Progress Report for Fiscal Year 2010

Center for Wood Utilization Research

at Oregon State University

Oregon State University

Corvallis, OR 97331 • (541) 737-1585 • USDA Special Grant

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A USDA NIFA Special Research Grant Program

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Note: Thomas E. McLain, now retired, served as co-PI when many of these projects were implemented.

Executive Summary

The USDA Special Grant for Wood Utilization Research (WUR) is developing the science, technology, management approaches, and business practices that (a) enhance the domestic and global competitiveness of the broad U.S. wood products industry; (b) maintain or expand sustainable and environmentally acceptable forest operations and product manufacturing; and (c) lead to more efficient use of renewable wood-based materials for the benefit of Americans.

Renewable wood is essential to human existence. Wood utilization research is critical to national needs because of the central role that this material plays in American society and the U.S. economy. In Oregon, the global competitiveness of our domestic industry is critical to providing jobs, especially in rural areas; reducing dependence on nonrenewable materials; and sustaining incentives for landowners to maintain private and public forests.

Most U.S. wood product manufacturers are small- to medium-sized businesses that have little capacity for research. With the WUR Special Grant, Oregon State University is part of a larger national program to address critical wood utilization research needs that vary across the U.S. and by discipline. Our principal focus is on the utilization of western species and the economic health of the Pacific Northwest industry. This report summarizes grant activities for FY 2010.

Nine ongoing projects and eight new projects were supported by the USDA Wood Utilization Special Grant Program at Oregon State University in 2010. WUR Project research generated 38 publications in peer-reviewed scientific journals, applied journals, proceedings, or books. Four graduate student theses resulted from WUR support in 2010. Technology transfer continued, with research results conveyed through 29 activities to scientists and practitioners in industry, academe, and government agencies, as well as to policy and decision makers and the public.

The WUR Special Grant enables faculty to leverage funding from industry and other sources to develop intellectual capacity and new knowledge. Support for graduate students is especially critical in the face of a looming shortage of well-trained scientists, engineers, managers, and teachers in the field.

Important highlights of completed projects this year include the following:

- Proposed changes to residential wall system designs can result in improved structural efficiency under seismic loads with little extra cost.
- Corporate social responsibility activities are becoming more widely valued for business success globally, mostly by larger companies, with very few regional differences between Europe, North America, Asia, and Latin America.
- A business plan was developed to capture 1% of the $2.5 billion hardwood flooring market within 10 years by using viscoelastic thermal compression technology to improve the hardness property and increase the usefulness of hybrid poplar and Douglas-fir in engineered flooring products.
- Surveyed wood design professionals were unwilling to favor wood marketed from family forests unless it was price competitive. However, designers' preference for it over similarly priced alternatives may open a new market niche for Oregon family forest wood.

- Low quality biomass from forest thinnings was successfully used to manufacture several wood-plastic composite products. The biomass reduced the use of petroleum-based plastics without the loss of desired properties and durability.
- Several curing agents were developed from renewable glycerol and have been evaluated for use in making plywood; the resulting soy flour/curing agent adhesive is 100% based on renewable materials.
- Predictable seasonal changes in bark loss from mechanically processed logs will to lead to changes in solid wood truck payloads, transport costs, bark, and available energy (from bark) delivered to mills.
- The potential to use LiDAR technology was demonstrated for broad-scale, forest-level biomass estimation.
- Better knowledge of road aggregate properties can improve cost-benefit analyses and potentially reduce investments in road construction and maintenance.
- During mechanical harvesting operations, the best approach for sorting and delivering wood to the highest value markets combined forecasts of acoustic velocity in logs on a local sample of felled stems with the use of optimal log-making algorithms programmed into the harvesting machines.
- Watershed scale reductions in road-related sediment to streams can be accomplished most economically by identifying and upgrading selected problem road segments rather than the entire road system.

The ongoing and completed projects described in this report are supported by the following USDA/NIFA Special Grants: 2008-34158-19302, 2009-34158-20075 and 2010-34158-20790.

Progress Reports

Improving Products and Processes to Enhance the Global Competitiveness of Oregon's Wood Products Industry

New Projects

An Assessment and Evaluation of Oregon's Wood Products Innovation System

Christopher Knowles, Scott Leavengood and Eric Hansen

Objectives: (1) identify key organizations (public and private) involved in Oregon's wood products innovation system; (2) identify key local, state, and federal policies and incentives related to wood products manufacturers; (3) develop detailed descriptions of roles and responsibilities of organizations, policies and incentives, and interactions among the organizations and policies; (4) identify primary opportunities and barriers to increased innovation in the sector; and (5) develop recommendations for overcoming the barriers.

Progress and Future Activities

A research plan is currently under development by the MS student conducting this project. It is expected that data collection will begin in late summer 2011 and continue into early 2012. The student has begun identifying key players in the innovation system through key meetings of the Pacific Wholesale Lumber Association, Forest Cluster Strategy team, and other events. The project will be completed by late summer 2012. A poster was presented at the Forest Products Society annual meeting in June, Portland, Oregon.

Duration: 7/1/2010–6/30/2012

Ongoing Projects

Hydrodynamic and Drying Properties of Biomass in Deep and Moving Bed Dryers

Michael R. Milota

Objectives: Determine the pressure drop for gas flowing through beds of different types of forest biomass at a range of superficial gas velocities that would be used in drying.

- Determine the terminal velocity/fluidization velocity as a function of particle equivalent diameter and sphericity for hammermilled forest biomass.
- Estimate electrical power requirements for operating a deep, moving, or fluidized bed dryer for forest biomass.
- Determine efficacy of using a spouted bed for mixing particles to achieve uniform final moisture content (MC).
- Determine the drying curves for several particle types in thin layer drying.
- Create a model for deep bed drying that predicts residence time, throughput, and energy requirements given dryer operating parameters and initial and final MC.

Progress and Future Activities

The 41-cm-diameter bed dryer for biomass was constructed, tested, and optimized. Two types of drying were evaluated. Thin layer drying was used to establish the drying kinetics for hemlock and Douglas-fir. The thin layer was approximately 5 mm in thickness to minimize temperature and humidity changes through the bed. This was done at temperatures from 50 to 200°C and airflow from 0.3 to 0.9 m/s. Grab samples were used to measure MC versus time. A model for the kinetics is being developed with drying rate as the independent variable and temperature, gas velocity, initial wood MC, and wood MC as the independent variables. Deep bed drying was also studied. Bed depth was 23 cm; bed weight was continuously recorded. A deep bed model is being developed. Input for the deep bed model is the drying kinetics from thin layer drying. Deep bed drying will be used for model verification.

Our findings were as follows:

- Drying kinetics for Douglas-fir do not differ significantly from those for hemlock, meaning that users should be able to use the same drying conditions for both.
- After a certain bed depth of ~10 cm, bed depth is not critical to dryer operation. Drying time will simply increase with depth because saturated air is leaving the bed. This suggests that thermal efficiency will increase somewhat with bed depth and that bed depth should be increased until the energy gains are offset by a

greater bed pressure drop or problems occur in flow uniformity through the bed (gas channeling).

- There is significant carryover at gas velocities greater than approximately 0.9 m/s (depending on particle size) and that gas velocities greater than this are not practical due to the terminal velocity of the particles.

Duration: 9/1/2009-8/31/2012

Identifying Customer Relationship Management Practices That Foster Innovation

Scott Leavengood and Eric Hansen

Objectives: To identify best practices in customer relationship management (CRM) that foster innovation. Specifically, to (1) identify 4 to 6 domestic forest products firms—2 to 3 with "company-driven" CRM (companies that proactively seek input from their customers) and 2 to 3 with "customer-driven CRM" (companies that wait for customers to contact them, then "spring into action"); (2) conduct case studies on each firm, with a specific focus on developing a detailed description of each firm's approach to CRM as well as their innovation performance; (3) compare and contrast practices used by company-driven and customer-driven CRM firms; (4) compare innovation performance between company-driven and customer-driven CRM firms; (5) develop a list of best practices in CRM as related to innovation performance; and (6) communicate the list of best practices to industry professionals to enable them to adapt existing quality management programs and improve innovation performance.

Progress and Future Activities

The MS student working on the project analyzed survey responses, identified candidate firms for interviews, and developed and pilot-tested interview questions. However, prior to beginning the data collection phase of the project, the student left the university to take a job in industry. His plans are to conduct the interviews and complete the project. However, all parties involved realized there are likely to be very significant delays in doing so.

Duration: 9/1/2009-8/31/2012

Marketing Sophistication to Improve Competitiveness of Medium-Size U.S. Sawmills

Eric Hansen

Objectives: (1) characterize the roles of marketing and levels of marketing sophistication (market orientation) within private, multi-site, U.S. sawmilling companies; (2) describe the evolution of marketing in these firms; and (3) assess impacts of marketing sophistication on firm competitiveness.

Progress and Future Activities

A case study protocol was developed and approved through the OSU Institutional Review Board. Potential respondents across the U.S. were identified. Interviews were ongoing and approximately 16 interviews had been conducted as of the writing of this report. Oral presentations were given at the IUFRO Group 5.10 meeting in Corvallis, Oregon and in the annual meeting of the Forest Products Society in Portland, Oregon (both in June 2011).

Duration 9/1/2009–8/31/2012

Completed Projects

Identifying the Relevance of "Family Forest" and "Family Business" Wood Product Origin for Industrial and Final Consumers

Christopher Knowles and Scott Leavengood

Objectives: to assess the relevance of family wood product origin for the two main consumer groups of forest products industry. Specifically, to (1) evaluate relevance of family wood origin and family wood processing to the final consumer; (2) determine demographic characteristics related to final consumer preferences for family wood and processing origin; (3) evaluate the relevance of family wood and family processing origin to industrial consumers in the secondary forest products industry; and (4) determine the demographic characteristics related to industrial consumer preferences for family wood origin and family processing origin.

Accomplishment and Impacts

- Data was collected from two audiences: (1) the general public via intercept interviews at the 2010 Benton County Fair and the 2010 Oregon State Fair; and (2) from Oregon design professionals including architects, engineers, and contractors. A total of 361 useable responses were received from design professionals representing a response rate of 20%.
- Results have been disseminated via presentations at the 2011 Forest Products Society International Convention and the IUFRO Division 5.10 and UNECE Team of Specialists in Forest Products Marketing Meeting, and preliminary results have been published in the pro-

ceedings of the latter. Two publications will be submitted to a refereed journal; a research brief will be published by the Forest Business Solutions group at OSU.

- Conjoint analysis was used to frame a scenario for design professionals wherein they purchased wood to frame a house. The lumber had three attributes, with three levels for each attribute: (1) Price: $13,500, $15,000, $17,500; (2) Wood origin: family, corporate, other; (3) Certification: FSC, other, none. Price was the most important factor, accounting for ~52% of the purchase decision, followed by certification (23%) and wood origin (25%). Within the wood origin factor, there was a strong, positive preference for wood from family origin and a negative preference for wood from other sources. This indicates that there may be some potential to develop a niche market for wood grown in Oregon family-owned forests. It is unlikely that this wood will be able to be sold for a price premium though.
- We are still in the process of analyzing this data. Future plans include using cluster analysis to determine whether there is a subset of respondents that base their purchase decision predominately on wood origin, indicating that a niche market may exist of those with a preference for wood from family-owned forests.

Duration: 8/1/2008–7/31/2011

Innovativeness and its Impact on Implementation of Social Responsibility Practices: Comparing U.S. Firms with Global Competitors

Eric Hansen

Objectives: to (1) compare U.S. companies to international competitors with respect to their innovativeness, learning orientation, market orientation, and implementation of corporate social responsibility (CSR) practices; and (2) identify the impact of innovativeness on implementation of CSR practices in the global forest products industry.

Accomplishment and Impacts

- A database of annual and sustainability reports from the world's largest pulp, paper, and packaging manufacturing companies was developed. The annual/CSR/sustainability reports of the top 100 global forest, paper and packaging industry companies reported by PricewaterhouseCoopers were content analyzed to identify implementation of each company's CSR activities. One MS student completed her degree based on this portion of the project
- A mailing list of three key contacts (CEO, top marketing person, and top CSR person) in the top 100 pulp, paper, and packaging companies was developed.
- A survey of the top 100 largest global pulp, paper, and packaging companies was conducted. The CEO, top marketing executive and top sustainability executive were targeted. Questionnaires were developed in English and then translated into Spanish, Portuguese, Chinese, and Japanese and provided to respondents in paper and electronic form. The survey was highly successful with an overall response rate of 31.5%.
- Results were disseminated via a two-page Research Brief from the Forest Business Solutions group at OSU and multiple poster and oral presentations at both domestic and international meetings.

We identified seven categories of corporate responsibility activities, including in economic, social, and environmental areas. Those activities that appear in reports more frequently are considered to be implemented at higher levels. The findings were as follows:

- Environmental activities are implemented most widely (most companies mentioned them); the reason for this may be that society is paying increasing attention to environmental issues, so it is critical for forest products companies to continuously address these in order to maintain a good public image.
- More than half of the companies mention workforce activities and leadership, vision and values in their company reports. Around half of the companies implement community activities. Supply chain activities and stakeholder engagement see very little attention.
- Marketplace activities are least commonly implemented. This may be a result of companies not associating these with CSR. For example, industry managers may associate product responsibility more with avoiding liability than with CSR. It is worth noting here that one of the common reasons for companies to embrace CSR is risk management, and therefore product responsibility may be considered an integral aspect of CSR.
- Issues of growing importance are (1) climate change—reducing carbon emissions and footprint are extensively mentioned in company reports; and (2) the use

of voluntary standards (e.g., ISO 14001), which can go beyond legislation and play an important role in terms of regulating the industry's overall CSR performance.

- Most implemented CSR activities were those associated with the environment, least implemented were associated with "ethical leadership," "responsible/fair remuneration" of the workforce, "promoting social and economic inclusion" in the supply chain, and "mapping key stakeholders and their main concerns."
- There were very few regional differences in implementation among Europe, North America, Asia, and Latin America. The level of sales was positively correlated with level of implementation, suggesting that larger companies with more resources implement more CSR activities than their smaller competitors.
- Second stage results showed differences between Asian Companies versus North American and European companies regarding CSR practices impacting return on capital employed. Although the impact for North American and European companies was insignificant, there was a significant impact for Asian companies.
- Innovativeness is not significantly related with CSR as a whole, but two CSR activity categories are associated with innovativeness: "leadership, vision and values" and "community activities." There is great potential for firms to enhance competitiveness in the marketplace by being more innovative these two categories.

Duration: 8/1/2008–7/31/2011

Sustainable Bio-based Materials for West Coast Highways: Feasibility Study

Lech Muszyński, Eric N. Hansen, Chris Knowles, Kevin Boston

Objectives: to determine the potential for a systematic substitution and/or partial replacement of petroleum-based plastics and other non-renewable materials of substantial carbon footprint (metals, concrete) in a wide variety of highway-related products (mileage/sign posts, snow fences, sound barriers, guardrails), with sustainable alternatives: advanced bio-based composites made from woody biomass from thinning and fire prevention operations.

Specific objectives are to (1) estimate the size of the market for a small set of highway products that appear to be likely candidates for substitution by wood/plastic composites; (2) identify existing and potential manufacturers of highway-related products interested in developing new products and supporting necessary research; (3) identify and review standards, specifications, and test requirements for the selected products and materials; (4) determine applications and materials most suitable for replacement or partial substitution with bio-based composites; and (5) evaluate durability, benchmark mechanical properties, and performance characteristics of composites manufactured with woody biomass generated from forest thinning, forest fuel removal operations, and urban wood.

Accomplishments and Impacts

This project involved four faculty, two graduate students, one high school ASE apprentice, and one visiting scientist from India. WUR support was instrumental in leveraging a USDA NNF fellowship program ($129,000 in 2008), which partially supported the effort.

- This project has generated 1 professional journal publication to date (with 5 others in various stages of completion), 1 paper in a non-refereed journal, 9 formal presentations at professional meetings, 2 proceedings papers and 6 non-technical presentations for industry and community oriented audiences.
- The graduate student working on this project (and a USDA NNF fellow) earned the Best Student Presentation Award ECOWOOD 2010 – 4th International Conference & Exhibition on Environmentally-Compatible Forest Products in Porto, Portugal.
- The project was summarized at three invited Oregon BEST meetings and featured as a showcase project in the Oregon BEST "e-news update" in 2009 and in 2010. It was also covered in Sustainable Business Oregon and in Oregon Business Magazine.

In this project, the sustainability of the materials and products is considered in the context of potential benefits to the health and safety of the forests and sustainable job opportunities in rural communities.

- Systematic use of sustainable materials and technologies for regional highway systems is likely to create a consistent demand for bio-particles that result from fire prevention operations like forest thinnings and physical forest fuel removal. It is expected that such demand will partially offset high costs of these operations.
- Significant gains may be realized in the overall carbon storage of the forest stand. Arresting the woody biomass in products rather than burning will further increase the total amount of carbon fixed in long-lived and recyclable products.
- Apart from improved fire safety, local communities will benefit from small- and medium-scale business opportunities generated around such production.
- This approach has already been considered as a model for utilization of invasive wood species in India and we

are collaborating with a Fulbright Fellow from ATREE, Royal Enclave Srirampura, Jakkur Post in Bangalore.

The major finding was that woody biomass from thinning and fire prevention operations (commonly perceived as low-grade when compared to commercial wood flour) can be used in wood-plastic composites without negative impact on their key mechanical properties or durability.

- The importance of this finding reaches far beyond the original scope of the project. It means that this low-grade woody biomass may be considered as the raw material source for wood-plastic composites in all kinds of commercial products, providing a utilization path alternative to burning.
- The project generated great interest from local entrepreneurs, rural community leaders associated with the Oregon BEST initiative, and ODOT sustainability office.

Duration: 8/1/2008–7/31/2011

Discovering New Knowledge for Future Opportunities and Benefits

New Projects

Characterization of Woody Biomass Fuels Prepared from Forest Slash

David Smith and John Sessions

Objectives: to (1) develop capability within OSU College of Forestry to reliably measure quality characteristics of solid biomass fuels; (2) collect representative samples of forest biomass fuels generated at various slash salvage sites and measure their quality characteristics; (3) document the relationship between logging site characteristics, logging slash recovery and grinding processes, and the quality characteristics of the biomass fuels produced; and (4) form the foundation of a reference database for a future family of fuel and non-fuel quality grade specifications for forest and other solid biomass products.

Progress and Future Activities

Objective #1 has been met through the acquisition of a bomb calorimeter for measuring fuel heat values and developing standard methods using other equipment on hand to measure particle size distribution, bulk density, MC, and ash content of biomass fuel samples.

- Standard protocols for sampling and analysis have been written, tested and used to determine the characteristics of nearly 50 samples of biomass collected from many different suppliers and sites.
- A presentation reporting partial results and announcing our capability to perform these analyses was given at The PacWest Biomass Energy Conference held in Seattle, WA in January, 2011.
- A summary presentation and capability announcement was also made to the Oregon Forest Biomass Working Group in February.

At both of these venues, the community of interest was invited to participate in the study by submitting samples for analysis and inclusion in our public database.

- Two undergraduate students and one graduate student have been employed to learn the methods and perform sampling and analysis. They reported on their work through posters prepared for presentation at OSU's CUE (Celebration of Undergraduate Excellence) and the Forest Products Society's 65th Annual Convention to be held in Portland, OR June 19-22, 2011.

To address project objectives #2 and #3, the project team visited nine sites where forest biomass was being processed by our two industrial partners.

- We documented operations and collected over 30 samples of processed material. Sample analysis reports were issued to the owners and/or operators of the biomass fuel processing operations.
- Case studies have been completed on two of these sites that explain the relationships between site characteristics, processing technology, productivity, and fuel chip characteristics.
- We have received nearly 20 samples of various size and fuel types from several industrial operations, which we have analyzed and reported the results. Further sampling and analysis is planned.

Data collected from processing sites and sample analysis has been compiled into a database as per objective #4. This database will be made accessible to the community of interest for use, and to submit additional data for management. We have been in contact with other researchers and groups interested in reviewing/sharing this type of information to advance the goal of bioenergy expansion through improved understanding and setting of quality specifications.

Our industrial partners are already using the results to improve planning and conduct woody biomass recovery.

Our work is also helping to provide some order in the marketplace between local biomass fuel users and generators. As biomass utilization grows, a methodology for setting, meeting, and verifying, fuel quality characteristics is essential for successful, value-driven commerce, particularly in the commercial/institutional sector.

Duration: 7/1/2010–6/30/2012

Ongoing Projects

Development of High Performance Cellulose-Based Nanocomposites

John Simonsen, John Nairn, and Lech Muszyński

Objectives: (1) develop predictive models of polymer nanocomposite interfacial properties utilizing CNC aerogel/polymer composite systems; and (2) use these models to develop high performance, high value, cellulose-based polymer nanocomposite prototypes.

Progress and Future Activities

- The new theory developed in this project has been named the "Nairn Model" after Professor John Nairn who developed it. He has shown that increased aspect ratio in cellulose nanocrystals (CNCs) can be compensated for by going to higher volume fractions of CNCs in polymer composites. This insight will likely have a strong impact on the direction of research in CNCs in this and other labs since to date most labs have not been focusing on high volume fraction composites.
- We have also made good progress in developing well-characterized composites with the successful fabrication of polymer infused aerogels. We have also discovered a new technique to crosslink the CNCs which may lead to improved composite properties.

A student is now in training to learn the lift-out techniques necessary to begin 3D TEM tomography of our prepared composite materials.

Duration 9/1/2009–8/31/2012

Completed Projects

Development and Characterization of Environmentally Friendly Wood Adhesives from Renewable Materials

Kaichang Li

Objectives: to develop and characterize environmentally friendly adhesives from renewable materials such as soybean flour for making wood composite panels, with a focus on novel curing agents for soybean flour-based adhesives.

Accomplishment and Impacts

Our formaldehyde-free soy-based adhesives have high viscosity, making it difficult to spray them onto wood furnish for making OSB and particleboard. This has been an obstacle for widespread application for particleboard production. We developed new methods that have solved this problem:

- A new method of spraying a curing agent onto a mixture of wood flakes and soy flour has been successfully developed for making OSB.
- A novel method of coating wood particles with a dilute soy slurry in water followed by drying and spraying of a curing agent has been developed for making particleboard. Two soy-based adhesives (soy flour + a polyamidoamine-epichlorohydrin (PAE), and soy flour + polyethylenimine+maleic anhydride) have been investigated with this new method for making particleboard panels.
- Several novel curing agents have been developed from renewable glycerol and evaluated as curing agents with soy flour for making plywood. These new soy-based adhesives can potentially be 100% based on renewable materials. The plywood panels bonded with these new adhesives meet strength and water-resistance requirements for interior applications.
- Plywood panels bonded with soy flour/curing agent adhesives met the water resistance requirement of interior plywood panels.
- Particleboard made with this new method exceeded industrial strength requirements of M-2 particleboard, the most commonly used particleboard.

Our new methods are viable for commercial production of particleboard panels and may facilitate the replacement of toxic urea-formaldehyde resins with formaldehyde-free soy-based adhesives in the commercial production of particleboard panels.

Duration 8/1/08–7/31/2011

Hygro-Thermal Mechanical Characterization of Wood in Transverse Compression

Frederick A. Kamke

Objective: to determine the time, temperature, and MC effects on the transverse compression modulus of wood.

Accomplishments and Impacts

The project played a key role in the creation of the Green Building Materials Laboratory (GBML) at OSU. The GBML is a collaborative effort between the College of Forestry and the College of Engineering. With funding from Oregon Built Environment and Sustainable Technologies (Oregon BEST) Center ($450,000), plus supporting funds from OSU, the new laboratory was constructed and a one-of-a-kind, large-scale VTC machine was built.

The new facilities have led to several new collaborations, including the European COST Action for Hydro-Thermal Modification of Wood (invested to join management team), research project with the University of Ljubljana in Slovenia, and the system has been used by three companies to investigate potential product applications.

- One of the company collaborations has led to a commercialization project with approximately $115,000 in funding from Oregon BEST and the OSU Venture Fund to develop engineering design plans for a commercial scale system.
- Students who benefitted from this project: 1 post-doctoral student received training in wood modification techniques, then accepted a position as laboratory director for a new research center in Slovenia; 1 MS student completed a commercialization study on VTC wood, then was hired by an Oregon investment firm; 4 MBA students used results from the project to develop a business plan for a company to adopt VTC technology; 1 visiting PhD student used data collected during this project to partially fulfill degree requirements; 1 visiting MS student used the equipment to collect data for his thesis.

Results have been disseminated internationally and locally through 16 presentations at professional meetings, including for local groups focused on utilization of Oregon timber. In addition, numerous groups have toured GBML and witnessed demonstrations of the VTC device.

- Stress and strain measurements obtained using the small VTC device have allowed us to characterize the compression behavior of hybrid poplar and Douglas-fir for the temperature range of 150°-170°C.
- We also discovered operating parameters that significantly improve the dimensional stabilization of these species, thus improving commercial application. The construction of the large VTC device has allowed process optimization work to continue with maple, hemlock, and spruce.
- The $2.5 billion hardwood flooring market was identified for a business venture based on VTC technology. A plan was developed to capture 1% of this market within 10 years. The plan capitalizes on the high hardness property of VTC wood and its ability to be used in engineered flooring.

Duration: 8/1/2008–7/31/2011

Identifying Wood Utilization Opportunities through LiDAR Analysis of Forest Biomass

Michael Wing and Curtis Edson

Objectives: to (1) apply Light Detection and Ranging (LiDAR) technology to identify and analyze forest biomass opportunities within even- and uneven-aged forest stands; (2) investigate LiDAR technology applications to support forest road transportation planning, including decision support for selection of forest biomass resource transportation routes; (3) examine whether LiDAR measurements and near-infrared reflectance values can be used to locate forest transportation networks and to differentiate between different forest biomass sources, including live trees, snags, and downed wood materials.

Accomplishment and Impacts

We completed three analyses involving tree dimensions and biomass estimates. Initial outputs included 11 spatial databases representing over 8,000 trees and downed woody debris locations over a range of silvicultural treatments.

- A PhD student has recently completed a dissertation based on this research (April 2011) and is now a faculty member at West Point Military Academy.
- One of the three manuscripts submitted for peer review has been accepted for publication in Forest Science pending revisions.

The first analysis evaluated the accuracy of mapping grade GPS receivers in determining tree locations with respect to their true position under temperate conifer forest conditions representing moderate and extreme slopes. GPS measurement accuracy was compared based on autonomous GPS measurements, post processing of code signals, and post processing of both code and carrier based signals, and with positions of over 600 trees in two stands.

- Using coded pseudorange measurement was the most accurate and recommended method among those that we tested for mapping-grade GPS surveying under a conifer dominant forest canopy. GPS horizontal position accuracy is degraded by forest canopy. Constant, unbroken communication between the receiver and the satellite must be maintained in order to avoid cycle slips and promote accurate coordinate measurement.
- Differential correction using pseudorange codes, which are not affected by cycle slips, was more accurate compared to carrier phase processing, but the error was still relatively high (>2.5 m).

The second analysis examined the accuracy of digital elevation models (DEMs) created through LiDAR data within a range of different forest canopy and topographic conditions. A secondary objective was to compare elevations determined by mapping grade GPS to a DEM that was interpolated from LiDAR. We know of no other studies that matched and compare ground truth points to the closest discrete LiDAR ground points.

- We compared 2,873 elevations determined with a total station to LiDAR elevation points at the closest horizontal location in five plots. The least amount of error occurred on a relatively steep slope (32%) in an 85 year old stand. This further confirms that LiDAR is capable of achieving very high vertical accuracies under forest canopy and on steep slopes. LiDAR overestimated ground elevation in this study, and when LiDAR is further used to estimate tree heights, the DEM error will contribute to underestimating tree heights.
- We compared 8150 GPS elevations to the closest LiDAR point in 11 plots. In the open, GPS elevation accuracy was surprisingly high compared to LiDAR elevations. Analysis of the plots under canopy reveals that error significantly increases, and the accuracy did not improve using C/A processing code only. Similar to the point-to-point comparison, the LiDAR DEM demonstrated surprisingly accurate elevations in open areas when compared to mapping grade GPS elevations; but the DEM analysis further confirms the inaccuracy of GPS acquired elevations when collected under forest canopy and on steep terrain.

The third analysis assessed the ability of LiDAR to accurately estimate forest biomass on an individual stem basis using FUSION, TreeVaW and watershed segmentation software programs and made comparisons to biomass estimates drawn from traditional field measurement. To assess the accuracy of LiDAR biomass estimation, two key components were analyzed including stem count and stem height. Pairwise and plot average height differences were assessed. Biomass analysis included comparisons of feature totals in each plot, mean biomass per feature in each plot, and total biomass by plot for each extraction method.

- Results from FUSION, TreeVaW, and watershed segmentation showed wide variation in the number of trees detected in each plot. Based only on field measured tree counts, tree delineation was best performed by watershed segmentation followed by TreeVaW and FUSION with overall percentages equaling 93%, 59%, and 44% respectively. All methods did considerably poorer in uneven aged and old growth treatments due primarily to missing understory trees.

Plot characteristics in this study were highly variable. The variability in the LiDAR biomass estimation results are a manifestation of the field variability. These results make it difficult to predict biomass on a by-plot basis with consistency. That said, many biomass estimates were within 10% to 20% of the field-based estimates. These overall results indicate promise in using LiDAR for broad, forest level biomass estimation.

Duration: 8/1/2008–7/31/2011

Enhancing Engineering Applications for Wood and Wood-based Products

New Projects

Bio-Compounds for Improved Decay Resistance of Next Generation of Engineered Products

Jeff Morrell and Fred Kamke

Objectives: to employ natural biocide compounds to enhance wood composite resistance to biological decay, specifically: (1) improve decay resistance of VTC composites to meet AWPA Use Category 3 requirements for non-ground contact exterior exposure; (2) achieve bending modulus of 3.0 x 106 psi and bending strength of 2.5 x 105 psi of the treated composite for at least 95% of the test specimens; and (3) exceed 50% of mean dry bending properties after six cycles of water soak and drying.

Progress and Future Activities

- We successfully recruited the new graduate student who conducted preliminary experiments to determine processing conditions for processing cinnamon leaf oil-treated poplar veneers using the VTC process.

The veneers are now in laboratory tests to determine their decay resistance compared with non-cinnamon leaf oil-amended veneers. In addition, western juniper foliage and heartwood residuals were collected from a site located near Sisters, Oregon. The material was steam distilled and a sufficient quantity of oil has been collected to process all of the poplar veneers. We will treat veneers with either pure cinnamon leaf oil or juniper extract along with varying ratios of either extract. These veneers will then be subjected to the VTC process. MOE will be assessed on all veneers, then selected veneers will be exposed to white or brown rot fungi over an 8-week period. Veneers will be assessed periodically over this time to determine if the oils provide protection to the otherwise decay susceptible materials. Finally, treated and untreated veneers will be subjected to a mold box test to determine if the oils markedly alter mold susceptibility.

- Planning and progress of this project has been disseminated through poster presentations.

Duration: 7/1/2010-6/30/2012

Evaluation of Structural Load Paths in Wood-Frame Residential Structures

Rakesh Gupta, Thomas H. Miller and Kenny G. Martin

Objectives: to develop an analytical model of a realistic wood-framed house using SAP2000 in order to gain a better understanding of the propagation of hurricane wind loads

through complex structures. Specifically, (1) develop and verify practical methods for modeling three-dimensional light-frame wood buildings with complex geometry using commercial structural analysis software; (2) explore critical load paths and system effects through the building under extreme wind loading; and (3) explore the effects of different geometry on the propagation of load paths.

Progress and Future Activities

Recent hurricane/tornado events have illustrated a lack of proper up-lift load path design in existing wood-framed residential structures. Additionally, the growing complexity of the geometry used in today's homes requires a better understanding of structural load paths.

- A detailed literature review has been completed on system behavior and modeling, wind loading, hurricane damage, and industry practices.
- The first step in modeling the whole building, development and validation of 2D truss models based on single truss tests (Wolfe et al. 1986) is complete.
- 3D roof models have been developed and validated against the 3D tests by Wolfe and McCarthy (1989) and Wolfe and LaBissoniere (1991).
- The results have been disseminated through two poster presentations at the professional meetings (FPS Annual Convention 2011 and WBC NSF/I/UCRC Meeting 2011).

It is expected that this project will provide a change in knowledge for residential building designers about the practical modeling methods that can be used to design safer buildings for natural hazards such as hurricanes and tornadoes. This model will also provide additional information about load path distributions under varying conditions within light-frame wood residential structures of more complex geometry.

Duration: 7/1/2010-6/30/2012

Key Variables Influencing Checking in Maple Plywood

Scott Leavengood and Lech Muszyński

Objectives: Conduct a multi-variable screening study to identify the key variables that influence checking in maple plywood. Specifically, (1) develop a comprehensive matrix of test variables affecting checking in maple plywood including groups of variables related to (a) veneer source, conditioning method, and cutting method; (b) panel construction, orientation of lathe checks in face veneer, and core type; and (c) finishing: unfinished, water-based, oil-based, and UV-cured. (2) Measure the intensity of checking for combinations of the identified variables. Optical measurement based on the digital image correlation (DIC) principle will be used to evaluate the extent and frequency of checking in test panels. (3) Identify the critical variables and interactions using standard statistical methods for factor screening experiments.

Progress and Future Activities

- The graduate student working on this project completed his coursework and has been working to gain expertise in using the laboratory equipment required for the project (i.e., production of composite panels and use of digital image correlation equipment and software). The student surveyed maple veneer producers in the eastern U.S. and Canada as well as hardwood plywood producers in Oregon and Washington to identify the matrix of test variables described above. He will begin sourcing materials (hardwood veneer, core material, and adhesives) in the summer of 2011, and will conduct the testing during summer and fall terms. Currently the test setup for optical measurement of checks in multiple specimens is under development. Sufficient progress has been made such that the project will complete on-time (summer of 2012).
- Status updates were presented at two meetings of the Western Hardwood Plywood Producers, the key industry collaborators in the project.

Duration: 7/1/2010-6/30/2012

Ongoing Projects

Experiments and Modeling for Orthogonal Cutting of Wood-Based Composites

John Nairn

Objectives: (1) construct a mechanical testing jig for measuring normal and tangential forces during orthogonal cutting and conduct experiments on wood-plastic composites (WPC), solid wood, and other wood composites; (2) model the experiments using recent advances in cutting theories; and (3) incorporate the new theories into realistic numerical simulations of cutting processes in wood and wood-based composites; and (4) train a graduate student.

Progress and Future Activities

- The mechanical testing jig was completed and optimized for testing protocol and many experiments

were run on cutting high and low density polyethylene (HDPE and LDPE) and two WPC with polyethylene as the plastic (Trex and Tiber Tech). For modeling objectives, the numerical simulation procedures were enhanced and used to model cutting forces. A new analytical model for cutting in elastic-plastic materials with strain hardening was needed (and was derived) for validation of numerical results.

- The numerical package based on the material point method was enhanced further and can now handle multi-physics issues needed for analysis of cutting.
- There are three concerns: (1) the modeling is rather simplistic and treats the material as elastic-perfectly plastic. HDPE is known to be more complex. (2) Toughness is found by extrapolating results to zero cut depth. Although the extrapolation can be done, the modeling is non linear and significant non-linearity occurs at very small cut depths that are inaccessible to conventional experiments. (3) The friction law includes an "adhesion" term with questionable physical significance. It is difficult to judge if this term is appropriate or if it influences the results. We conclude that better modeling (such as numerical modeling being developed here) with more realistic material response is needed along with new methods less reliant on extrapolation into non-linear regions.
- We have continued collaborations with two groups in the U.K. (J.G. Williams, Imperial College and Tony Atkins, Reading) and have presented the results of this project in a special session on cutting theory and experiments at a September 2011 conference on fracture.

Some sample simulations have been posted on a publically available web site (see http://www.cof.orst.edu/cof/ wse/faculty/Nairn/MPMSamples/index.html).

Studies of Trex yielded the reliable result for toughness of WPC. Its toughness is very different from solid wood (i.e., WPCs do not cut "just like wood," as often advertised). The concerns about interpretation of these experiments are similar to those for HDPE. Advances in these areas will improve interpretation of experiments for both materials.

- The numerical modeling has led to new understanding this year. The results show that there is significant contact force on the bottom of the tool caused by the cut material tending to rise due to cutting action. Surprisingly, all cutting theories (including classic metals cutting models developed over a century ago) ignore these forces. We think that approach is wrong. When the bottom forces are included, the numerical model and analytical model agree better. In our opinion, numerical modeling with all forces will be able to guide interpretation of cutting experiments.

The MS student on this project has taken a leave of absence. The work is continuing with a student worker along with data interpretation and numerical modeling by the PI.

Duration 9/1/2009–8/31/2012

Completed Projects

Improving Performance of Conventional Wood Frame Shear Walls Under Seismic Loads

Rakesh Gupta

Objectives: to improve the performance of wood-frame shear walls under seismic loads by significantly reducing or preventing gypsum wall board (GWB) from cracking under these loads. Specifically, to (1) design four new systems of oriented-strand board (OSB) and GWB wood-frame shear wall assemblies that direct strain to the OSB; (2) determine the failure progression of the proposed wood frame shear wall assemblies; (3) compare performance of these assemblies with each other and traditional wood frame shear walls; (4) develop a hybridized system to test and determine whether effects are cumulative.

We tested seven different 2440 mm x 2440 mm shear wall specimen designs containing double top plates and double-end studs. Vertical studs were No. 1 and Better grade kiln-dried Douglas-fir dimension lumber. Walls were vertically sheathed with two OSB panels on one side and with GWB panels on the other. OSB panels were connected to the wood frame with framing nails with two different nail spacings. GWB panels were attached vertically to the wood frame with drywall screws. All walls were anchored to a fabricated steel beam that was welded to the strong floor to simulate a rigid foundation.

Three of the seven designs had window openings and four did not. Fourteen walls (2 per design) were tested to failure under seismic loads. The designs were as follows:

Shear Wall Designs without Openings

- IRC Design (control without openings), represented the minimum requirements for a shear wall in the 2009 International Residential Code (IRC).
- SEPSTUD (separated stud) Design had a double bottom plate as well as a double middle stud built to increase the edge distance and therefore increase the strength of the GWB connection. The two middle studs were separated by 114 mm to allow for a 57.2 mm edge distance around the entire GWB panel. 3INNAIL Shear Wall Design, which was built to see how an increase in the strength of the shear wall and stiffness of the OSB side of the wall affects the performance of the GWB.
- 3INNAIL design: the OSB to wood frame connection was altered by decreasing the nail spacing by a factor of 2, resulting in an edge nailing of 76.2 mm o.c., or 3 inches and and a field nailing of 152 mm o.c. A double bottom plate and double middle studs were also added to the wood frame. This was to ensure that the heavy nailing pattern would not split the kiln-dried wood studs. The double bottom plate and middle studs also allowed for a larger edge distance for the GWB.
- 2OSB Design was built to more evenly distribute the load between the GWB and OSB. This design was exactly like the IRC design except that OSB panels were applied to both sides of the wood frame as indicated by the name 2OSB. The GWB panels were then applied on top of the additional OSB panels.

Shear Wall Designs with Openings

- IRCWIN Design (control design for shear walls with openings). Each shear wall had a window opening of 1105 mm x 610 mm located in the very center of the wall, with a header and sill of No. 2 and Better grade kiln dried Douglas-fir with an 11.1 mm OSB spacer in between. The nailing pattern for the OSB to wood frame connection was the same as the IRC design.
- OSBWIN Design was the adaptation of the 2OSB design to have window openings and was the same as the IRCWIN design except that OSB panels were applied to both sides of the wood frame and GWB was attached to the top of the additional OSB panels. The nailing pattern for the OSB was the same on both sides of the wood frame as the IRCWIN design.
- 4PNLWIN Design was built to prevent failure of partition walls with openings by the cracking of the GWB near the corners of the openings. GWB panels were cut and applied such that they connected at the window opening corners. This allowed for a gap between panels near the corners which could allow panel rotation before cracking occurred. Additional jack studs above the windows were required for application. The nailing pattern for the OSB-to-wood-frame connection was the same as for the IRCWIN design.

Findings were as follows:

- Less GWB damage was observed in the 3INNAIL, 2OSB, and 2OSBWIN designs compared to IRC or IRCWIN. Increasing shear wall stiffness and strength resulted in less GWB damage for a given loading or displacement.
- Adding OSB to both sides of a shear wall (2OSB and 2OSBWIN designs) gave superior performance up to failure because similar stiffness on both sides of the wood frame equalized load sharing and less GWB damage.
- Increasing the strength of the GWB connection by using a larger edge distance (SEPSTUD design) improved GWB performance up to 1% drift, but affected the performance negatively at 2% and 3% drifts.
- Panels around window openings (4PNLWIN design) increased GWB performance up to 1% drift, but affected performance negatively at 2% and 3% because the stiffness of the GWB, as applied in this design, was lower and similar to that of the OSB, allowing for equal load sharing at low drifts. Once the GWB panels begin to crack, stiffness increased along with GWB damage.
- Little damage was observed in GWB for walls loaded to the allowable strength. This implied that walls damaged in the Northridge Earthquake were loaded above allowable strengths. The shear walls were more likely loaded beyond 1% drift.
- The 3INNAIL, 2OSB and 2OSBWIN designs exhibited more efficient use of shear wall materials at 1% and 2% drifts. The 3INNAIL design exhibited the most efficient use of shear wall materials at 1% drift and the 2OSB and 2OSBWIN designs exhibited the most at 2% drift. Because most buildings are built to be displaced to 2% drift in an earthquake, sheathing shear walls with OSB on both sides is the most efficient use of materials.

Duration: 8/1/2008–7/31/2011

Extending the Timber Resource through Improved Harvesting, Transportation, and Manufacturing

New Projects

Biomass Assessment and Technology for Harvesting and Utilizing Forest-Fuels and Logging Slash from Steep Slopes in Oregon

Loren Kellogg and Temesgen Hailemariam

Objectives: to (1) complete a biomass assessment of harvesting cooperation characteristics on steep terrain in Oregon for utilizing forest fuels from restoration thinning, and logging slash from conventional harvesting operations; (2) complete a steep slope harvesting systems and technologies needs analysis for utilizing forest fuels and logging slash; (3) identify and suggest strategies to address gaps between current steep slope harvesting practices and harvesting practices for improved utilization of biomass.

Progress and Future Activities

- An international literature review and paper were completed on steep slope smallwood harvesting technology and biomass utilization. FPInnovations, Vancouver, British Columbia, was consulted regarding similar work.
- A field site in the Oregon coast range was identified for conducting a unique trial with steep slope ground-based CTL and cable harvesting technology.
- A draft study proposal was completed and approved by the landowner and harvesting contractor for implementation during the summer of 2011.
- A preliminary assessment of FIA data was completed and certain aspects were identified for future detailed analysis for use in describing steep slope biomass utilization site characteristics.

The research project description and plans were included in several OSU Forest Engineering course presentations, seminars, and primary education activities.

Duration: 7/1/2010-6/30/2012

Reducing Steep Slope Thinning Costs and Increasing Wood Production Through Use of Tethered Feller Buncher and Grapple Yarding

John Sessions, Jeffrey Wimer and Michael Wing

Objectives: (1) Test and demonstrate use of a tethered feller buncher for thinning on steep slopes; (2) measure grapple yarding productivity in a thinning following felling and bunching to corridors by a feller buncher; (3) apply Light Detection and Ranging (LiDAR) technology to identify preferred landscape locations for logging practices; and (4) measure ground disturbance and residual stand damage.

Progress and Future Activities

- We identified a test 10-acre area on McDonald-Dunn Forest and ran preliminary profiles. In late summer 2010, the cutting contractor with the self-leveling steep slope feller buncher who was part of the original project concept (Mike Bruer Contract Cutting) decided not to participate. Lee Miller demonstrated that harvesters could operate on up to 75% slopes without tethering, which exceeded the slope steepness on test areas on the College Forest. This opened new areas for investigation for steep slope mechanical harvesting to improve forest operations on steep slopes.
- We met with Lee Miller during Winter 2011 to discuss options to use a harvester on steep slopes to prepare logs for a skyline operation. Subsequent meetings with Starker Forests indicated that Miller and Starker were willing to sponsor a test project on Starker Forest at no cost to the College. Loren Kellogg joined the project. As part of his research, a PhD student will do the layout, time study and analysis to compare the steep slope harvester skyline concept with steep slope forwarder and conventional skyline and forwarder operations. He has funding from other sources to finsh this project except for funding measurement of ground disturbance from the steep slope harvester and forwarder activities.

Duration: 7/1/2010-6/30/2012

Woody Biomass Supply Chain Management Tools for Small Businesses and Communities

Glen Murphy

Objectives: (1) Develop four tools that will assist decision making by small businesses and communities along the forest to energy woody biomass supply chain; (2) evaluate tools and technologies for monitoring of woody biomass MC for three types of material—logs, chips and hog fuel; (3) develop and trial a workshop for small businesses and communities and that effectively communicates the research results from objectives 1 and 2; and (4) undertake the preliminary design for a Western Woody Biomass Knowledge Center website that will be used to communicate effective technology and practices to potential users.

Progress and Future Activities

Management of the woody biomass forest-to-energy supply chain is complex, involving spatial, physical, temporal, and operational issues, and U.S. management tools contain gaps, require much input on the part of users, and could be better integrated. This project aims to improve this situation.

- Discussions were undertaken with researchers from Europe who have been working on biomass for energy

supply for 30+ years. Moisture management was identified as a key to improving the economics of biomass supply. A literature review was completed on factors affecting and approaches to modeling air-drying biomass.

- We collaborated with researchers from Ireland on a climate-based air-drying model for Sitka spruce and prepared and submitted a journal paper on the model.
- Air-drying biomass trials were initiated in two Douglas-fir and two poplar stands Oregon. The trials cover different drying conditions within a stand and different material types. Changes in MC are monitored at 10-day intervals. Collaboration with industry is essential to the success of the trials since industry freely provides much of the raw materials, equipment, and labor required. The trials will be run for a 12-month period.
- Two software tools (a Fuel Cost Comparison tool and a Delivered Woodfuel Sales Calculator) were designed and prototyped based on similar tools independently developed for Ireland by Glen Murphy and Pieter Kofman.
- A number of tools for measuring moisture in solid wood and chips were investigated. One tool for measuring the moisture of wood chips (Wile BioMoisture meter) was field tested in Sitka spruce in collaboration with researchers from Ireland.
- A seminar on the air-drying biomass trials was presented to graduate students at Oregon State University. Presentations on approaches to air-drying of biomass and modeling of seasonal impacts of air-drying were given to three Oregon forest industry companies.
- Funds for this WUR project are helping to support the training of an MS student and to develop new fundamental and applied knowledge.

Undertaking the literature review and collaborating with Irish researchers in the development of an air-drying model for Sitka spruce has improved our understanding of modeling approaches and tool developments for the Pacific Northwest (PNW) region of the U.S. The funds have also allowed us to build new relationships with a wider sector of the PNW forest industry and to collaborate with biomass supply chain researchers from Europe.

Duration: 7/1/2010-6/30/2012

Ongoing Projects

Improved Log Tracking Systems – Ensuring the Right Fiber Gets to the Right Processes

Glen Murphy

Objectives: Identify and evaluate costs and benefits of current and near-future log tagging and tracking systems that may be appropriate for PNW forest-to-mill supply chains: (1) review the international literature to identify and evaluate available tagging and tracking technologies; (2) survey PNW forest companies to determine tagging and tracking technologies currently being used and how they are integrated into supply-chain management systems; (3) identify forest wood suppliers who are using technologies not currently used within the PNW; (4) determine which technology is most appropriate for each fiber market (e.g., veneer, poles, large sawlog, small sawlog, pulp); (5) identify and report on near-future technologies, within or outside of the forest industry sector, that are still at the experimental stage but may be of interest of interest to the PNW forest industry; and (6) develop a research plan for gathering detailed operational information for four or five case-studies of the most appropriate technologies and applications.

Progress and Future Activities

- Completed a review of the international literature to identify (1) tagging/tracking technologies currently available and their advantages/disadvantages; and (2) near-future technologies of interest to PNW companies.
- Designed and pretested a survey to determine the current log tagging and tracking systems used by Oregon companies; distributed it to 89 companies and received 49 surveys back; and summarized the results in a paper that has been submitted for publication.
- Data collection on system costs has also been initiated.

Optimally matching wood quality to markets should lead, not only to improved product uniformity, productivity, profitability, and sector competitiveness, but also to reduced wastage, energy consumption, and environmental impacts along the seedling-to-customer supply chain. State-of-the-art log tagging and tracking technologies should help to ensure that the right fiber gets to the right process.

Funds for this WUR project have led to a change in knowledge as a result of the survey regarding current log tagging and tracking practices for domestic markets in Oregon and how this compares with tracking for markets elsewhere. There is also increased awareness of large European-based projects aimed at improved log tracking.

Duration 9/1/2009–8/31/2012

Improving Forest Biomass Transportation through GPS Monitoring and Chip Transport Modeling

John Sessions and Michael Wing

Objectives: to (1) monitor biomass chip-van movement with GPS technology on forest roads; (2) develop a model for predicting chip-van travel time on forest roads; and (3) investigate GPS technology applications for improving biomass transportation.

Progress and Future Activities

Three analyses have been completed. One manuscript has been accepted into a peer-reviewed journal, one is ready for review and one is in preparation.

- Data were collected from multiple chip vans used in three separate forest biomass transportation operations. Approximately 186,000 GPS measurements were recorded for the entire study.
- The GPS analysis investigated the accuracy and reliability of consumer-grade GPS receivers for vehicle tracking on forest roads under varying forest canopy types in mountainous terrain. Where inconsistencies were found between measurements, we investigated whether forest canopy or other operational characteristics influenced inconsistencies. Although our GPS testing focused on transportation of biomass from forest supply locations to distribution and processing centers, study results are applicable to any transportation process involving vehicles operating in steep, forested terrain
- Accuracies varied depending on cover type and among receiver sets. The least desirable accuracies were found in mature forest cover conditions. Consumer-grade GPS measurements were acceptable and likely exceed accuracy requirements for tracking and improving biomass transport from forest supply locations to distribution and processing centers.
- The range of accuracies for vehicles operating within mature cover is probably acceptable for other forest transportation monitoring/planning applications, including mapping road locations; other receivers may be needed where greater positional accuracy is required.
- Truck simulation models were developed to predict travel time for loaded and empty chip vans on steep forest roads, using principles of vehicle mechanics to determine limiting speeds on grades and curves including considerations of sliding, overturning, stopping sight, and vehicle power train considerations. Predicted travel time agreed closely with observed travel times for the fitted and validation data set. The chip-van simulation model travel time predictions were compared to travel time predictions from a widely used log truck travel time prediction model on forest roads.
- The results provided a method for producing horizontal alignment directly from GPS data and a travel time model for empty and loaded chip vans that closely approximates observed travel times. The study identified the importance of transition speeds between road sections on overall travel time and provided a method of measuring driver behavior that can be used to train deterministic models.
- This chip-van transportation model much more closely predicted travel time than did the widely used USDA Forest Service Log Truck Transportation model. The chip-van transportation model will contribute to improved cost feasibility analyses for biomass removals and fleet management.
- Study results were presented at Forest Transportation Workshop sponsored by the Forest Engineering, Resources and Management Department and the Western Forestry Association, October 26, 2011, Eugene, OR.

Duration 9/1/2009–8/31/2012

Improving Log Truck Scheduling through Advanced Planning and Monitoring Techniques

John Sessions and Kevin Boston

Objectives: to (1) define the fleet management problem faced by the Oregon and Washington forest industry; (2) evaluate current state of GPS usage and fleet management used in the forest industry; and (3) design and test scheduling and dispatch systems for several business models.

Progress and Future Activities

- A literature search of log truck scheduling methods and software is underway. The typical log truck scheduling problem addressed in the literature is to assign trucks to routes to minimize cost while meeting delivery schedules subject to several types of side constraints including time windows for load pickups and deliveries and maximum driver working hours.
- Interviews with log truck contractors have been initiated to understand their fleet management problems, identify opportunities for improvement, and look for case studies. Initial contact has identified lack of co-

ordination between logging contractors and trucking contractors as a contributing factor to the lack of adoption of log scheduling software. For example, the log truck contractor may provide trucks simultaneously to a several logging contractors, but the truck contractor may only know the number of trucks that the logging contractor will need the next morning, not the mill destination or number of loads that must be picked up and delivered during the day. This suggests improvements in contractor coordination with improved planning may provide cost savings.

- A test of off-the-shelf GIS software has been developed.
- A graduate student has been recruited for this project and has completed preparatory classes in transportation planning, GIS, and combinatorial optimization.

Duration 9/1/2009–8/31/2012

Completed Projects

Acoustic Log Sorting on Processors and Harvesters

Glen Murphy and Barbara Lachenbruch

Objectives: (1) Develop analytical and operational procedures for implementing acoustic-based log segregation of Douglas-fir on a mechanized processor head; (2) determine whether acoustic measurements should be gathered on a harvester head transversely (from one side of the log to the other) using time-of-flight equipment or longitudinally using resonance-based equipment; (3) develop and test acoustic forecasting procedures based on regression models, nearest-neighbor methods, or other methods. Forecasting procedures are needed to minimize cost and productivity impacts of the new measurement system and to improve the accuracy of the acoustic measurements. (4) Develop optimal log-making algorithms that can accommodate acoustically measured wood properties and that could be implemented on a mechanized processor bucking computer.

Accomplishment and Impacts

- Samples from five sites on Roseburg Forest Products land in Oregon were measured during the summer of 2009. Acoustic velocity was measured longitudinally along the stem and transversally across the stem. Data analyses were carried out on the effects of site, tree variables, and log location on acoustic velocity.
- We evaluated four approaches for forecasting acoustic velocity based on stem measurements: time of flight (across the tree bole), resonance (full tree length), resonance (first 3 m butt log segment), and resonance (log segment 6-9 m above the butt).
- We designed three optimal log-making algorithms that could accommodate acoustically measured wood properties and be implemented on a mechanized processor bucking computer, where acoustic velocity is obtained prior to optimization for (1) a whole tree of known length and (2) a single butt log prior to optimization of the remainder of the stem, and (3) where profiles of the butt logs of a specified number of similar stems are used to initiate optimization of the full stem.

Results of the research activity were disseminated to researchers, students and forest industry representatives by

- preparing an MS thesis and publishing a paper (in review) in a peer-reviewed journal
- presenting three seminars to students at OSU and staff at Roseburg Forest Products (participant in the study)
- giving a paper at the 43rd Forest Mechanization Conference held in July 2010 in Padova, Italy.

Increasing value recovery along the forest-to-mill supply chain can be expected to improve both global competitiveness of the PNW forest industry and regional employment. Improving scanning, forecasting, and optimization systems to assist operators in log making can help increase the value recovery from mechanical harvesters. We examined approaches for measuring and forecasting acoustic velocity as a surrogate for wood stiffness.

Funds for this WUR project helped support the training of an MS student and develop new fundamental and applied knowledge. Specifically it was learnt that:

- Gathering acoustic velocity data in a transverse manner using time of flight equipment was not as reliable or accurate as gathering data in a longitudinal manner using resonance-based equipment.
- Wood density, MC, specific gravity and bark percentage were not significant predictors of resonance acoustic velocity of a section of a tree.
- Distance of a log section from the butt of the tree was found to be strongly correlated with acoustic velocity.
- Differences in acoustic velocity profiles between stands indicate a possible need for stand-specific calibration procedures.
- Forecasts of acoustic velocity, based on a minimal number of measurements on felled stems, could be combined with optimal log-making algorithms on a harvesting machine to sort and allocate wood to the most appropriate markets.

Duration: 8/1/2008–7/31/2011

Alternate Maintenance Practices for Improved Environmental Performance of Forest Roads in Working Forests

Arne Skaugset, Amy Simmons and Chris Surfleet

Objectives: (1) Evaluate alternative road maintenance schemes to determine the cost of mitigating road-related sediment associate with wood hauling; and (2) build on extensive previous work in western Oregon to design and cost out alternatives to eliminate the road-related sediment from the hydrologically responsive road segments connected to the stream system.

Accomplishment and Impacts

Research on the hydrology and sediment yield of individual road segments has shown that sediment yield from individual road segments is correlated with the characteristics of the road segment, hillslope, and hydrology of the road. Models exist that predict the amount of sediment that will be produced by an individual road segment given the nature of that segment. Few situations exist where the total sediment yield from a roaded watershed was measured and actual measurements of sediment yield from road segments in the watershed was simultaneously measured.

- From 2002 to 2007 the sediment yield from the Oak Creek watershed near Corvallis, Oregon, and sediment yield from individual road segments across the watershed, especially road segments directly connected to streams, were measured. These data enabled the researcher to determine the actual contribution of the roads to the sediment yield of the watershed.
- Sediment yield data from the winter of the 2006 and 2007 water year showed that the 2006 water year had the greatest precipitation and runoff of all the years of record, so it should be indicative of the performance of the road systems. The total yield of suspended sediment for the mouth of the watershed and for the 15 road segments directly connected to the stream system were reported for both water years.

The PNW has tens of thousands of miles of legacy logging roads. These roads are perceived to be an ongoing environmental liability that causes long-term, chronic changes in watershed hydrology and increased and chronic delivery of fine sediment to streams. During the last two decades there was an ongoing effort to remove, decommission, or upgrade the quality of the legacy roads to mitigate the perceived environmental liability. Programs to upgrade the environmental quality of legacy roads are not selective. They are designed to treat entire road systems and extensive areas of roaded watersheds. This is an expensive approach to mitigate environmental impacts.

- In this study, the sediment yield data from the individual road segments shows that it should be possible to be more selective in the approach to the environmental upgrade of forest roads. For example, in Oak Creek about half of the road segments accounted for about 80% of the road related sediment data. For the cost of extensive upgrades on only seven road segments, 77% of the road related sediment could be eliminated or significantly reduced. It is hypothesized that the road systems for most roaded and forested watersheds in the humid, temperate PNW will behave similarly.
- The relative amount of sediment from the road segments that are totally connected to the stream and the entire watershed indicate that road-related sediment in forested watersheds managed in a contemporary environment may not be much of a problem as perceived. If the road system is well constructed and maintained on a regular basis, the data show that during average years when logging is not a part of the ongoing process, road-related sediment is well within the error term associated with calculated total annual sediment yield at the watershed scale. In-place, constructed forest road systems may not be the source of accelerated erosion that they are perceived to be.

Duration: 8/1/2008–7/31/2011

Seasonal Impacts of Bark Removal by Mechanized Processors on Log Volume, Value and Wood Quality Assessment

Glen Murphy

Objectives: (1) develop procedures for rapidly determining the quantity of bark on tree stems before and after processing by single-grip processors; (2) quantify the impacts of time of year on bark removal for five commercial tree species in Oregon; (3) and evaluate the seasonal impacts of bark removal on five metrics of interest to the forest industry (log stiffness, log transport weight, bark as cogeneration fuel, log volumes, and value recovery).

Accomplishment and Impacts

- Quantification of seasonal bark loss for five Oregon commercial tree species (Douglas-fir, western hemlock,

ponderosa pine, lodgepole pine, and red alder) was conducted from mid-fall 2009 to late summer 2010 on 600+ stems. Measurements on each stem included tree length, butt diameter overbark, acoustic velocity of the whole tree (with and without limbs), visual and taped presence/absence of bark, and bark thickness. Data analyses were carried out on the effects of species and season on bark loss, acoustic velocity, truck payloads, transport costs, and bioenergy delivery. We compared measured and visually assessed estimates of bark loss.

Results of the research activity were disseminated to researchers, students and forest industry representatives by:

- Publishing two papers in peer-reviewed journals
- Distributing preliminary results to 10 logging crews and forest companies participating in the project
- Distributing results of earlier WUR projects on acoustic sorting to project participants as indicator of what would be done and why.

Bark makes up 10% to 25% of the overbark volume and weight of a tree. Past interest in determining what factors affect bark removal has usually been related to surface damage and fungal degrade in logs. Bark has gone from being a waste product to a by-product of wood utilization, however. Understanding what factors effect bark loss will allow us to better manage this product. Funds for this WUR project helped to develop new fundamental and applied knowledge about bark loss. Specifically it was learnt that:

- Bark loss in late spring and early summer increases substantially (up to 5 times as much as in winter).
- Bark loss is species dependent: Douglas-fir incurs more than twice as much bark loss as ponderosa pine.
- Distribution of bark loss along the stem is species dependent: we found greater areal bark loss towards the top of the stem in ponderosa pine than towards the bottom, but there was no such trend for Douglas-fir.
- Visual estimates of bark loss were within 5% of measured bark loss on average.
- Freshly felled and delimbed stems were more likely to lose bark than stems that sat for a few weeks.
- Preliminary data analysis showed that acoustic velocity was not affected by bark loss, counter to our earlier research showing that acoustic velocity increased by up to 5% as bark loss increased. Variability between sites and trees may account for this difference.
- In winter, bark is expected to account for 3%-4% more of a stem's weight than in late spring to early summer.
- There were considerable differences between species in the contribution of bark to total weight, but not in the percent drop in weight between seasons.
- Seasonal changes in bark loss could lead to changes in solid wood truck payloads, transport costs, bark, and available energy (from bark) delivered to mills.

Duration: 8/1/2008–7/31/2011

The Impact of Road Aggregate Properties on Wood Transportation Costs

Kevin Boston, John Sessions, and Marvin Pyles

Objectives: (1) Evaluate variability in road surfacing aggregate strength and durability by testing to improve understanding of rock wear; (2) develop a model to enable forest managers to select road rock sources based on performance criteria associated with wood transportation costs.

Accomplishment and Impacts

- Material from 10 quarries has been collected along with managers' qualitative judgment regarding the quality of the rock as being excellent, good, or fair with regard to its use in as a surface rock for forest roads.
- A variety of tests have been completed on all of the material including LA Abrasion, micro Deval, Sand Equivalency test, and gradation.
- Data show a tremendous range in outputs from the rock sampled. Managers' judgment generally agrees for the 6 of the 10 rock types showed, but one rock type rated as "good" gave poor results in the rock tests and one rated as "marginal" performed near the top of the materials sampled.
- These results have been disseminated at three professional talks in the last two years, including the Forester Forum in Coeur d'Alene, Idaho in 2010, the Oregon Society of American Forester annual meeting in 2010, and the Bureau of Land Management, Engineering Workshop meeting in March of 2011. A student MS thesis and a journal paper are in preparation.
- This work illustrates how the use of these material tests may contribute to better cataloguing of the available rock and aid in determining its value. Companies can spend of 20% of their road costs on surfacing rock. Rock sources are becoming scarcer. This study provides a baseline for future studies of rock durability that will enable forest engineers to perform more informed cost benefit analyses of alternative rock sources with a goal of reducing transportation costs for the industry.

Duration: 8/1/2008 – 7/31/2011

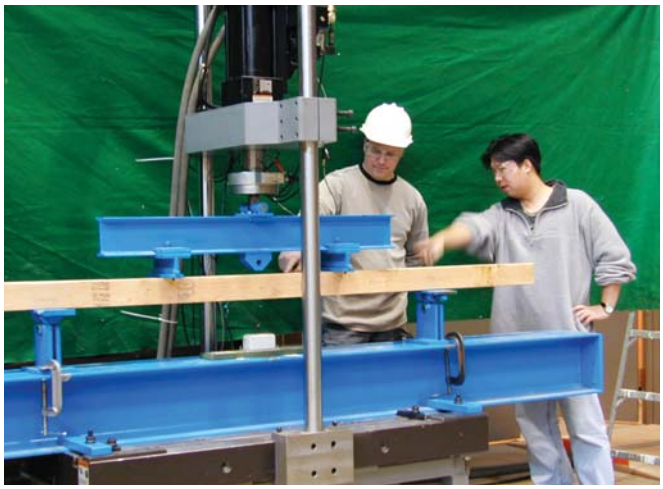
Science to Support Environmentally Responsible Wood Procurement

NEW PROJECTS

Optimization of Dryer Systems for Energy Use and VOC Emissions

Fred Kamke, Mike Milota, and David Smith

Objectives: The proposed research addresses USDA Wood Utilization Research Special Grant Strategic Plan Theme "Maintain or expand sustainable and environmentally acceptable forest operations and product manufacturing." The project focuses on green methodologies for drying and enhancing wood properties through thermal-hydro-mechanical (THM) modification and associated gas emissions.



Specifically, to characterize (1) emissions from THM processing of wood in relation to time, temperature, steam pressure and wood species; and (2) non-volatile degradation products from THM in regard to chemical reactivity and potential reaction mechanisms; and (3) demonstrate in situ chemical reactivity to reduce gas emission and improve water resistance of resulting THM products.

Progress and Future Activities

This project planned to use a rotary drying system for the analysis and modeling of gas emissions. The dryer system was to be donated by an industrial partner. The dryer was built, but the company pulled out of the project and did not delivery the dryer. The model was to be adapted from an existing rotary dryer model. The system was changed to the thermal-hydro-mechanical process recently installed at OSU. The THM process begins with wet wood, induces high-temperature exposure, and produces gas emissions and thermal degradation of the resulting product. The basic science in relation to the environmental impact is similar between a rotary dryer and the THM process. Consequently, the physical system was changed to THM processing. The scope of the project and available funding for personnel support is not sufficient to develop a numerical model for the THM system. The system change caused a delay in recruiting a graduate research assistant. Only preliminary work was accomplished during the reporting period.

- Planning and progress of this project has been reported at two professional meetings.

Duration: 7/1/2010-6/30/2012

Publications, Theses, and Technology Transfer Activities and Presentations

Publications

Craig, J., C. Dibrell, and E. Hansen. 2011. Natural environment, market orientation, and firm innovativeness: An organizational life cycle perspective. Journal of Small Business Management 49(3):467–489.

Dibrell, C., J. Craig, and E. Hansen. 2011. The effect of managerial attitudes toward the natural environment on market orientation and innovation relationships. Journal of Business Research 64:401–407.

Edson, C., and M.G. Wing. 2011. Tree location measurement accuracy with a mapping-grade GPS receiver under forest canopy. Forest Science (in press).

Eichorn, S.J., A. Dufresne, M. Aranguren, N.E. Marcovich, J.R. Capadon, S.J. Rowan, C. Weder, W. Thielemans, M. Roman, S. Renneckar, W. Gindl, S. Veigel, H. Yano, K. Abe, M. Nogi, A.N. Nakagaito, A. Mangalam, J. Simonsen, A.S. Beight, A. Bismarck, L.A. Berglund, and T. Peijs. 2010. Review: Current international research into cellulose nanofibers and nanocomposites. Journal of Materials Science 45(1):1.

Goodall, S.I., and R. Gupta. 2010. Optimizing the performance of gypsum wall board in wood frame shear walls. Journal of Performance of Constructed Facilities 25(4):287–298.

Gu, K., and K. Li. 2011. Preparation and evaluation of particleboard with a soy flour-polyethylenimine-maleic anhydride adhesive. Journal of American Oil Chemists' Society 88:673–679.

Hamner, R., and C. Knowles. 2011. Identifying the Relevance of "Family Forest" Wood Product Origin for Oregon Industrial Customers and Specifiers. Proceedings, The Joint IUFRO/UNECE Team of Specialists in Forest Products Marketing Meeting, June 15–18, Corvallis, OR.

Han, X., and E. Hansen. 2011. Are more innovative companies more likely to embrace CSR? Wood Science and Engineering, Oregon State University. Forest Business Solutions 9(1):1–2.

Hansen, E. 2010. The role of innovation in the forest products industry. Journal of Forestry 108(7):348–353.

Kamke, F.A., and A. Kutnar. 2011. Influence of stress level on compression deformation of wood in 170°C transient steam conditions. Wood Materials and Science Engineering 6:105–111. DOI.org/10.1080/17480272.2010.535907.

Kamke, F.A., and A. Kutnar. 2010. Transverse compression behavior of wood in saturated steam at 150°–170°C. Wood and Fiber Science 42(3):377–387.

Kamke, F.A., and V.M. Rathi. 2010. Apparatus for viscoelastic thermal compression of wood. European Journal of Wood and Wood Products. Published online, June 24, 2010; DOI 10.1007/s00107–010–0461–7.

Karas, M., and L. Muszyński. 2011. Sustainable bio-composites for highway infrastructure: Feasibility of material substitution in existing products. BioResources 6(4):3915–3932.

Karas, M., and L. Muszyński. 2010. Sustainable bio-composites for highway infrastructure: Feasibility of material substitution in existing products. ECOWOOD 2010 – 4th International Conference & Exhibition on Environmentally-Compatible Forest Products, September 8–9, Oporto, Portugal (in press).

Kutnar, A., M. Humar, F.A. Kamke, and M. Sernek. 2011. Fungal decay of viscoelastic thermal compressed (VTC) wood. European Journal of Wood and Wood Products 69(2):325–328.

Kutnar, A., and F.A. Kamke. 2010. Compression of wood under saturated steam, superheated steam, and transient conditions at 150°C, 160°C, and 170°C. Wood Science and Technology. Published online, October 7, 2010; DOI 10.1007/s00226–010–0380–0.

Kutnar A., and F.A. Kamke. 2010. Densified wood for green composites. In: Green Composites: Properties, Design and Life Cycle Assessment, F. Willems and P. Moens, eds. Nova Science Publishers, Hauppauge, NY, pp. 197-204.

Kutnar, A., and F.A. Kamke. 2010. Densified wood for green composites. In: Proceedings, 4th International Conference on Environmentally-Compatible Forest Products, September 8–9, Porto, Portugal (in press).

Kutnar, A., and F.A. Kamke. 2010. The influence of heat treatment on the set recovery of compressive deformation. In: Proceedings, 1st International Conference on Processing Technologies for the Forest and Bio-Based Products Industries, October 7–8, Salzburg/Kuchl, Austria, pp. 42–47.

Kutnar, A., F.A. Kamke, and M. Sernek. 2010. Utilization of plantation wood in high performance wood-based structural composites. In: Proceedings Wood Adhesives 2009, September 28–30, South Tahoe, NV, pp. 167–172.

Kutnar, A., L. Rautkari, and F.A. Kamke. 2010. Compressive creep of wood at high strain levels and variable moisture condition. In: Proceedings, World Conference on Timber Engineering, June 20–24, Riva del Garda, Trentino, Italy (in press).

Moon, R., A.A. Martini, J. Nairn, J. Simonsen, and J. Youngblood. 2011. Cellulose nanomaterials review: Structure, properties and nanocomposites. Chemical Society Review 40:3941–3994.

Murphy, G.E., and S.J. Pilkerton. 2011. Seasonal impacts on bark loss for Douglas-fir and ponderosa pine harvested on the

Pacific Northwest coast of USA. International Journal of Forest Engineering (in press).

Murphy, G.E., and S.J. Pilkerton. 2011. Seasonal impacts of bark loss on simulated payloads, bark delivery and transport costs. Forest Products Journal 61(1):71–76.

Muszyński, L. 2009. Is what you see all you can get? Bridging experimentation and modeling with advanced imaging techniques. In: Proceedings of the Final Conference of COST Action E49: Processes and Performance of Wood-Based Panels, Sept. 14–15, Nantes, France. M. Irle, ed., pp. 71–83.

Panwar, R., E. Hansen, and R. Anderson. 2010. A framework for identifying social and environmental issues: A case of the US forest products industry. Social Responsibility Journal 6(1):18–32.

Panwar, R., E. Hansen, and R. Kozak. 2011. Evaluating social and environmental issues by integrating the legitimacy gap with expectational gaps: An empirical assessment of the forest industry. Business & Society (in press).

Prasittisopin, L., and K. Li. 2010. A new method of making particleboard with a formaldehyde-free soy-based adhesive. Composites Part A 41:1447–1453.

Rautkari, L., F.A. Kamke, and M. Hughes. 2011. Density profiles relation to hardness of viscoelastic thermal compressed (VTC) wood composite. Wood Science and Technology. Published online, January 13, 2011; DOI: 10.1077/s00226-010-0400-0.

Rautkari, L., F.A. Kamke, and M. Hughes. 2011. Potential error in desity profile measurements for wood composites. European Journal of Wood and Wood Products 69(1):167–169.

Rautkari, L., A. Kutnar, M. Hughes, and F.A. Kamke. 2010. Wood surface densification using different methods. In: Proceedings, World Conference on Timber Engineering, June 20–24, Riva del Garda, Trentino, Italy (in press).

Schwarzkopf, M., J. Huang, and K. Li. 2010. A formaldehyde-free soy-based adhesive for making oriented strandboard. Journal of Adhesion 86:352–364.

Sessions, J., J. Wimer, F. Costales, and M. Wing. 2010. Road assessment for biomass transport in steep terrain. Western J. of Applied Forestry 25(3):144–153.

Simwanda, M., M.G. Wing, and J. Sessions. 2011. Evaluating global positioning system accuracy for forest biomass transportation tracking within varying forest canopy. Western Journal of Applied Forestry 26(4):165–173.

Skaugset, A.E., C.G. Surfleet, M.W. Meadows, and J. Amann. 2011. Evaluation of erosion models for forest roads. Transportation Research Record: Journal of the Transportation Research Board 2203:3–12. Transportation Research Board of the National Academies, Washington, DC.

Thompson, D.W., E.N. Hansen, C.D. Knowles, and L. Muszyński. 2010. Opportunities for wood plastic composite products in the U.S. highway construction sector. Bioresources 5(3):1336–1352.

Tze, W.T.Y., J. Yao, M. Taylor, and J. Simonsen. 2011. Raman spectroscopic studies of load transfer in nano-cellulose-filled poly(lactic acid) composites. 18th Annual International Conference on Composites/Nano Engineering, July 4–10, Anchorage, AK.

Tze, W.T.Y., J. Yao, M. Taylor and J. Simonsen. 2011. Raman spectroscopic studies of load transfer in nano-cellulose-filled poly(lactic acid) composites. World Journal of Engineering (in press).

Theses

Edson, C.B. 2011. Light detection and ranging (LiDAR): What we can and cannot see in the forest for the trees. Ph.D. Dissertation. Oregon State University, Corvallis. 278 pp.

Karas, M. 2010. Sustainable bio-composites for West Coast highways. M.S. Thesis. Wood Science and Engineering, Oregon State University, Corvallis. 176 pp.

Kokenge, K. 2011. Opportunities and challenges for decision support systems in timber transportation. M.S. Thesis. College of Forestry, Oregon State University, Corvallis. 135 pp.

Meadows, M.M. 2009. Using in situ turbidity to estimate sediment loads in forested headwater streams: A top-town versus bottom-up approach. M.S. Thesis. Oregon State University, Corvallis. 140 pp.

Technology Transfer Activities and Presentations

Ding, J., L. Muszyński, and J. Simonsen. 2010. Morphology based modeling of micro-mechanics and failure mechanisms in bio-materials with polymer matrices. 64th International FPS Convention, Madison, WI (oral presentation).

Ding, J., L. Muszyński and J. Simonsen. 2010. Morphology based modeling of micro-mechanics and failure mechanisms in bio-materials with polymer matrices. 64th International FPS Convention, Madison, WI (poster).

Hamner, R., and C. Knowles. 2011. Identifying the relevance of "family forest" wood product origin for Oregon industrial customers and specifiers. Presented at Joint IUFRO/UNECE Team of Specialists in Forest Products Marketing Meeting, June 15–18, Corvallis, OR.

Hamner, R., and C. Knowles. 2011. Identifying the relevance of "family forest" wood product origin for Oregon industrial customers and specifiers. Presented at The Forest Products Society International Convention, June 12–21, Portland, OR.

Hansen, E.N., S. Leavengood, and R.Mosier. 2011. Customer Relationship Management, A Construct to Promote Innovation in the Forest Products Industry: Insights from Pacific Northwest Companies. Forest Products Society International Convention, June 21, Portland, OR.

Kamke, F.A. 2010. VTC Technology. BEST FEST, July 27, Portland, OR.

Kamke, F.A. 2010. Viscoelastic thermal compression—a technique to improve wood properties. Presented at Society of American Foresters—Mary's River Chapter, November 16, Philomath, OR.

Karas, M., and L. Muszyński. 2011. Effect of low-grade woody biomass content on tensile properties and resistance to environmental exposure in wood-HDPE composites. 65th Joint FPS/SWST International Convention, June 19–22, Portland, OR (poster).

Karas, M., and Lech Muszyński. 2010. Sustainable bio-composites for highway infrastructure: Feasibility of material substitution in existing products. ECOWOOD 2010--4th International Conference and Exhibition on Environmentally-Compatible Forest Products, September 8–10, Porto Portugal (Best Student Presentation Award).

Karas, M., S. Lippert, J Lüdke, and L. Muszyński. 2011. Sound transmission loss in wood-polypropplene composites. 65th Joint FPS/SWST International Convention, June 19–22, Portland, OR (poster).

Kelley, J., and J. Simonsen. 2011. Cellulose nanocrystals for battery separators. EPRI-ONAMI Workshop on Nanotechnology, January 12–13, Charlotte, NC.

Kutnar, A., and F.A. Kamke (speaker). 2010. Effect of steam treatment on set recovery and mechanical properties of densified wood. Presented at 64th International Meeting of Forest Products Society, June 20–22, Madison, WI.

Kutnar, A., and F.A. Kamke. 2010. Densified wood for green composites. 4th International Conference on Environmentally-Compatible Forest Products, September 8–9, Porto, Portugal.

Kamke, F.A., and A. Kutnar. 2010. Structural composite from FSC certified hybrid-poplar. International Convention of Society of Wood Science and Technology and United Nations Economic Commission for Europe – Timber Committee, October 11–14, Geneva, Switzerland.

Kamke, F.A., V. Rathi, and A. Kutnar. 2010. Structural composites from modified wood. Presented at International Academy of Wood Science Meeting, June 23–26, Madison, WI.

Kutnar, A., and F.A. Kamke. 2010. The influence of heat treatment on the set recovery of compressive deformation. 1st International Conference on Processing Technologies for the Forest and Bio-Based Products Industries, October 7–8, Salzburg/Kuchl, Austria.

Kutnar, A., L. Rautkari, and F.A. Kamke. 2010. Compressive creep of wood at high strain levels and variable moisture condition. World Conference on Timber Engineering, June 20–24, Riva del Garda, Trentino, Italy.

Manning, Rob. 2010. Finding and supporting The 'Best' ideas. OPB News, September 14, Portland, OR. http://news.opb.org/article/13094–finding-and-supporting-best-ideas.

Muszyński, L. 2009. Micro-mechanics research for sustainable bio-composites. Focus (Fall):10–11 (featured).

Muszyński, L. 2010. A webpage presenting the USDA NNF project objectives and activities including a summary of this WUR project was launched in mid-November. http://facstaff.forestry.oregonstate.edu/chris-knowles/national-needs-fellowship.

Muszyński, L., M. Karas, and D. Thompson. 2010. Sustainable bio-composites for West Coast highways. Oregon BEST Fest '10. September 13, Portland, OR (invited panel presentation).

Rautkari, L., A. Kutnar, M. Hughes, and F.A. Kamke. 2010. Wood surface densification using different methods. World Conference on Timber Engineering, June 20–24, Riva del Garda, Trentino, Italy.

Simmons, A. 2009. Oak Creek field tour for Benton County Soil and Water Conservation District. Approximately 40 participants. Discussion focused on the sediment and water yield from forest roads to streams in the Oak Creek Watershed.

Skaugset, A. Online database of water discharge, stage, precipitation, and climate from the Oak Creek Watershed is available for public use. Hosted on the Forest Science Data Bank website.

Skaugset, A. 2009. Physical hydrology and meteorology of the Upper Oak Creek Watershed in Western Oregon, 2001–2006. Forest Science Data Bank, Corvallis, OR [Database]. Available: http://andrewsforest.oregonstate.edu/data/abstract.cfm?dbcode=HF022.

Stark, J. 2010. Highways going "green." (Advisor: L. Muszyński). 21st ASE (Apprenticeship for Science and Engineering) Symposium, August 20, University of Portland, OR (presentation).

van der Voo, L. 2010. Green innovation not always a sure market bet. Sustainable Business Oregon, November 3. http://www.sustainablebusinessoregon.com/articles/2010/11/researcher-pursues-wood-based-highway.html.

Waldroupe, A. 2010. Wood waste flour could create a new building material. Oregon Business Magazine, May. http://www.oregonbusiness.com/articles/84–may-2010/3352–next-wood-waste-flour.

Yao, J., W.T.Y. Tze, M. Taylor, and J. Simonsen. 2010. Nano-cellulose/PLA adhesion: Evaluation using a micro-Raman tensile technique. Forest Products Society 64th International Convention, June 20–22, Madison, WI.

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