WOOD UTILIZATION SPECIAL GRANT IMPACTS
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IMPROVED UTILIZATION OF WOOD AND REDUCED ENERGY USE DURING LUMBER PROCESSING THROUGH EFFECTIVE DRYING

M. Milota, Oregon State University

Issue: Drying lumber in the Western U.S. consumes over 60 million GJ of fuel. Over half of this is natural gas and the balance is from wood. Large quantities are also dried in the southern U.S. Dramatically reducing energy use would require major changes in the drying process; however, small changes in the way a mill is operated can have a significant impact on the energy use. Environmental compliance is also energy intensive if regenerative thermal oxidizers are used.

Response: We assessed where energy is used in lumber processing and the viability of available models to predict the drying process. We modified these models for computer use and developed a user friendly interface. We explored using near infrared spectrophotometry and permeability measurements for sorting lumber and the use of high temperature drying as ways to reduce moisture variability. We also determined the emission levels of volatile organic compounds and hazardous air pollutants.

Impact: Lumber drying was found to be responsible for as much as 85% of the energy required to process logs into lumber and most of the airborne emissions. Specific information is guiding mill management in comparing their energy use to industry norms and in setting goals for energy reduction. The simulation of operational parameters such as fan reversals and air velocity to reduce moisture content variability in the dried product resulted in several mills are adapting to higher temperature drying to reduce time and increase energy efficiency. We estimate that, applied statewide, a 1% increase in final moisture content would result in mills saving 0.7 GJ annually. This is equivalent to over 6 million therms of natural gas at approximately $1 per therm. [2 MS students graduated; 6 publications generated]

ASSESSING THE CHEMICAL-MECHANICAL RELATIONS IN NAILED LIGHT-FRAME CONNECTIONS SUBJECT TO FUNGAL DEGRADATION

J.J. Morrell, R. Leichti, Oregon State University

Issue: Moisture intrusion is endemic on most modern buildings and can reduce the effective capacity of the structure, making it vulnerable to more serious damage during weather or earthquake events. Fungal decay often results from moisture intrusion. There are few good tools for assessing damage from fungal attack and even less information on how to effectively retrofit a structure without wholesale wood replacement. This is especially true when there are possible decay effects on strength and stiffness of nailed connections. Developing a better understanding of damage associated with fungal attack

and identifying improved methods for assessing damage will allow engineers and homeowners to make informed choices about repair.

Response: This study concentrated on the effects of decay on shear wall connections typical of residential structures. These connections play a major role in the ability of a structure to maintain its integrity during weather or earthquake events. Test methodologies were developed to assess the effects of wetting and fungal attack on connector behavior. This test method was originally applied using a single decay fungus and Douglas-fir/OSB assemblies, but is now being extended to other fungi and material combinations. The effort involves traditional monotonic and cyclic testing of connectors coupled with non-destructive tools that might be used in situ by an engineer to assess the degree of damage to a wood member.

Impact: Inspecting and repairing a structure with water intrusion can easily cost $100,000 or more for a single dwelling; with multifamily units the costs can quickly run into the millions of dollars. This research showed that wetted wood connections need not be replaced to maintain structural capacity if moisture is removed within 20 weeks. Shear walls that experience some wetting retain nearly all of their original capacity and do not need to be replaced. This knowledge, coupled with better moisture and decay detection methods could translate into millions of dollars in savings. [1 Ph.D. student graduated; 3 publications generated]

INNOVATION AND NEW PRODUCT DEVELOPMENT IN THE GLOBAL FOREST SECTOR

E.N. Hansen, Oregon State University

Issue: Countries with fast-developing economies, such as China, have had a profound impact on the competitiveness of U.S. firms. For example, Department of Commerce statistics show dramatic job losses within the U.S. furniture industry between 1999 and 2003. Most of these losses are a direct result of low-cost Chinese imports. This dramatic employment loss and poor performance have spurred a renewed interest in innovation among Western economic development specialists, researchers and industry practitioners. This project was designed to build a better understanding of innovation and new product development within the forest industry. Understanding the state-of-the art in the sector will allow for development of an improved approach to innovation management and new product development to foster long-term, global competitiveness.

Response: Although innovation topics have seen extensive coverage in the academic literature, there is still a lack of understanding regarding firm innovativeness and its relationship with firm performance. The most significant research hurdle in this area is inconsistent measurement of innovativeness. Accordingly, a primary objective of this project was to develop a measure of firm innovativeness. A general understanding of the state-of-the-art in new product development in the forest industry was developed. Because Chinese furniture imports have been especially problematic for the survival of U.S. furniture firms, another aspect of this project was to assess current practices in innovation and new product development in China. By better understanding the approach taken by Chinese firms, U.S. companies can better position themselves to remain competitive.

Impact: This research benefits manufacturers of primary and secondary wood products, policymakers, and researchers. Manufacturers can use the information as they manage for increased innovativeness and competitiveness. Industry competitiveness is critical to the health of the U.S. economy. According to Department of Commerce statistics, the average annual salary for production workers in wood product manufacturing and furniture and related product manufacturing is approximately $26 thousand. Every one percent loss in production employees in these sectors is equivalent to over $200 million in annual payroll and subsequent contribution to the U.S. economy. Policymakers can use information from this work to create new or adapt existing policies to provide the best setting for increased innovativeness by industry. Finally, this work is further developing the academic field of innovation management specific to the forest sector which results in increased interest by other researchers, and ultimately, improved knowledge and understanding. [2 MS students, 2 Ph.D. graduated; 6 publications generated]

EVALUATION OF SYSTEM BEHAVIOR OF THREE-DIMENSIONAL WOOD TRUSS ASSEMBLIES

Rakesh Gupta, Oregon State University

Issue: Light-frame wood roof assemblies are designed and analyzed as though they are comprised of individual trusses rather than as a complex structural system. Although the current design procedure is relatively simple, it is always conservative and does not take credit for load-sharing between components. As a result, roofs tend to be over designed. If load-sharing in light-frame wood roof truss assemblies can be rationally considered in truss design then better and more cost-effective roofs will result. More efficient use of wood as an engineering material will result with potentially lower environmental costs to society and the homeowner.

Response: A system design procedure (SDP) that analyzes assemblies (three-dimensional, 3D, analysis) as a system was developed. This 3D structural analysis program can be used to analyze and design whole truss assemblies in order to include system effects directly.

Impact: This research directly benefits the home building industry and ultimately the consumers by efficiently designing the whole house and possibly saving on material and labor costs. Specifically, system behavior of truss assemblies can improve the conventional truss design method by: (a) including system behavior directly, (b) increasing safety through improved analysis, and (c) reducing construction through lower grade and size of truss members. [4 MS students graduated plus 1 foreign diploma thesis student; 6 publications generated]

STRUCTURE-BIOACTIVITY RELATIONSHIPS OF SOME HEARTWOOD TERPENOIDS AND CHEMICAL TRANSFORMATIONS TO VALUE-ADDED PRODUCTS

J. Karchesy, Oregon State University

Issue: Heartwood essential oils and related products are known to have commercial value. If that value could be enhanced then new economic opportunity could be derived

from a low value wood and residues. This would result in more efficient utilization of natural resources and identify potential new processes and markets for low-value forest resources.

Response: Research on structure and bioactivity of selected Northwest heartwoods showed that some essential oils and their chemicals have the ability to act effectively as natural pesticides and anti-microbials for both human and veterinary use. Relationships between molecular structures were clearly established, identifying most valuable compounds and oils. Toxicology studies on two of Oregon's cedar wood oils found that Western Juniper and Port Orford Cedar essential oils had no toxic effects or elicit hypersensitivity reactions, or acute skin irritation at low concentrations to which animals would be exposed in bedding use. This research was done jointly with the OSU College of Veterinary Medicine.

Impact: The above research will help open new markets for these forest-based materials. These materials will be natural and thus may also have the advantage of being "green". An Oregon entrepreneur is using this research to market juniper and Port-Orford oils to all-natural product manufacturers in Japan and a major US cleaning products company. New employment opportunities have been created as a result. [2 MS students graduated; 7 publications generated]

CHEMISTRY OF MILL RESIDUES FOR INCREASED AND IMPROVED RESOURCE RECOVERY IN TRADITIONAL FOREST PRODUCTS OPERATIONS

J. Karchesy, Oregon State University

Issue: Improved economic opportunity may be realized if new products can be derived from very low value residues generated through mill or forest operations. These residues can be a disposal problem, or at best sold for limited gain. If chemicals, extracts or other biobased products can be made from residues then the forest sector, especially in rural areas, may be strengthened and society can gain access to new biobased materials.

Response: Research conducted in conjunction with the Centers for Disease control discovered new potential for forest-based materials and chemicals to act as biocides for control of some insect pests and for control of forest fungal pathogens such as sudden oak death disease. Condensed tannins from conifer bark were also found useful in collaborative research on new adhesives.

Impact: The new biobased materials offer safer alternatives to petrochemical-based pesticides. This work opens new market opportunities for some forest products industries. Results have been so promising, that field trials by the CDC are being used to evaluate these materials. On the issue of sudden oak death alone, it has been estimated that California nurseries loss in revenue may have been up to $100 million in 2004 due to restricted shipments and fear of spreading this plant disease. [1 Ph.D. students graduated; 7 publications generated]

MECHANISTIC STUDY OF THE FUNGAL DEGRADATION OF LIGNIN

Kaichang Li, Oregon State University

Issue: The production of white paper requires a process for selective removal of lignin, one of the major components of wood. Commercially, this requires harsh conditions and may result in environmental pollution under certain conditions. White-rot fungi are microorganisms known to efficiently degrade lignin and their use may offer opportunities to improve paper-making processes and reduce the risk of environmental pollution.

Response: We have purified and characterized two lignin-degrading enzymes laccase and manganese peroxidase from two newly isolated fungal strains *Trichophyton rubrum* LKY-7 and *T. rubrum* LSK-27. Degradation of pine, yellow poplar and sweet gum by three fungi Pycnoporus cinnabarinus, *T. rubrum* LKY-7 and *T. rubrum* LSK-27 were studied in detail. We found that *P. cinnabarinus* could degrade non-phenolic lignin although it only secrets laccase as a sole lignin-degrading enzyme and laccase is not able to degrade non-phenolic lignin substructures alone. This result suggested that the fungus *P. cinnabarinus* uses a laccase/mediator system for lignin degradation. We then investigated mechanisms by which a laccase/mediator system oxidized lignin and found that an effective mediator must have certain structural features and certain chemical properties such as high redox potential. A number of new effective mediators were developed and evaluated for degradation of lignin in unbleached kraft pulps.

Impact: Results from this research enabled us to gain a much better understanding of the mechanisms by which white-rot fungi degrade lignin. This mechanistic study provided critical scientific knowledge that can be used to selectively remove lignin from wood for various applications such as bio-pulping. Our study of a laccase/mediator system and the mediators also provided science building blocks that can be exploited for the development of an environmentally friendly and cost-competitive pulp bleaching technique. [1 MS students, 2 Ph.D. graduated; 11 publications generated]

INVESTIGATION OF INTERFACIAL ADHESION OF WOOD-PLASTIC COMPOSITES

Kaichang Li, Oregon State University

Issue: Wood-plastic composites (WPCs) have many property advantages over wood and plastics, and are one of the rapidly growing sectors in wood-based composite industry with over $1 billion in annual sales. However, hydrophilic wood is not compatible with hydrophobic thermoplastics and the interfacial adhesion between the two is weak. As a result, currently available WPCs are heavy and weak relative to wood.
Response: This study investigated how wood and plastic bond to each other and explored methods of enhancing adhesion between the two in WPCs. Several superior systems to make the components more compatible were developed. These compatibilizing systems were more effective than currently available ones in improving the strength and stiffness of WPCs. These were evaluated for their ability to enhance interfacial adhesion. Other studies were made on how and why the compatibilizing systems worked.

Also studied were the effects of wood extractives on the interfacial adhesion between wood and polyethylene. Removing extractives from wood flour prior to mixing with plastic greatly enhanced the strength and stiffness of the resulting wood-polyethylene composite materials.

Impact: This study increased our understanding of how to improve the interfacial adhesion between wood and plastics. The successful development of superior compatibilizers will enable us to develop superior wood-plastic composites that are stronger and lighter than wood-plastic composites currently available in the market. Commercialization of these compatibilizing systems is under way. Research in this area greatly facilitates the improved utilization of low-grade woody biomass from forest thinning and adds value. [1 MS students, 1 Ph.D. graduated; 8 publications generated]

MONITORING, CONTROLLING, AND REDUCING THE AIRBORNE EMISSIONS AND ENERGY USE DURING WOOD PROCESSING

M. Milota, Oregon State University

Issue: Organic pollutants from drying wood can result in significant deterioration of air quality as defined in Title I of the Clean Air Act. A small fraction of the volatile organic compounds (VOCs) are HAPs (hazardous air pollutants) and are regulated under Title III of the Clean Air Act because they impact human health. This regulation has the potential to significantly impact the costs of manufacturers and the competitiveness of the domestic industry.

Response: Prior work verified that a laboratory dryer can be used to estimate the emissions from a commercial lumber dryer. A laboratory dryer was used to generate a database of emission factors for major western species and southern pine. Recognizing that it is not practical to measure emissions for every possible condition, we also determined emissions as a function of temperature and humidity in the dryer for several common western species – ponderosa pine, western hemlock, and Douglas-fir. We also conducted a survey of the literature to determine various methods to remove pollutants from dryer and press exhaust gas.

Impact: This research has benefited western and southern producers by reducing or eliminating the need for source testing at individual dryers. These source tests are not only difficult to accomplish, they are expensive to do on a mill scale. The emission levels measured save testing individual kilns at a cost of $10 to $20million state wide The public benefits from this work because the mills are more likely to be in compliance resulting in cleaner air due to reduced ozone levels. We determined that there is considerable variability among species in the generation of HAPs during drying. This was a new discovery which led to additional study. Our survey of the literature resulted some initial testing, then a follow-up project which was later funded by the Department of Energy to test a new innovative method of removing organic pollutants from exhaust streams using ionic liquids. This, if successful, could replace regenerative thermal oxidizers resulting in fewer emissions. [2 MS students graduated; 3 publications generated]

INVESTIGATING VENEER SURFACE ROUGHNESS CHARACTERISTICS AFFECTING GLUE BOND PERFORMANCE IN PLYWOOD

J. Funck, J. Reeb, Oregon State University

Issue: Gluebond quality is essential to the structural integrity of plywood panels and to avoiding delamination of products in service. Manufacturers are now using rougher veneer to produce plywood than in the past. To compensate, plywood manufacturers typically increase the amount of adhesive used, but the effectiveness of doing so has not been verified. Many questions exist about how veneer roughness, lathe checks and annual ring characteristics affect plywood gluebond quality. A better understanding of the influence of these veneer characteristics will allow manufacturers to improve veneer quality rather than increase adhesive spread rate. In addition, improved gluebond performance will lead to better performance in the field, affecting many homeowners and other users.

Response: Research was conducted on plywood manufactured with veneer of different roughnesses and adhesive quantities. The results clearly showed that veneer roughness has a significant influence on glue-bond quality as measured by strength and the percent failure in wood or adhesive. Gluebond quality was found to be influenced by both veneer roughness and characteristics such as lathe checks and annual rings. Percent wood failure was mainly influenced by veneer roughness, along with some contribution from annual ring characteristics which determined how the specimens failed. Load at failure was mainly determined by wood material properties, in particular, lathe check frequency along with some influence of veneer roughness.

Impact: The report from this study won First Place in a national competition sponsored by the Forest Products Society. In part, the award recognized the value of the research results to plywood manufacturers by quantifying the potential reduction in adhesive costs by peeling smooth veneer with fewer lathe checks. It has been estimated that 20 to 70 percent of the veneer used in a typical plywood mill can be classified as rough. Manufacturers using rough veneer typically increase press pressure and increase adhesive spread rates by approximately 10%, which translates to 3 to 5 pounds per thousand square feet (MSF) of single glue-line. If prices of phenol-formaldehyde adhesives range from $9.00 to $11.00 per thousand square feet of panel production (3/8-inch basis), and assuming an annual U.S. softwood plywood production of 16.5 billion square feet (3/8-inch basis), a decrease in adhesive costs resulting from using smoother veneer could range from 3 to 12 million dollars per year for the industry as a whole. [2 MS students graduated; 3 publications generated]

UTILIZING FOREST FUELS FOR BIOENERGY CONVERSION FROM WILDFIRE RISK REDUCTION SILVICULTURE IN CENTRAL AND EASTERN OREGON

Loren Kellogg, Chad Davis, and Michael Vanderberg, Oregon State University

Issue: Thinning of high wildfire risk forests to improve forest health has the potential to provide substantial wood fiber a variety of forest and energy products. The main challenges are dependable access to federal lands for treatment and the perceived high costs of harvesting and transporting to a processing facility.

Response: An analysis was completed that evaluated potential costs and benefits of biomass harvesting treatments, including results from pilot tests of innovative harvesting equipment.

Impact: The analysis projected that if all "at risk" acres were treated over a 20 year period in southern and eastern Oregon, the biomass harvested could generate 164 megawatts (MW) of renewable energy, or 2.9% of Oregon's 2004 total installed electrical generation capacity. The forest operations could also potentially provide $3.2 - $6.5 million annually in new forest worker wages, and reduce costs of fighting wildfires by up to $118 million annually. [1 Ph.D. supported, 1 Ph.D. graduated; 4 publications generated]

STABILITY ASSESSMENT OF HIGH RISK SITES IN FORESTED WATERSHEDS

Arne Skaugset, Oregon State University

Issue: In western Oregon, about 23 % of private industrial forest land, or about 1 million acres, is landslide prone. Timber harvesting is correlated with an increase in the density of landslides after intense storms, under the hypothesis that living tree roots are critical to slope stability. Current policies propose removing large acreages from timber harvesting to mitigate for landslides.

Response: Because landslides routinely occur in areas where root reinforcement is left intact, a study was conducted to seek alternative mechanisms, including the effects of a forest canopy in smoothing rainfall intensity spikes.

Impact: The research demonstrated that after harvesting, the loss of rainfall storage within the tree canopy and an associated increase in the rainfall intensity delivered to the soil can be sufficient to explain a harvesting induced occurrence of landslides. Reduced canopy density is an alternative failure mechanism to root reinforcement and mitigation measures for this mechanism would be different.

The current precautionary approach to removing land from the timber base to protect root systems is, potentially, an annual cost **to the private timber industry in western Oregon** of $250 to $500 million a year. This result informs the debate regarding landslide mechanisms, harvesting effects, and the appropriate mitigation for them, but further study is needed to refine results. [1 Ph.D. graduated; 5 publications generated]

LANDSLIDES, DEBRIS FLOWS, AND AQUATIC HABITAT IN CONTEMPORARY, INTENSIVELY MANAGED FORESTED LANDSCAPES

Arne Skaugset and Michael Wing, Oregon State University

Issue: At issue is whether or not the knowledge and tools available for estimating aquatic habitat and for identifying likely landslide source areas and depositions sites are sufficient to assist land managers and regulators seeking to balance public safety risks with aquatic habitat benefits. In the absence of trustworthy information, precautionary approaches often propose to limit harvesting of productive forests. Large wood and boulders delivered to streams by landslides in managed forested landscapes can create pools and structural complexity in streams that benefits fish. Various models exist that identify potential landslide sites from digital elevation models (DEMs) and other techniques and that route debris flows from high risk sites to deposition sites in or near streams; however, their site specific value is often challenged.

Response: A study was conducted to test the potential for linking aquatic habitat inventory data with estimates of watershed slope stability using models that predict potential location and density of landslides to identify areas of high intrinsic aquatic habitat value. This effort was unsuccessful because the aquatic habitat inventory data, which was estimated ocularly by field crews, was too coarse to be useful in explaining observed landscape variability. A follow up project evaluated the landslide estimation models and used different topographic indices to identify potential landslide locations. Results showed that simple indices based on percent slope and upslope contributing area were as good as or better for identifying landslide locations than complex models combining topography and slope stability calculations.

Impact: Improved methodologies for identifying landslide prone terrain and linkages with aquatic habitat are crucial to land managers seeking to balance aquatic habitat protection goals against unnecessary removal of timber supplies from wood utilization. [1 M.S student graduated; 1 publication generated]

HILLSLOPE FAILURE MECHANISMS IN SHALLOW FOREST SOILS

Marvin Pyles, Oregon State University

Issue: Improvements in forest road construction and management practices have significantly reduced the occurrence of landslides and the resulting sediment into streams. Efforts to reduce “in-unit” landslides associated with timber harvesting have been less successful, and have often centered on limiting timber harvest on sites perceived to be high risk. The direct physical cause and effect relationships remain elusive.

Response: A study examined mechanisms of failure associated with reinforcement of shallow forest soils by plant roots, and the potential for static liquefaction of the soil that could make reinforcement ineffective. Testing of intact forest soil samples found that

static liquefaction is not possible; however, the data were not robust enough for publication in the Geotechnical literature.

Impact: The results are valuable in refining the focus of further research, but are not robust enough to influence land management or policy development. In the absence of better information, precautionary approaches that reduce timber harvest can cost the forest sector $250 to $500 million a year from private lands alone. [2 MS students graduated]

APPLYING PRECISION FORESTRY TECHNIQUES FOR ADDING VALUE ALONG THE WOOD SUPPLY CHAIN

Loren Kellogg, Glen Murphy, and Michael Wing, Oregon State University

Issue: One approach to meeting wood supply and utilization challenges is to apply rapidly improving technical tools designed to speed high quality field work and data analysis. Some technical tools used in precision forestry to capture, manipulate, and analyze spatial data include laser rangefinders, global position systems (GPS), and geographic information systems (GIS), but there has been little independent testing under rigorous field conditions.

Response: Several applied research projects were completed to evaluate the performance of precision forestry tools for improving the timber supply chain.

Impact: Field studies determined that relatively inexpensive GPS receivers provide acceptable resolution under a forest canopy for many forest operations activities at a significant cost savings over traditional forest mapping and analysis approaches. For the current harvest level in Oregon, the studies estimate that approximately $ 750,000 could be saved in harvest planning field work each year. Similar testing of commercially-available digital range finders recommended one laser-based tool for accurately measuring tree heights to support wood harvest operations. [1 MF student graduated: 6 publications generated]

SMART SENSOR SYSTEMS FOR IMPROVED WOOD UTILIZATION

Glen Murphy, Oregon State University

Issue: Global competition is putting increasing pressure on US and PNW timber producers, requiring new ways of adding value and service. Incorporation of smart sensor systems into mechanized harvesters is one area of technology that potentially offers step change solutions for improving wood utilization and adding value.

Response: Research that evaluated various sensing technologies demonstrated that contact sensor systems can be used to measure external log properties, near infra-red sensor systems can be used to measure internal wood properties, and aroma tagging and electronic nose systems can be used to track logs from forest to mill. Sensor systems also can be made "smarter" by combining them with spatial models of stem characteristics, such as bark thickness and density gradients. It was shown that the gains of 10% or more

in added value are possible.

Impact: The Pacific Northwest forest sector harvests about 7 billion board feet of timber per year valued at about $3 billion. A conservative estimate of the improvement in value recovery for the forest growers would be $150 million per year if smart sensor systems were used throughout the sector. Additional benefits would accrue to the wood utilization companies. [2 Ph.D. students graduated; 12 publications generated]

PLANNING FOR FIRE-KILLED TIMBER SALVAGE CONSIDERING ECONOMIC VALUES AND ENVIRONMENTAL RISKS

John Sessions, Oregon State University

Issue: Approximately 500,000 to 750,000 acres of federal forests burn in the western United States each year and forecasts are for increased fire activity with global warming. Current federal procedures delay the recovery of fire-killed timber losing timber value and increasing restoration costs.

Response: A mathematical model has been developed to predict the loss of recoverable timber value as a function of time since fire, logging system, and distance from road. Increases in logging costs associated with wood deterioration are a major component of loss in economic value with helicopter and skyline logging systems.

Impact: This research benefits consumers of woods products, federal owners of fire-killed timber, and county governments that rely on revenue-sharing from timber harvests on federal lands. Potential benefits for one fire alone were estimated at $100 million if federal managers had acted promptly. Legislators have cited this work as part of the scientific backstop behind HR 4200, the Forest Restoration and Recovery Act which would speed up decision making on the federal lands. [1 MS student supported, 1 Ph.D. graduated; 2 publications generated]

IMPROVING THE PLANNING, SCHEDULING AND TRACKING OF THE PRIMARY FOREST SUPPLY CHAIN

Kevin Boston, Oregon State University

Issue: As the forest products industry faces increasing competition from international wood producers it is important to be able to forecast the demand, supply and production capacity of participants in the supply chain effectively.

Response: This research developed and tested the use of a geographic information system that collected mark-up maps of daily logging production and used them to develop a logging production forecasting tool. An annual logging crew scheduling model was then developed to apply these production estimates to allocate harvest units and crews to most efficiently meet the customer demand. Both can be integrated into and enhance supply chain management decision support systems.

Impact: The potential benefits from a supply chain management system are enormous

for Oregon, as well as other areas of the country. It has been documented that a fully optimized supply chain can potentially increase sales revenue by 3 to 7%. The total harvest value in Oregon recently was approximately US$ 1.1 billion on 3,752 million board feet of harvest. A 5% improvement in sales could yield Oregon companies an additional US$ 55 million. [1 MF student graduated; 1 publication generated]

DEVELOPMENT OF METHODOLOGIES TO EVALUATE THE IMPACT OF CONSTRUCTION PRACTICES, MATERIALS, AND ROAD USE ON THE ECONOMIC AND ENVIRONMENTAL PERFORMANCE OF AGGREGATE FOREST ROADS IN THE OREGON COAST RANGE

Kevin Boston, Oregon State University

Issue: Forest roads are a major cost center for forest operations and have the potential for sediment pollution of streams if poorly managed. The forest industry does not typically utilize geotechnical information to develop aggregate compaction standards for road construction. The result can be deceased environmental performance or unnecessarily high transportation costs. Some opportunities may also exist to reduce transportation cost through the use of recycled aggregate, but more information is necessary for widespread adoption.

Response: The study demonstrated that a significant improvement in road performance could be gained from improved construction practices. Additional work evaluated the potential economic benefits from using recycled aggregate.

Impact: A conservative economic evaluation showed that improved subgrade compaction could reduce road rock cost by 19%. For a large firm in Oregon that builds or reconstructs 100 miles of road per year, this savings could approach $190,000 and result in superior roads that generate less sediment due to reduced rut formation. An economic evaluation of recycling rock showed a potential savings of between $13,000 and $19,000 per mile. Again, a firm building 100 miles of spur roads will potentially save between $1.3 and $1.9 million dollars per year. [1 MF student graduated; 1 publication generated]

The Hydrology of Forest Roads

Arne Skaugset, Oregon State University

Issue: A cost effective transportation system that meets environmental standards is an essential element of a wood utilization supply chain. On private industrial forest land in Oregon there are about 25,000 miles of existing roads. Forest roads affect the hydrology of hillslopes and watersheds by creating surface runoff and intercepting subsurface flow, and then routing it to stream crossings or to a point location downslope of the road. Forest owners in Oregon have invested nearly $100 million over the past decade to upgrade existing road systems to meet evolving environmental regulations aimed at protecting aquatic habitat. While new standards for existing roads exist, their efficacy is unknown. Decision support tools and new knowledge that improve the scientific

knowledge base about the effects of forest roads on hillslope hydrology will help guide future investments and inform future regulations.

Response: A watershed level study was conducted to examine sources of runoff associated with specific road segments. The majority of the road segments produced runoff from just the road surface and that runoff was inconsequential. The balance of the studied road segments produced runoff from intercepted subsurface flow and that runoff had the potential to be of more consequence. Within the study watershed, for those road segments that intercepted subsurface flow and were connected to streams, only 8 out of approximately 99 had sufficient runoff flowing directly to a stream that could potentially affect watershed hydrology.

Impact: This process level research showed that only about 10 percent of the studied road segments had the potential to cause changes in watershed hydrology. Results suggest that further effort is warranted to develop decision support tools for finding and mitigating the drainage from problem road segments. The benefit from such an approach should be less total road systems management expenditures. [1 MF and 2 MS students graduated]

Meeting Timber Supply Goals through Improved Transportation Networks in Landslide Prone Terrain

John Sessions and Michael Wing, Oregon State University

Issue: The transportation of wood products from the forest to the mill is a substantial portion of the overall cost associated with wood production. Within the past decade, several transportation planning decision support systems that combine heuristic programming techniques with geographic information systems (GIS) technology have been developed to meet forest operation challenges. The advancement of GIS and heuristic tools to assist planners in transportation system management may yield significant benefits in reducing transportation network costs.

Response: The goal of this research was to develop a decision support system for the selection of transportation routes that takes slope stability into account. The Analytical Hierarchy Process (AHP) was identified as a potential tool for quantifying environmental benefits and helping to organize a decision matrix that managers of forested road networks could use as a decision support system. Study results revealed that a combination of heuristics, benefit analysis strategies, environmental impact evaluations, and expert judgment could produce a road management schedule that better addresses the current road management challenges.

Impact: Findings published in 2006 have contributed to the scientific basis for assessing and mitigating the environmental consequences of forest road use in the timber supply-chain. A decision support system revealed that cost reductions in road maintenance and construction projects were estimated to be three to six times greater for activities scheduled through a benefit maximization strategy rather than a benefit-cost ratio evaluative approach. [1 Ph.D. student graduated; 2 publications generated]

The Design of Forest Roads to Minimize the Delivery of Fine Sediment While Transporting Logs during Wet Weather

Arne Skaugset, Oregon State University

Issue: Forest products manufacturers depend on a steady supply of logs and seek to minimize costs associated with large log decks. Most large forest owners desire to harvest timber year round, including during winter conditions when log markets often peak. Thus there is economic incentive to haul logs on aggregate surfaced logging roads during wet winter conditions. Research shows that hauling logs on aggregate roads during wet weather can cause an increase in sediment yield from the road, often by several orders of magnitude, resulting in degradation of aquatic habitat. A standard solution has been to restrict log truck traffic during wet weather. Other solutions could include alternative engineering designs for the aggregate pavement that minimize hauling-related sediment during wet weather.

Response: A method was developed that incorporates environmental performance into the design of an aggregate pavement for low volume roads. When completed, this research will present alternative designs and costs for aggregate roads suitable for winter hauling.

Impact: An analysis to identify the costs associated with restricting log hauling during the winter predicted losses to the landowner of 2 to 18 percent of net revenue. The 25 year average harvest from private industrial forest land in Oregon has yielded net revenue of around $1.6 billion annually. Thus, restricted wet weather hauling could cost the industry in Oregon $32 to $290 million a year. Assuming there are 25,000 miles of road on private, industrial timber land in Oregon, this would allow between $1,300 and $11,500 dollars to be spent per mile of road every year to upgrade it for winter hauling. This research could enable the timber industry to haul logs during more days in the winter, which will generate more revenue and also result in road systems that are more environmentally benign. [1 Ph.D. student supported; 1 publication generated]