silvicultural practices (spacing, rotation length, harvesting options) on the amount of available nutrients in the soil. Economical aspects are not evaluated.

Using a chain of models to optimize the management of a forest resource: what about the precision of the results? Case study on carbon sequestration in a Sessile Oak stand

Gilles LE MOGUÉDEC

LERFOB, Centre INRA de Nancy, Champenoux, France

A chain of models is used in our team to optimise the management of a forest resource. As shown by Nepveu et al. in the present workshop, several criteria can be computed, each of them lead to a different optimal silviculture.

Once a criterion is chosen and the corresponding optimal solution found, it should be asked how reliable this solution is. In other words, what is the precision associated to this solution ?

Very often, when results from a model are presented, a confidence interval is given from the residual of this model. But this residual is not an error, it is a part of the model. The sensitivity to the estimation of the parameters of the model and the uncertainty on the inputs are rarely taken into account. However there exist some methods that allow to study them.

In this presentation, we will present two families of method to study the precision of the results. They will be illustrated with results from models of the chain "From the plant to the plank" available in our team. First model is a distance-independent growth model *Fagacées* that delivers the ring profile of each tree in a stand in relation with the stand conditions and the silviculture applied. These profiles are then used by the second model to compute the wood density in logs. This density is closely related to the carbon contents of the logs. These models are used to compute a silvicultural schedule that maximises the Carbon stored in the logs. The precision of the result is studied at this "optimal" silviculture.

For this study, we will consider several kinds of "precision":

a) if the model contains a residual random variable, the residual variance has to be estimated;
b) most of the time, parameters of the models have to be estimated, the sensitivity of the results to the values used for these parameters has to be studied (sensitivity analysis);
c) there is an uncertainty due to the precision on the inputs of models (uncertainty analysis).

When the model is simple enough, for example when the model has an explicit expression such as a regression equation, analytic formulae can give directly the expressions of the different kinds of precision. This the case for our density model. Results are very general and numeric applications can be performed in every area of interest by using the same formulae.

But most of the time, models are too complicated so that an analytic study is not possible. This is the case for the model *Fagacées*. In this case, a numeric study has to be performed. The main disadvantages of this method are its cost in terms of computational resources and the fact that the results are only locally valid. They could not be extended to another area than the one where the analysis has been performed.

However, there are several strategies to reduce the number of numeric evaluations to be done. Take the case of an sensitivity analysis on the parameters of the models. If a joint distribution of these parameters is available (or at least a variance matrix for the estimators of these parameters), it can be used to simulate a sample of parameters. The final result is then a variance on the outputs that can lead to a confidence interval. If this information is not available, for example if some of the parameters have been arbitrarily given a value, a design of experiment on the different values to be tested for the different parameters should be constructed. In this case, the result will be only an approximate formula that gives the variation on the outputs due to the variation on the parameters values. This results could be used to detect which parameters are the most sensitive and then to decide on which part of the model a further study should be performed if necessary.

Once the study done on each model of the chain, the results have to be used together to determine the precision on the final result from the whole chain. The global precision on the result is already an interesting result, but the study could also be used to detect the eventual weak link within the chain.

Optimizing the chain from the plant to the plank in Sessile Oak by taking into account considerations related to sustainable management

Gérard NEPVEU[1], *Gilles LE MOGUÉDEC*[1], *Jean-François DHÔTE*[2], *Thiéry CONSTANT*[1], *Frédéric MOTHE*[1], *Edith GUILLEY*[3]

[1]*LERFOB, Centre INRA de Nancy.Champenoux, France*
[2]*LERFOB, France*
[3]*CIG-Université de Genèv, Genève, Suisse.*

The main title of this Workshop is « *Connection between forest resources and wood quality : modelling approaches and simulation software* ». Models are explicitly mentioned as tools for help in the management of a forest resource and in estimating the quantity and quality of resulting products. The underlying idea is to use models to find the best management of a forest resource, *id est* they are used to optimise the management. The logical consequence of these considerations is that the models have to contain explicitly tools for optimisation, or that they have to be used by optimisation software.

The chain of models available for Sessile oak in our team starts with a distance-independent growth model called *Fagacées* that delivers the ring profile of each tree in a stand in relation with the stand conditions and the silviculture applied. It computes also the volume of wood with(out) knot in each log. The following models compute some basic wood properties (wood density, spiral grain, ...) from these profiles in each point of the logs. All this information are then used by a sawing model in order to compute the properties of boards issued from the tree population. Some other models can be used to compute additional outputs from the intermediate results of the existing models. For example, there is a relation between the carbon content of wood and its density.

At the day, the connection between all of these models is not achieved. We will present results obtained from a part of the chain. It starts from the growth model *Fagacées* and uses a wood density model to compute the density of the logs. From these models are computed:

a) volume of different compartments (crown, wood with/without knot in the log) within diameter classes;
b) bark volume (part of the log in which most of the mineral elements are stored);
c) carbon content of wood;
d) some economical criteria.

Each of these criteria could represent an objective function to optimise. Some of them such as carbon content or bark volume could represent objective functions for sustainable management consideration. The question is to find a silvicultural management that optimise the considered objective.

Each of the considered criteria leads to a different optimal silvicultural scenario. The ways of combining the different solutions are discussed in the presentation.

In addition, since a silvicultural revolution in Oak takes in France approximately two centuries, the economical indexes have to take the time into consideration. It is classically done by using the rate of discount. The value of this rate has to be chosen according to the hypothesis about manager's point of view (public or private manager for example). The used value is to be carefully discussed since the results are very sensitive to this parameter.

In further developments, we intend to connect all the available model and to define more precisely the criteria to be optimised. We intend also to use other optimisation algorithms that allow to be less restrictive on the family or scenarios used (in order to the thinning to be also optimised for example). Finally, we intend to extend our work to a whole forest resource and not only a single stand. These future developments are presented in the conclusion of the presentation.

ANEXO 2

THE NAMES AND ADDRESSES OF THE PEOPLE PARTICIPATING IN THE WORKSHOP

Sencer Alkan
Forintek Canada Corp.
2665 East Mall
Vancouver BC, Canada V6T 1W5
E-mail:alkan@van.forintek.ca
Phone:604-222-5684

John Arlinger
SkogForsk - The Forestry Research Institute of Sweden
Science Park
Uppsala, Sweden SE-751 83
E-mail:john.arlinger@skogforsk.se
Phone:46 18 188503

Miguel Badia
Equipe Qualite Bois du Lerfob
Centre INRA de Nancy
Champenoux, France 54280
E-mail:badia@nancy.inra.fr
Phone:33 3 83 39 41 42

Jean Beaulieu
Canadian Forest Service
Natural Resources Canada
1055 du Peps
Sainte-Foy QC, Canada G1V 4C7
E-mail:beaulieu@cfl.forestry.ca
Phone:418-648-5823

Robert Beauregard
Universite Laval
Dept. des Sciences du Bois et de la Foret
Pavillon Abitibi-Price
Universite Laval QB, Canada G1K 7P4
E-mail:Robert.Beauregard@sbf.ulaval.ca
Phone:418-656-7684

Gero Becker
Institut fur Forstbenutzung und Forst.
Albert-Ludwigs-Universitat Freiburg
Werderring 6
Freiburg, Germany 79085
E-mail:fobawi@uni-freiburg.de
Phone:49 761-203 37 64

Frederic Blaise
LORIA
Campus Scientifique B.P. 239
Nancy Cedex, France 54506
E-mail:blaise@loria.fr
Phone:33 383 59 2029

Jean-Francois Bouffard
Universite Laval
Dept. des Sciences du Bois et de la Foret
Pavillon Abitibi-Price
Quebec City QB, Canada G1K 7P4
E-mail:jeffbouffe@hotmail.com
Phone:418-659-2647

David Briggs
Univ. of Washington
College of Forest Resources
Box 352100
Seattle WA, 98195
E-mail:dbriggs@u.washington.edu
Phone:206-543-1581

Franka Brüchert
Institute for Forest Science
Freiburg University
Werderring 6
Freiburg, Germany 79085
E-mail:franka.bruechert@fobawi.uni-freiburg.de
Phone:0049-761-203 9244

Charlie Cartwright
BC Ministry of Forests
Cowichan Lake Research Station
PO Box 335
Mesachie Lake, BC Canada V0R 2N0
E-mail:Charlie.Cartwright@gems1.gov.bc.ca
Phone: 250-749-6811

Kerrie Catchpoole
CRC Sustainable Production Forestry
Queensland Research Institute
PO Box 631
Indooroopilly QLD, Australia 4068
E-mail:~~catchpk~~@qfslab.dpi.qld.gov.au
Phone:61-7-3896 9503

Alexander Clark
USDA Forest Service
Southern Research Station
320 Green Street
Athens GA, 30602
E-mail:aclark@fs.fed.us
Phone:706-559-4323

Dave Cown
New Zealand Forest Research Institute
Private Bag 3020
Rotorua, New Zealand
E-mail:dave.cown@forestresearch.co.nz
Phone:64-7-343-5525

Richard Daniels
Warnell School of Forest Resources
University of Georgia
Athens GA, 30602
E-mail:ddaniels@uga.edu
Phone:706-542-7298

Renaud Daquitaine
Equipe Qualite Bois du Lerfob
Centre INRA de Nancy
Champenoux, France 54280
E-mail:daquitaine@nancy.inra.fr
Phone:33 3 83 39 41 39

Jean-Francois Dhôte
Equipe Dynamique Des Systemes Forestiers du Lerfob
Centre INRA de Nancy
14 rue Girardet CS 4216
Nancy Cedex, France 54042
E-mail:dhote@nancy-engref.inra.fr
Phone:33 3 83 39 68 56

C. Mario Di Lucca
BC Ministry of Forests
Research Branch
PO Box 9519 Stn. Prov. Govt.
Victoria BC, Canada V8W 1L4
E-mail:mario.dilucca@gems4.gov.bc.ca
Phone:250-387-6679

Paulina Fernández
Pontifica Universidad Catolica de Chile
Av. Vicuna Mackenna 4860 Macul
Santiago, Chile
E-mail:pfernan@puc.cl
Phone:56-2-686-4884

James Funck
Oregon State University
Dept. of Wood Science and Engr.
119 Richardson Hall
Corvallis OR, 97331-5751
E-mail:Jim.Funck@orst.edu
Phone:541-737-4207

Barry Gardiner
Forestry Commision Research Agency
Northern Research Station
Roslin Midloth, Scotland UK EH259SY
E-mail:Barry.Gardiner@forestry.gsi.gov.uk
Phone:44-131-445-5124

Rolando Coro Gonzalez
Universidad de Santiago de Compostela
Escuela Politecnica Superior
Campo Univ. S/N
Lugo, Spain 27002
E-mail:rocgonzalez@terra.es
Phone:982-252231 x23222

James Goudie
BC Ministry of Forests
Research Branch
PO Box 9519 Stn. Prov. Govt.
Victoria BC, Canada V8W 9C2
E-mail:jim.goudie@gems4.gov.bc.ca
Phone:250-387-6535

Lana Goudie (Accompanying person)
469 Admirals Road
Victoria BC, Canada V9A 2N2
E-mail:LanaGoudie@shaw.ca
Phone:250-386-9282

Nathan Goudie
469 Admirals Road
Victoria BC, Canada V9A 2N2
Phone:250-386-9282

Anders Grönlund
LuLea University of Technology
Skelleftea Campus
Skeria 3
Skelleftea, Sweden S-93187
E-mail:anders.gronlund@tt.luth.se
Phone:46-0910-585307

Erlend Ystrom Haartveit
Norwegian Forest Research Institute
Hogskolevein 12
Aas, Norway N-1432
E-mail:erlend.haartveit@skogforsk.no
Phone:47 64949095

Kevin Harding
Queensland Forestry Research Institute
Queensland Dept. of Primary Industries
PO Box 631 Indooroopilly
4068 QLD, Australia
E-mail:Kevin.Harding@dpi.qld.gov.au
Phone:61 7 3896 9766

Sebastian Hein
Institute for Forest Growth
Universitat Freiburg
Bertoldstr. 17
Freiburg, Germany 79085
E-mail:sebastian.hein@iww.uni-freiburg.de
Phone:49 761 203 3737

Henrik Heräjärvi
Finnish Forest Research Institute
PO Box 68
Joensuu, Finland FIN-80101
E-mail:henrik.herjarvi@metla.fi
Phone:358-13-251-4037

Olav Albert Høibø
Agricultural University of Norway
PO Box 5044
Aas, Norway N-1432
E-mail:olav.hoibo@isf.nlh.no
Phone:47-649-48943

Veli-Pekka Ikonen
University of Joensuu
Faculty of Forestry
PO Box 111
Joensuu, Finland FIN-80101
E-mail:vpikonen@forest.joensuu.fi
Phone:358-13-2514401

Marie Johansson
Chalmers University of Technology
Steel and Timber Structures
Gotenborg, Sweden 412 96
E-mail:marie.johansson@stechalmers.edu
Phone:46-31-772-2028

Meng Zhen Kang
Chinese Academy of Sciences
Institute of Automation LIAMA
Beijing #2728
Beijing, China 100081
E-mail:mzkang@nlpr.ia.ac.cn
Phone:(8610) 62647459

Anu Kantola
METLA - Finnish Forest Research Institute
Jokiniemenkuja 1
PO Box 18
Vantaa, Finland FIN-01301
E-mail:anu.kantola@metla.fi
Phone:358 9 8570 5305

John King
Research Scientist, Forest Genetics,
Research Branch,
British Columbia Ministry of Forests,
P.O. Box 9519 Stn Prov Govt
Victoria, B.C. V8W 9C2, Canada
Email: john.king@gems7.gov.bc.ca
Phone: 250 387 6476

Shinya Koga
Kyushu University
Dept. of Forests - Faculty of Agriculture
Tsubakuro 394 Sasaguri
Kasuya Fukuoka Prefecture, Japan 811-2415
E-mail:kogafor@mbox.mc.kyushu-u.ac.jp
Phone:81 92 948 3117

Gilles Le Moguédec
Equipe Qualite Bois du Lerfob
Centre INRA de Nancy
Champenoux, France 54280
E-mail:moguedec@nancy.inra.fr
Phone:33 3 83 39 41 42

Shengquan Liu
Anhui Agricultural University
Forest Products Department
Changjian Xilu, 130
Heifei City, Anhui Prov. China 230036
E-mail:liusq@mail.hf.ah.cn
Phone:0086-551-2823795

Eini Lowell
USDA Forest Service
PO Box 3890
Portland OR, 97208
E-mail:elowell@fs.fed.us
Phone:503-808-2072

Sven-Olof Lundqvist
STFI - Swedish Pulp & Paper Res. Inst.
Box 5604
Stockholm, Sweden S-11486
E-mail:svenolof.lundqvist@stfi.se
Phone:46 8 676 7510

Douglas Maguire
Oregon State University
Dept. of Forest Science
Corvallis OR, 97331
E-mail:doug.maguire@orst.edu
Phone:541-737-4215

Annikki Mäkelä
University of Helsinki
Department of Forest Ecology
PO Box 27 (Latokartanonkaari 7)
University of Helsinki
Helsinki, Finland
E-mail:annikki.makela@helsinki.fi
Phone:358 9 191 58 108

Harri Mäkinen
Finnish Forest Research Institute
PO Box 18
Vantaa, Finland FIN-01301
E-mail:harri.makinen@metla.fi
Phone:358-9-85705308

Jukka Malinen
University of Joensuu
Faculty of Forestry
PO Box 111
Joensuu, Finland FIN-80101
E-mail:Jukka.Malinen@jeonsuu.fi
Phone:358-13-2513625

Thomas C. Maness
Associate Professor
Faculty of Forestry
University of British Columbia
Vancouver BC V6T 1Z4
E-mail: maness@interchange.ubc.ca
Phone:604-822-2150

Celine Méredieu
INRA Unite de Recherches Forestieres
Equipe Croissance et Production
BP 45
Cestas Gazinet, France 33611
E-mail:celine.meredieu@pierroton.inra.fr
Phone:33 5 57 12 28 61

Judy Mikowski
USDA Forest Service
PO Box 3890
Portland OR, USA 97208
Phone:503-808-2003

Nico Mönnig
Global Forest Products
PO Box 69
Sabie, South Africa 1260
E-mail:nmonnig@globalforestproducts.net
Phone:2713-7641011

Frederic Mothe
Equipe Qualite Bois du Lerfob
Centre INRA de Nancy
Champenoux, France 54280
E-mail:mothe@nancy.inra.fr
Phone:33 3 83 39 41 45

Gerard Nepveu
Equipe Qualite Bois du Lerfob
Centre INRA de Nancy
Champenoux, France 54280
E-mail:nepveu@nancy.inra.fr
Phone:33 3 83 39 40 61

Leif Nutto
Institut fur Forstbenutzung und Forst.
Arbeitswissenschaft
Universitat Freiburg
Werderring 6
Freiburg, Germany 79085
E-mail:leif.nutto@uni-freiburg.de
Phone:49 761-203 37 64

Mats Nylinder
Dept. of Forest Products and Marketing
Swedish University of Ag. Sciences
Box 7060
Uppsala, Sweden 750 07
E-mail:Mats.Nylinder@spm.slu.se
Phone:46-18-672470

Johan Oja
Resource Characterization Scientist
Forintex Canada Corp.
2665 East Mall
Vancouver, BC V6T 1W5 Canada
E-mail:johan@van.forintex.ca
Phone:604-224-3221

Dominique Pauwels
Gembloux Agricultural Univeristy
Unit of Forest Mgnt. and Economcis
Passage des Deportes 2
Gembloux, Belgium 5030
E-mail:pauwels.d@fsagx.ac.be
Phone:32 81 62 22 94

Sandrine Perret
CEMAGREF
Research Unit
Domaine des Barres
Nogent sur Vernisson, France 45290
E-mail:sandrine.perret@cemagref.fr
Phone:33 2 38 95 05 48

Hans Petersson
Chalmers University of Technology
Department of Structural Mechanics
Goteborg, Sweden 412 96
E-mail:hp@chalmers.se
Phone:46-31-772-1984

C. Sue Price
Environmentek CSIR
PO Box 17001
Congella
KwaZulu Natal Durban, South Africa 4013
E-mail:sprice@csir.co.za
Phone:27-31-261-8161

Laurent Saint-André
CIRAD-Foret
Campus de baillarguet TA 10/C
Montpellier CEDEX, France 34398
E-mail:standre@cirad.fr
Phone:33-0-4-67-59-37-47

Karin Sandberg
AB Tratek
Skeria 2
Skelleftea, Sweden 931 77
E-mail:karin.sandberg@tratek.se
Phone:46-910-58-52-42

Ute Seeling
Institute of Forest Utilisation
Forest Products Lab
Werderring 6
Freiburg, Germany 79085
E-mail:ute.seeling@fobwai.uni-freiburg.de
Phone:49 761 203 3765

Thomas Seifert
Technische Universtaet Muenchen
Am Hochanger 13
Freising, Germany 85354
E-mail:seifert@lrz.tum.de
Phone:49 8161 714 713

Isabel da Silva Pinto
VTT Technical Res. Centre of Finland
PO Box 1806
VTT, Finland FIN-02044
E-mail:isabel.pinto@vtt.fi
Phone:358 9 456 5565

Ryan Singleton
Oregon State University
Dept. of Wood Science and Engr.
119 Richardson Hall
Corvallis OR, 97331
E-mail:Ryan.Singleton@orst.edu
Phone:541-383-4011

Geoff Smith
State Forests of New South Wales
Cnr Hood and High Sts
Coffs Harbor NSW, New Zealand 2450
E-mail:GeoffSm@sf.nsw.gov.au
Phone:61-2-6652-8677

Charles Sorensson
Tree & Technology Ltd.
RD 2
Te Teko
Whakanate, New Zealand
E-mail:charles.sorensson@treetech.co.nz
Phone:64-7-322-9038

Reeta Stöd
Finnish Forest Research Institute
PO Box 68
Joensuu, Finland FIN-80101
E-mail:reeta.stod@metla.fi
Phone:358-13-251-5334

Christine Todoroki
Forest Research
Sala Street Private Bag 3020
Rotorua, New Zealand
E-mail:christine.todoroki@forestresearch.co.nz
Phone:64-7-343-5662

Eric Turnblom
College of Forest Resources
University of Washington
Box 352100
Seattle WA, 98195
E-mail:ect@u.washington.edu
Phone:206-543-2762

Philip Turner
Environmentek CSIR
PO Box 17001
Congella
KwaZulu Nat. Durban, SouthAfrica 4013
E-mail:pturner@csir.co.za
Phone:27-31-261-8161

Arto Usenius
VTT Technical Res. Centre of Finland
PO Box 1806
VTT, Finland FIN-02044
E-mail:arto.usenius@vtt.fi
Phone:358 9 456 5540

Erkki Verkasalo
The Finnish Forest Research Institute METLA
PO Box 68 (Yliopistokatu 7)
Joensuu, Finland FIN-80101
E-mail:erkki.verkasalo@metla.fi
Phone:358 13 2514000

Holger Wernsdörfer
Inst. of Forest Utilization & Work Science
University of Freiburg
Werderring 6
Freiburg, Germany 79085
E-mail:wernsdor@nancy.inra.fr
Phone:0049-761-203-3764

Elisabeth Wilhelmsson (Accompanying person)
SkogForsk - The Forestry Research Institute of Sweden
Science Park
Uppsala, Sweden SE-751 83
Phone:46 18 188555

Lars Wilhelmsson
SkogForsk - The Forestry Research Institute of Sweden
Science Park
Uppsala, Sweden SE-751 83
E-mail:lars.wilhelmsson@skogforsk.se
Phone:46 18 188555

Jeff Welty
Weyerhaeuser Co.
PO Box 9777-WTC 1A3
Federal Way, WA 98063
E-mail:jeff.welty@weyerhaeuser.com
Phone:253-924-6315

Kana Yamashita
Forestry and Forest Products Research Institute
Wood Property Division
PO Box 16 Tsukuba Norin
Kukisaki Ibaraki, Japan 305-8687
E-mail:zaikana@ffpri.affrc.go.jp
Phone:81-298-73-3211

Barb Young
BC Ministry of Forests
Research Branch
PO Box 9519 Stn. Prov. Govt.
Victoria BC, Canada V8W 9C2
E-mail:barb.young@gems4.gov.bc.ca
Phone:250-387-6535

S.Y. Tony Zhang
Forintek Canada Corp.
319 rue Franquet
Sainte-Foy QC, Canada G1P 4R4
E-mail:Tony.Zhang@qc.forintek.ca
Phone:418-659-2647

Centre for Advanced Wood Processing

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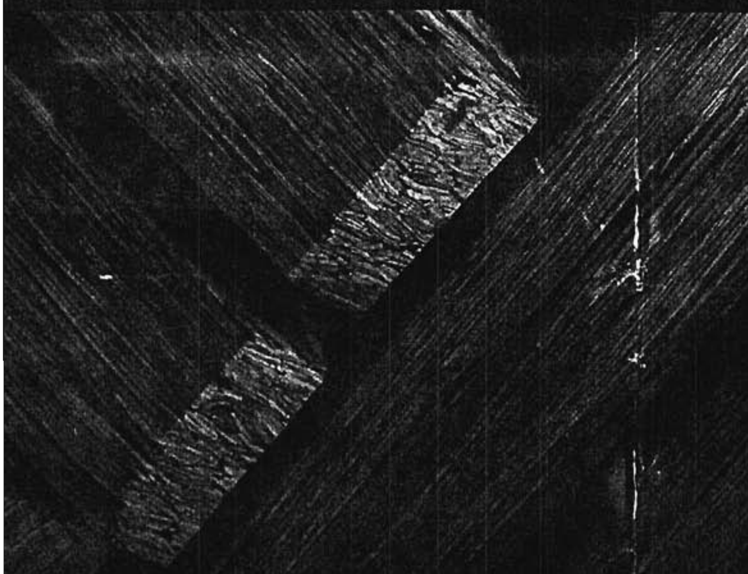
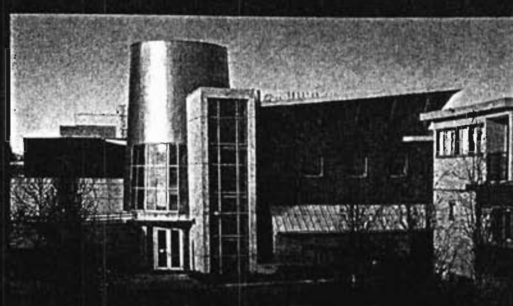
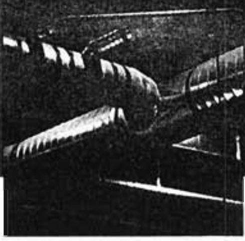


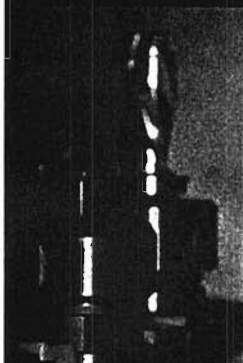
Research, technology transfer and education for Canada's wood processing industry

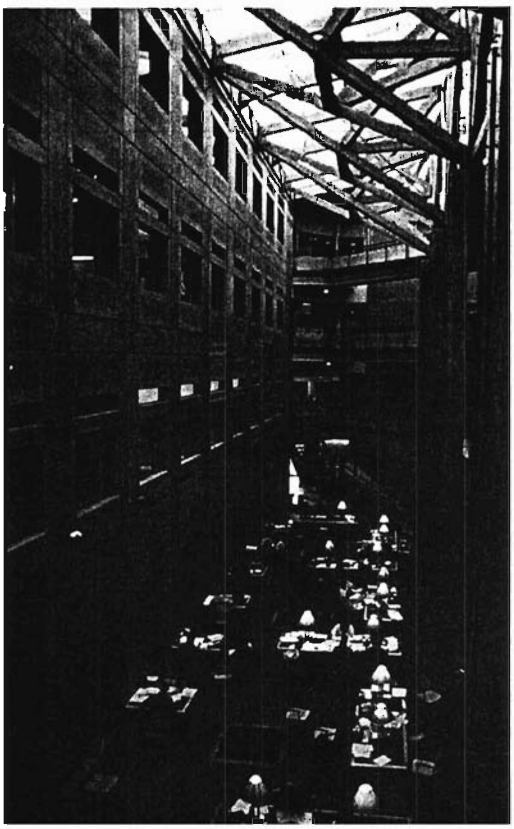




Centre for Advanced Wood Processing

The Centre for Advanced Wood Processing is Canada's national centre of excellence for the wood products industry. The National Education Initiative, a group of leading private-sector companies, articulated the vision that led to the Centre being constituted through a partnership of the governments of Canada and British Columbia, Forest Renewal BC, Canada's wood products industry and the University of British Columbia, in 1996. This partnership supported the creation of the Centre and provides ongoing guidance through an active advisory board that has strong industry representation.





Atrium of UBC's Forest Sciences Centre.

Faculty of Forestry

The University of British Columbia

Forest Sciences Centre

Suite 2900 - 2424 Main Mall

Vancouver, BC Canada

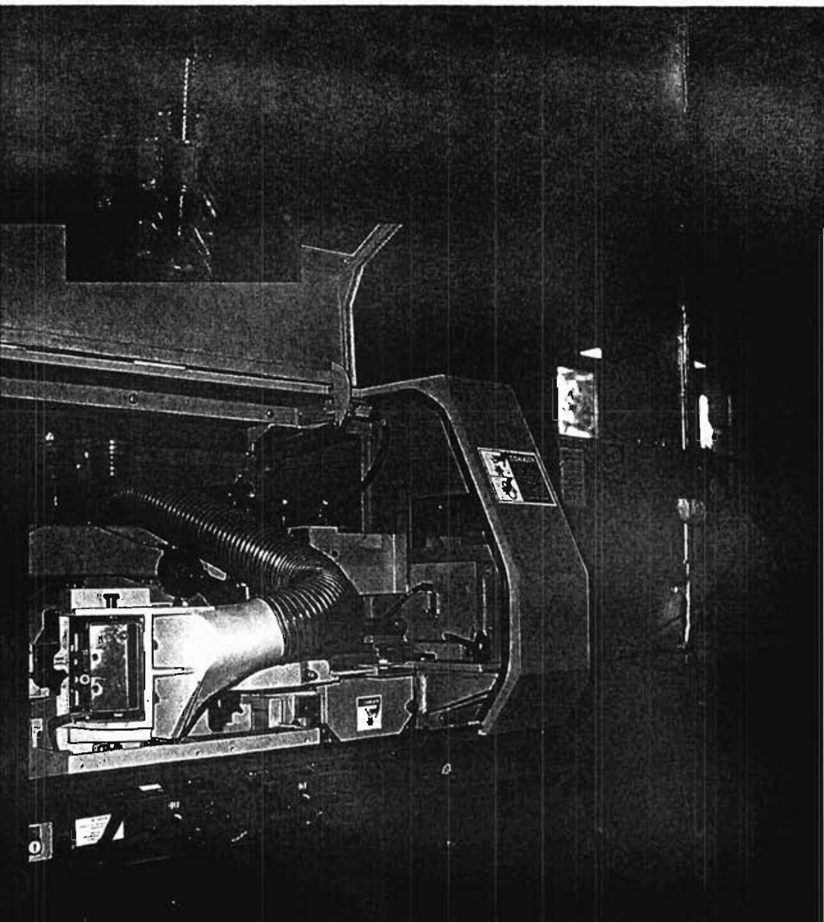
V6T 1Z4

Tel: 604-822-6448

Fax: 604-822-9159

Email: cawp@interchange.ubc.ca

Web: www.cawp.ubc.ca



Students gain experience on a variety of state-of-the-art equipment.

Hands-on learning enhances industry skills set

Access to leading-edge technical and managerial skills is made available to Canadian industry through the Cooperative Education Program.

The co-op program is a combined effort of the University of BC, undergraduate students enrolled in the UBC Faculty of Forestry's Wood Products Processing program, and participating employers from Canada's wood processing sector.

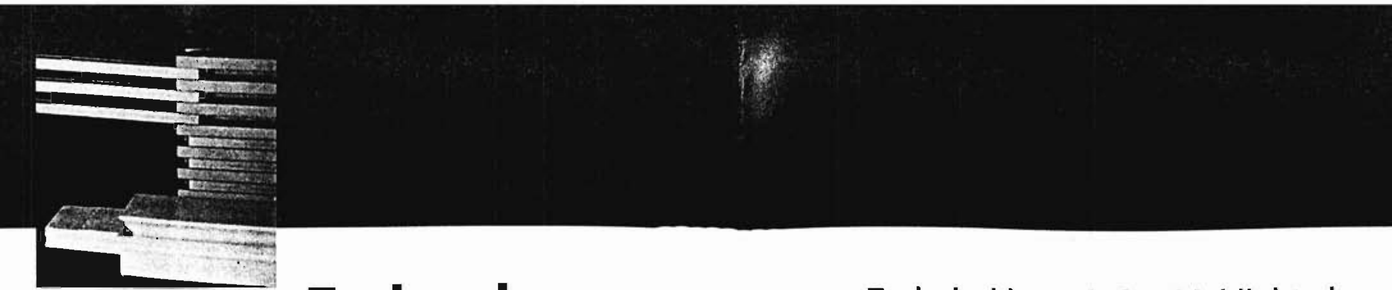
The program introduces companies to employment candidates schooled in state-of-the-art technical processes and operations for the wood processing industry, as well as business systems, trouble-shooting and problem solving.

Co-op program students complete five work terms covering up to 19 months of their five-year degree program. They are paid as regular employees, matched to on-the-job experience suited to their academic studies, and typically engage in a wide range of projects that can include:

- production process re-engineering
- material flow analysis
- product testing
- time and motion studies
- yield calculations
- safety procedures
- quality control and assurance

Managerial skills emphasized

UBC's Wood Products Processing program, run by the Department of Wood Science, prepares students for management-level careers in production management, quality control, project evaluation and product development. The degree program is designed to produce graduates with comprehensive knowledge and understanding of wood as a raw material, and who are capable of planning, building and managing wood products manufacturing facilities containing advanced computerized equipment.



Technology transfers to Canadian industry

Education, life-long learning, retraining and knowledge transfers are tailored to the needs of Canada's value-added wood products industries.

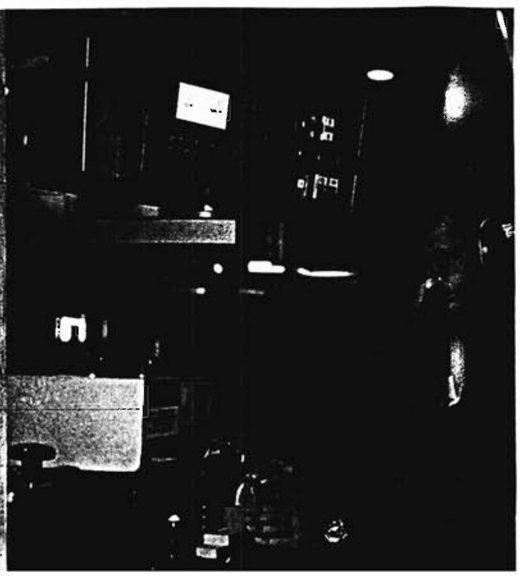
Our strength in applied research and development allows the Centre for Advanced Wood Processing to transfer leading-edge technical knowledge and innovation to Canada's wood products industry.

We operate a continuing education program to help people acquire and hone the advanced skills required to keep pace with change in our industry. Education, life-long learning, retraining and knowledge transfers are tailored to the needs of Canada's value-added, primary, secondary and tertiary wood products industries.

Our programs focus on technological developments in wood processing equipment and materials, business management, organization and computerized information systems. They include seminars and workshops at the Centre for Advanced Wood Processing, and at key locations across Canada.

Information about pending seminars and workshops is available from the Centre for Advanced Wood Processing.

www.cawp.ubc.ca



Technical knowledge highlighted

Conferences feature internationally-recognized specialists in wood and wood processing, highlighting specific areas of interest to the Canadian industry.

Our recent conferences include:

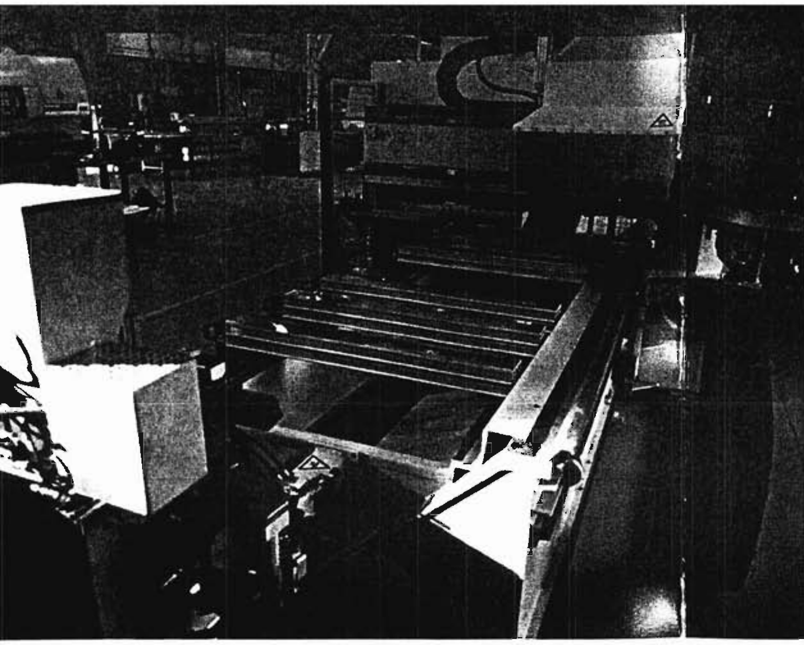
- International Value-Added Wood Processing Conference series (Vancouver, Toronto)
- International Conference on Global Markets for Value Added Wood Products (Halifax)
- Wood Finishing Technology Conference (Vancouver, Atlanta)
- Industrial Symposiums on Tooling and Machining for the Wood Industry (Vancouver, Raleigh)

Sessions combine theory, application

Workshops presented by the Centre for Advanced Wood Processing combine classroom theory with shop work in a broad range of specialized fields, with emphasis on specialized processing equipment and systems.

Featured topics include:

- quality control, management and teamwork
- marketing for value-added wood products manufacturers
- integrating and using advanced machines and processes
- wood machining, tooling and problem analysis
- kiln drying
- traditional and advanced wood finishing
- local and exotic wood veneering technology
- equipment costing and selection
- process design, layout and optimization



CAWP

Applied research advances Canada's capabilities

We are committed to advancing existing wood processing methods and technologies, to developing new ones, and to applying and to transferring the results of our work to industry.

The Centre for Advanced Wood Processing works hand-in-hand with Canada's wood products manufacturers to improve knowledge, systems and technologies for application in industry.

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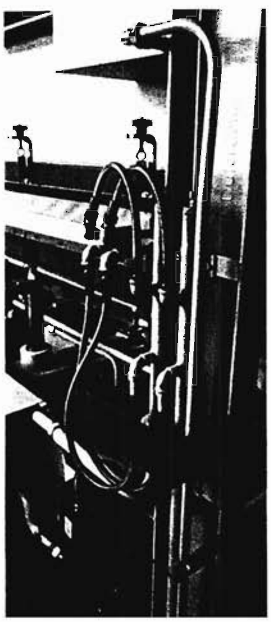


Research projects are conducted in association with our programs for graduate students, extension services and continuing education. We also collaborate on projects with other research institutes, to promote the broad integration of technology into industry.

Applied research is tightly-focused and emphasizes practical, cost-effective solutions to industry needs. Recent studies include work on:

- improving process- and company-wide production planning
- systems simulations for value-added manufacturing
- developing improved computerized scanning systems for locating quality problems in wood products
- designing integrated high-speed machines, machining technology and instruments for primary and secondary wood processing
- benchmarking technology and quality control for wood products manufacturing
- market research to increase understanding and access to lucrative domestic and foreign markets

Extension Services

We also provide cost-effective, independent technical support to help firms benefit from the knowledge and capabilities honed through our ongoing education and research programs. Faculty, staff and graduate students are available as consultants, for proprietary and applied projects.

Services are available across a wide spectrum of expertise. Examples include:

- sawing and cutting technologies for improved machined-surface quality
- quality control and assurance procedures, including real-time computer-based statistical process control systems
- ISO 9000 consultation
- product testing, including the evaluation of wood product finishes
- plant layout and design
- end-user identification, preferences and perceptions of quality

Technology transfers to Canadian industry

Education, life-long learning, retraining and knowledge transfers are tailored to the needs of Canada's value-added wood products industries.

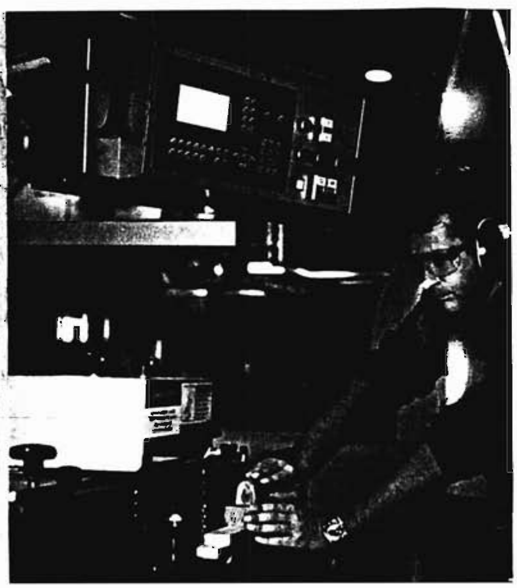
Our strength in applied research and development allows the Centre for Advanced Wood Processing to transfer leading-edge technical knowledge and innovation to Canada's wood products industry.

We operate a continuing education program to help people acquire and hone the advanced skills required to keep pace with change in our industry. Education, life-long learning, retraining and knowledge transfers are tailored to the needs of Canada's value-added, primary, secondary and tertiary wood products industries.

Our programs focus on technological developments in wood processing equipment and materials, business management, organization and computerized information systems. They include seminars and workshops at the Centre for Advanced Wood Processing, and at key locations across Canada.

Information about pending seminars and workshops is available from the Centre for Advanced Wood Processing.

www.cawp.ubc.ca



Technical knowledge highlighted

Conferences feature internationally-recognized specialists in wood and wood processing, highlighting specific areas of interest to the Canadian industry.

Our recent conferences include:

- International Value-Added Wood Processing Conference series (Vancouver, Toronto)
- International Conference on Global Markets for Value Added Wood Products (Halifax)
- Wood Finishing Technology Conference (Vancouver, Atlanta)
- Industrial Symposiums on Tooling and Machining for the Wood Industry (Vancouver, Raleigh)

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ANEXO 3

Forintek Canada Corp.

Forintek Canada Corp.

Creating Technological Solutions to Meet Members' Needs—Adding Value from Forest to Market

IUFRO Working Group Tour
September 11, 2002

Introduction to Forintek	☐ Forintek is a client-focused organization, and through membership, industry and government are getting the leading edge scientific advice and technological support they need to compete, diversify, enter new and higher value markets, or secure the use of wood products in key markets world-wide. ☐ Forintek's partnership structure ensures maximum opportunity for both industry and governments to participate in formulating the short- and long-term directions of wood products research in Canada.
Resource	☐ Linking resource properties to end-product value: Forintek's knowledge of the fibre characteristics of the existing and future forest, coupled with an extensive database, assist industry in linking resource properties to end-product value.
Lumber Manufacturing Drying Wood Protection	☐ A key objective is to increase recovery and quality in the sawmill. Some Forintek technologies available to assist members achieve this are: Bandsaw Monitoring System, Bandsaw Active Guide System, Scanning Improvements, Log Rotation, Optitek and Video Tooth Inspector™. ☐ Forintek is leading the way for members with a wide array of research and program initiatives aimed at optimizing kiln operations and value recovery. Some examples are: Kiln Monitoring System, training seminars, kiln audits to evaluate energy consumption, drying options for quality, and equalizing and conditioning treatments that reduce stress. ☐ The group's main objectives are to develop and transfer low environmental impact technologies that will: eliminate infection or stain on products during storage and transit to markets; and reduce the value loss in logs that occurs between harvesting and product manufacturing.
Composites Products Manufacturing	☐ Through an alliance with the Alberta Research Council, the research program covers all aspects of composites manufacturing for softwood and hardwood veneer, plywood, laminated veneer lumber, oriented strandboard, particleboard and medium density fibreboard. The goal is to reduce manufacturing costs while maintaining and improving product quality and consistency.
Durability	☐ Research on durability issues is designed to: document the durability of wood-based building materials and systems; develop building design solutions and wood treatments to ensure wood-based building materials carry an acceptable service life with minimum impact on the environment; and develop test methods and performance criteria appropriate for biodeterioration hazards anticipated in the wood products' intended end-uses.
Structural	☐ Our structural performance research provides the technical basis to keep wood systems competitive with respect to other materials, both in the codes and in the minds of engineers, architects and builders.

Seismic	❑ Forintek's internationally recognized seismic research program has demonstrated that affordable seismic performance is one of the strongest attributes of platform-frame wood buildings.
Fire	❑ Our fire experts are developing computer simulation tools to verify the fire performance of different assemblies. The research also addresses the impact of fire safety design features on sound transmission.
Environmental Impact and Sustainability	❑ Forintek supplies information and analytical tools to: assess the environmental impact of wood-based products; support governments' environmental policies; and help consumers make informed choices about construction materials.
Market Intelligence	❑ The *Market & Economics Group's* mandate is to offer market intelligence to Forintek scientists and members. The focus has been on matching attributes demanded with those that Canada can or could supply for added-value, both in Japan and North America. For the latter, this has included investigating wood-use in residential construction, the repair and renovation sectors, and exploring avenues for increased wood use in the non-residential sector.

ANEXO 4

British Columbia's forests are this province's greatest asset – vital to our economy, ecology and to our quality of life. UBC's Malcolm Knapp Research Forest shows that a forest can support all three of these – and thrive in the process. Historically, the forest has been shaped by two major forces: fire and logging. Two fires, one in 1868, and another in 1931 raged across much of the land mass. Between 1900 and 1931, there was also extensive logging in the forest, which was all but abandoned after the 1931 fire. The land was donated to UBC in 1949 for education, demonstration, and research.

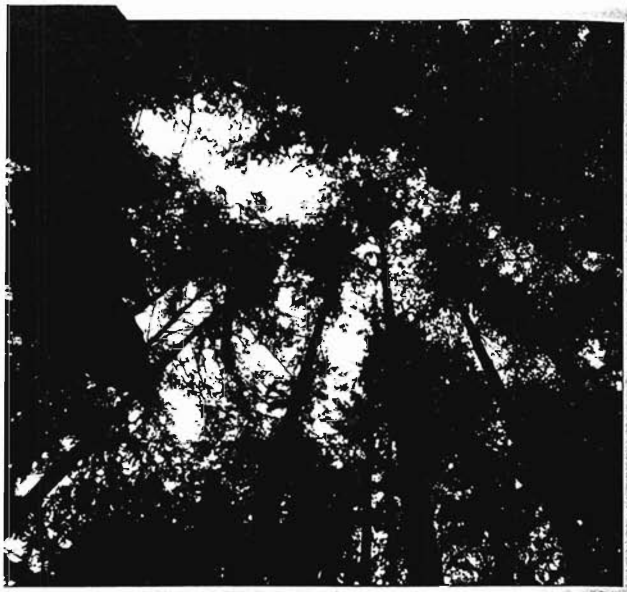
RECREATION

Located in Maple Ridge, bordering Golden Ears Provincial Park, the Malcolm Knapp Research Forest is just a one hour drive from downtown Vancouver. This 5157 hectare "working" forest boasts more than 200 km of trails and roads for walking and hiking, with stunning views from its mountainous areas, and several lakes, rivers and streams throughout. Due to the research needs of the forest, smoking, bicycles, dogs, and horses are not allowed.

The Loon Lake Outdoor Education Center is on the verge of becoming a world class venue where wilderness recreation and education can be linked in a setting of unparalleled beauty. It offers camp facilities for overnight groups, with swimming, canoes, rock climbing and other sports to enjoy. Staff are available to provide meal services and other assistance to groups using the education centre.

The Malcolm Knapp Research Forest is also a popular venue for winter activities, such as snowshoeing and cross country skiing.

Children represent the future. What would you want them to know about our forests?



EDUCATION & KNOWLEDGE

Along with these recreational uses is the educational side of the research forest. Each year, researchers study the ecological structures and species that live and thrive here, obtaining more information that will help to protect our natural heritage. At the same time, students from the UBC Faculty of Forestry and other schools learn about all aspects of the forest ecology, along with current forestry practices and standards. The forest management professionals who run the Malcolm Knapp forest also offer educational sessions to classes of children and other groups interested in learning more about forestry and related issues. The demand for this knowledge is growing at an increasing rate, as children and adults everywhere recognize the importance of our forests both to the future and to our past.

RESPONSIBILITY

At the Malcolm Knapp Research Forest, the emphasis is on responsible use of resources to ensure sustainability. This is a working forest, where specific sections are harvested and replanted – something we have been doing since the forest was granted to UBC in 1949. One of the most important things we do is to illustrate responsible forest use in order to further the science of forestry and to help ensure all of B.C.'s forests can be sustained for generations. The Malcolm Knapp Forest's lands are being managed to conserve and protect fish, water, soil, wildlife, biodiversity, community values and traditional native uses.

DID YOU KNOW THAT...

- More species of birds live in Malcolm Knapp Research Forest than in the neighboring Golden Ears Provincial Park. Multiple ages of forest provide habitats for a wider variety of birds.
- The Malcolm Knapp Research Forest is the largest privately held research forest in Canada. It operates as a financially self sufficient business with annual sales of over $2 million, and employs over 30 people year round.
- 50,000 people annually visit the Malcolm Knapp Research Forest. They come to learn, enjoy, study, look and listen to nature.
- Loon Lake Camp was originally built in 1948. Since then, over 4000 UBC Forestry students have completed field training while resident at the camp. Many more thousands of school children have spent time there as well.
- Over 750 research projects have been installed to date in the Malcolm Knapp Research Forest.
- Almost a third of the Malcolm Knapp Research Forest was burned in 1868. Much of these forests have been harvested and replanted, and now bear a third crop of healthy forest.
- Malcolm Knapp was a professor of Forestry at UBC who had a vision. In 1943, that vision paved the way to establish the forest that today bears his name.

THINGS YOU CAN DO AT THE MALCOLM KNAPP RESEARCH FOREST:

1. Paddle a canoe with a friend
2. Take an educational walk with one of our guides
3. See [illegible] wildlife trees from the Blue Trail

4. Pull yourself across Loon Lake on the cable ferry
5. Watch the stars at the Liquid Mirror Observatory
6. View and learn about the latest in forestry research

7. [illegible]
8. [illegible] logging [illegible]