Forest Engineering Seminar 2008

Tuesday, February 26, 2008

Richardson Hall 115

Forest Modeling **Moderator: Matt Thompson**	
8:25 am to 8:50 am	**Nicolas Zegre and Arne Skaugset** *The Development of Model-Based Change Detection Methods to Evaluate the Effects of Contemporary Forest Practices on Headwater Catchment Behavior*
8:50 am to 9:15 am	**Michael Vanderberg** *Hazardous Fuel Reduction in Western Forests – Gross Revenue Generation, Carbon Flux Accounting, and the Role of Post-Treatment Residual Forest Ecosystem Fire Risk: A Quasi-Meta Analysis at the Project Level*
9:15 am to 9:40 am	**Dorian A. Calderon Sanchez** *Optimization of Forest Transportation Scheduling in Smurfit-Kappa Cartón de Colombia S.A. Forestry Project, South Zone, Southwestern Colombia*
9:40 am to 10:05 am	**Henk Stander** *Methods for Dealing with Uncertainty in Optimizing Forest Product Supply Chains*
Break **10:05 am to 10:20 am**	
Sensing Technology in Forestry **Moderator: Chris Surfleet**	
10:20 am to 10:45 am	**Francisca Belart and Glen Murphy** *High Speed Measurement of Wood Density from Chainsaw Chips Using NIR Sensor Technology and Multivariate Analysis*
10:45 am to 11:10 am	**Dzhamal Amishev and Glen Murphy** *In-Forest Assessment of Veneer Grade Douglas-Fir Logs Based On Acoustic Measurement of Wood Stiffness*
11:10 am to 11:35 am	**Brian Wing and Kevin Boston** *Developing Standing Tree Acoustic Sampling Techniques to Include Wood Density Prediction in the Inventory System*
11:35 am to 12:00 pm	**Lewis Jordan** *A Comparison Of Sampling Methods for A Standing Tree Acoustic Device*
Lunch **12:00 pm to 1:00 pm**	
Sensing Technology in Forestry (continued) **Moderator: Chris Surfleet**	
1:00 pm to 1:25 pm	**Joshua Clark and Glen Murphy** *Estimation of Forest Biomass with Hemispherical Photography*

Forest Roads **Moderator: Henk Stander**	
1:25 pm to 1:50 pm	**Christopher G. Surfleet** *Road Sediment Sampling and Estimation: Oak Creek and South Fork Albion River Watersheds*
1:50 pm to 2:15 pm	**Justin Pattison, Kevin Boston and Marvin Pyles** *Influence of Season and Method in the Evaluation of Subgrade Strength under an Aggregate Surfaced Forest Road*
2:15 pm to 2:40 pm	**Matt Thompson** *Optimal Policies for Aggregate Recovery and Reuse on Forest Roads*
Break **2:40 pm to 2:55 pm**	
Forest Soils **Moderator: Dzhamal Amishev**	
2:55 pm to 3:20 pm	**Sang-Kyun Han** *Soil Compaction Associated with Cut-To-Length and Whole-Tree Harvesting of Conifer Forest*
3:20 pm to 3:45 pm	**Robert A. Slesak** *Contribution of Belowground Organic Matter Source to Changes in Soil C and N Following Harvesting*
3:45 pm to 4:10 pm	**Terry Craigg** *Assessments of Changes in Forest Soil Quality*
Drinks & Snacks **Woodstock's Pizza on Kings Blvd** **5:00 pm to 7:00 pm**	

The Development of Model-Based Change Detection Methods to Evaluate the Effects of Contemporary Forest Practices on Headwater Catchment Behavior

Nicolas Zegre and Arne Skaugset

Understanding the effects of forest management on catchment behavior is important to maintaining healthy aquatic and terrestrial ecosystems. The relationship between forest harvesting and hydrologic response has been the focus of experimental hydrologists for decades in the Pacific Northwest, USA and elsewhere. Though forecasting the effects of land management on catchment behavior is of primary importance, there remains considerable debate as to the most satisfactory means of doing so. Critics of the paired-catchment design suggest that statistics-based change detection is black-box in nature, lacks insight into watershed processes, restricted to small basins, lacks temporal stationarity, and suffers from short hydrometerological time-series records.

Model-based change detection has been suggested as an alternative to overcome the shortcomings of the traditional paired-catchment approach. Several different approaches using model change detection to evaluate anthropogenic effects of land management have been conducted using water balance models, rainfall-runoff models and process-based distributed models. The benefits of using hydrology models for change detection are significant for discerning the effects of land management on hydrology under various climatic and physiographic conditions and spatial scales. By generating streamflow through model simulation, a single catchment functions as both reference and treated catchment, thereby removing spatial and temporal variation between two different catchments. The use of a simulated reference catchment offers the ability to develop diagnostic tools for change detection based on stationary processes within a single catchment that can be used for long-term prediction. In this context, hydrology models can be used to represent catchments in virtual experiments to evaluate the effects of climate change, disturbance, and regime shifts on catchment behavior.

In this study, we present the development of a model-based change detection method to evaluate the effects of contemporary forest practices on hydrology at a headwater catchment scale. The HBV-EC partially distributed conceptual rainfall-runoff model is applied to Fenton Creek, a small headwater catchment nested in the Hinkle Creek Paired Watershed Study. Recognizing limitations associated with hydrologic model parameterization, structure and prediction, model uncertainty and equifinality are addressed using the Generalized Likelihood Uncertainty Analysis (GLUE) and Regional Sensitivity Analysis (RSA) methods. This study further advances the application of hydrologic models to discern the effects of disturbance on catchment behavior by synthesizing time-series statistical methods and predictions based on explicit modeling approaches.

Hazardous Fuel Reduction in Western Forests – Gross Revenue Generation, Carbon Flux Accounting, and the Role of Post-Treatment Residual Forest Ecosystem Fire Risk: A Quasi-Meta Analysis at the Project Level

Michael Vanderberg

Hazardous fuels reduction (HFR) is one method of addressing the shift in many western forest conditions and the associated economic and environmental costs. The areas of gross revenue generation resulting from residual utilization, carbon storage and CO_2 emission offsets created through long-lived solidwood product (SWP) and energy produced from biomass, and carbon sequestration in the post-HFR residual stand were evaluated within the condition of the likelihood, or probability of varying wildfire severity. The results of the analysis lead to a framework in which gross revenue, carbon storage, and carbon sequestration can be optimized (e.g., maximized) while accounting for the probability of a wildfire event type.

Forest carbon pathway (FCP) analysis compares the utilization of residuals from HFR treatments in terms of both carbon sequestration in forests and storage in long-lived SWP, and the mitigation of fossil fuel CO_2 emissions to the atmosphere by bioenergy production and substitution to the outcomes of no treatment (NT) alternatives. Eight other potential scenarios besides the NT and no treatment/severe wildfire (NTSF) options are included in the FCP anaylsis: HFR treatment/no SWP (T), HFR treatment/no SWP/low-severity wildfire (TF), HFR treatment/SWP (TP), HFR treatment/SWP/low-severity wildfire (TPF), HFR treatment/bioenergy (TB), HFR treatment/bioenergy/low-severity wildfire (TBF), HFR treatment/SWP/bioenergy (TPB), and HFR treatment/SWP/bioenergy/low-severity wildfire (TPBF). The analyses were based on a time period of 80 years.

Using NT as a baseline, the two treatment options of TP, TB, and TPB have the potential to sequester, store, and/or mitigate the same amount, or more, of carbon and CO_2 emissions, while theoretically lowering the probability of high-severity wildfire. Options T and TF leave the treatment residual on site, sequestering the same, or less, carbon than other active treatment scenarios, but add no economic value to the process. Options TB and TBF are misleading when evaluated from only a carbon sequestration and storage standpoint, as the CO_2 emissions avoided are relatively high. The FCP analysis shows options TP, TB, and TPB to be clear avenues for adding value to HFR treatments from both a forest carbon flux accounting and gross revenue viewpoint.

Also, assuming that a high-severity wildfire occurs as in option NTSF, and a low-severity wildfire occurs in treatments TPF, TBF, and TPBF, and accounting for both carbon sequestration, storage, and CO_2 emissions, FCP analysis shows that an HFR project which utilizes the treatment residuals in any way has greater potential to sequester

and store carbon and mitigate atmospheric CO_2 emissions than simply leaving the stand-at-risk untreated. It should also be noted that the fossil fuel emissions values used in the FCP analysis due to treatment, transportation, and processing during the HFR procedures are conservative, providing even more value-adding power to all active treatment options.

Optimization of Forest Transportation Scheduling in Smurfit-Kappa Cartón de Colombia S.A. Forestry Project, South Zone, Southwestern Colombia

Dorian A. Calderon Sanchez

A proposal for the construction of a mathematical model to optimize the log transportation scheduling in the case of Smurfit-Kappa Carton de Colombia S.A. (SKCC) Forestry Project, located in Western Colombia is presented. The model goal is to create a daily-based schedule for the trucks used for pulp transportation from landings to the pulp mill. SKCC is the biggest pulpwood-based company in Colombia, owning the biggest area in forest plantations within the Country. (44,430 ha planted with pines and eucalyptus). In this paper the case of the log transportation from South zone to pulp mill will be analyzed. The SKCC Forestry Project, South Zone, is located in Cauca Department, Southwestern Colombia (9,154 ha of pines and 4,942 ha of eucalyptus). The landings are located in an average distance of 145 km away from the pulp mill. Currently, the Company is studying transportation costs and logistics. During this evaluation some points have been detected as improvement opportunities, related to pulp wood supply chain.

The main purpose of this project is to create a truck-landing-mill scheduling optimizer system for pulpwood supply, developing an algorithm which allows the Company the most effective use of transport resources and to suggest the type and quantity of trucks in order to increase the current fleet and serve as basis to develop strategies increase the control over dispatches.

Detailed actual information about controlled trucks, those owned by the Company and forest contractors is being collected, in order to characterize the current transportation system. This data will be processed using any programming language, and applying the Simulated Annealing Algorithm that allows the optimization of combinatorial problems.

The project is in the phase of adapting factual information about transportation variables, and the first approaches of the model have been performed, showing the high opportunity of improvement. These results will indicate gross lines for the hauling system development for SKCC, in order to increase control over the hauling fleet and truck specialization.

Methods for Dealing with Uncertainty in Optimizing Forest Product Supply Chains

Henk Stander and John Sessions

The mathematician, John Allen Paulos, once said "Uncertainty is the only certainty there is, and knowing how to live with insecurity is the only security". This is certainly very true in the context of forest products supply chains, which deals with the products of natural processes (timber), in an environment that was shaped (and is still being shaped) by natural forces, under market conditions that are exposed to both local and international economic drivers.

The first step towards dealing with uncertainty is to understand and define it. Here, it is particularly important to distinguish between risk and uncertainty. Some draw no distinction between the two. Others have defined uncertainty as the state of ignorance that exists when the likelihood of outcomes is not known, while under risk the likelihoods are known. This notion is generally rejected, since the notion of perfect knowledge is a contradiction in itself. A more acceptable stance is that uncertainty is defined as imperfect knowledge, and risk is defined as the undesirable consequences of imperfect knowledge. All risks are therefore uncertain, but not all uncertainty is risky.

In dealing with uncertainty, we need to also understand how it originates. From an agricultural point of view, uncertainty arises from production, market, human and institutional factors. Supply chain managers tend to classify uncertainty according to its source, and therefore distinguish between environmental, organizational and network-related sources. To cope with these uncertainties, organizations can deploy financial remedies such as insurance and forward contracts, or they can use strategic moves such as avoidance, control, cooperation, imitation and flexibility. An organization can therefore either decide to accept the uncertainty and orientate its internal processes towards dealing efficiently with risk (flexibility), or it can refuse to accept the uncertainty and focus its efforts on getting into a position where the probability of risky situations is minimized (avoidance, control, cooperation, and imitation).

A number of techniques have been developed through the years to deal with uncertainty in optimization problems. Here we will be examining chance-constrained programming (CCF) and utility theory. CCF is a mathematical programming technique, which maximizes the problem solution, subject to meeting the problem constraints with a certain probability. Here, each parameter used will be described by an expected value and variance. These values will be incorporated directly into the constraints and objective function, together with the predetermined probability of meeting the constraints. The usage of this technique will be illustrated by means of an example.

The foundations of utility theory was established by Daniel Bernoulli and Gabriel Cramer in 1738, who showed through the St. Petersburg Paradox that maximizing

expected value is a poor proxy for human choice between uncertain financial outcomes. This is due to the fact that the utility that individuals associate with money extends beyond its monetary value. The initial theory postulated by Bernoulli and Cramer was formalized in 1953 through the Von Neumann-Morgenstern (VNM) axioms. It was however shown that these axioms did not hold under all circumstances, especially the linearity axiom which was shown not to hold through the Allais Paradox. This led to the introduction of stochastic dominance testing. Under this set of theory the assumptions of utility are relaxed significantly, and it utilizes the pair-wise comparison of the cumulative distribution functions of risky outcomes. In particular we will investigate the implementation of first-degree, second-degree and third-degree stochastic dominance. We will also investigate a derivative of second-degree stochastic dominance testing, called stochastic efficiency with respect to a function (SERF). This method utilizes the same principles inherent in second-degree stochastic dominance testing, but in far more efficient manner.

High Speed Measurement of Wood Density from Chainsaw Chips Using NIR Sensor Technology and Multivariate Analysis

Francisca Belart and Glen Murphy

Forest products companies in the U.S. face vigorous competition from other wood producers around the world and other industries (steel, aluminum, plastics, composites). To be competitive, forest companies need to control costs, sort and allocate logs to the most appropriate markets, and recover more value at time of harvest. Interest in log sorting based on internal wood properties is increasing.

Wood properties, such as stiffness and density, are now being considered by log buyers. Assessing these properties in-forest and in real-time will be a challenge for log supply managers. The utility of near infrared (NIR) technology for measuring wood density has been shown to be promising in laboratory conditions. So, the idea of this study is to extend this work to conditions that are similar to field harvesting operations. Douglas-fir wood samples (178 disks) were collected from McDonald-Dunn forest and processed in OSU Oak Creek laboratories. Processing conditions were organized to simulate a harvester head environment using a chainsaw, and a chute to concentrate chips. The reason for doing this simulation is the idea of attaching the NIR sensor to the harvester head in order to obtain real time estimations of density. A rugged Prospectra D2 NIR sensor was used to collect spectral data.

The generated spectra were analyzed in two forms, raw data (without any transformations) and transformed data (2nd derivative). Then, two types of models were applied, Partial Least Squares (PLS) and Multiple Linear Regression (MLR). All four methods were applied in order to find the one that best fits the data.

Model results were also obtained for validation (full cross validation) and calibration sets. At this stage data analysis is continuing and preliminary results show that correlations for calibration sets (R) are high, but when validation is applied we obtain large drops in R values. The most adequate model appears to be MLR based on 2nd derivative transformed data.

This research provides insight into how these technologies could be incorporated into the design of mechanized harvesters and processors to enhance bucking and sorting for optimal matching of wood properties to markets.

In-Forest Assessment of Veneer Grade Douglas-Fir Logs Based On Acoustic Measurement of Wood Stiffness

Dzhamal Amishev and Glen Murphy

Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) is of great economic importance for the forest products industries of the United States, Canada, New Zealand, and parts of Europe. Harvesting younger trees increases the variability in product performance and limits log producers in their ability to meet market demand for wood products.

Acoustic technology has proven to be a well established non-destructive technique for assessing potential product performance by identifying logs with high stiffness. In an ongoing endeavor to optimize merchandizing and enhance timber value recovery, seven second growth Douglas-fir stands of similar age class in Western Oregon were sampled, totaling 1,400 trees and more than 3,000 logs. This research investigated the effects of spatial as well as internal and external log characteristics on Douglas-fir wood stiffness.

In-forest log acoustic measurements, as well as dynamic modulus of elasticity values correlated well with the actual G1/G2 veneer grade recovery (R2 of 0.91 and 0.82, respectively) once bark removal adjustments were made. External log characteristics such as diameter and length were found to have limited predictive capability in terms of acoustic velocity and hence wood stiffness. The presence and size of branches was found to be negatively correlated to acoustic velocity readings and the addition of the tree length difference improved the regression model. Logs produced from the lowest part of the tree had the largest acoustic velocity and velocity decreased in each subsequent log along the length of a tree stem. However, investigating this relationship only for the butt log it was found that longer logs had higher acoustic velocities than shorter ones as compared to the acoustic velocity reading on the whole tree.

Developing Standing Tree Acoustic Sampling Techniques to Include Wood Density Prediction in the Inventory System

Brian Wing and Kevin Boston

Non-destructive testing (NDT) of raw wood materials has become a crucial issue in the forest products supply chain as economic pressures to maximize extracted value have increased. A NDT technique that has grown with recent innovation is the use of acoustic wave sensing technology to evaluate intrinsic wood quality properties early in the supply chain. This technology can assist with managing wood quality, assessing forest value and improving the timber quality of future plantations by providing better estimates of wood quality characteristics. Initial research has shown that a log's acoustic measures can be used to predict the strength and stiffness of structural lumber that would be produced from that log. The application of this research has led to optimized log sorting techniques at both the landing and the mill. The next logical step is to apply this technology to measure wood properties in standing trees, thereby providing timber sellers and purchasers with a means for improved harvest scheduling and timber marketing. Additionally, the use of standing tree acoustic tools could be applied to the evaluation of silvicultural treatment effects and genetic improvement efficiency. New acoustic tools have been developed to assess the intrinsic wood properties in standing trees; however knowledge of the practicality and variability associated with these tools is limited. A stand census study with a new standing tree acoustic tool (Director ST-300TM) will be conducted in a second-growth Douglas-fir stand with three primary objectives; 1) to quantify the stand-level variability associated with the tool's measurements of acoustic velocity, 2) to verify correlation of the tool's measurements with wood density characteristics, and 3) investigate which whole and within stand sampling schemes best represent and describe the variability associated with the acoustic velocity and wood density measurements. Preliminary results will be presented during the presentation; however the final results will not be completed until Fall 2008.

A Comparison Of Sampling Methods for A Standing Tree Acoustic Device

Lewis Jordan

One method of evaluating potential product performance is the use of acoustic tools for identifying trees with high stiffness. Acoustic velocities for 100 standing loblolly pine (Pinus taeda) trees, obtained with the transmitting and receiving probes placed on the same-face and opposite-faces, were compared. Significant differences in velocity between the two methods were found, with velocity determined using the opposite-face method generally dependent on stem diameter, or the amount of wood through which the stress wave must pass. The only opposite face method whose velocities did not vary with diameter at breast height was for an assumed flight path where the stress wave traveled from the transmitting probe around the circumference of the stem in the outerwood and then down longitudinally to the receiving probe. Variation in velocities from hit-to-hit was 62% less using the opposite-face method compared to the same-face method.

Estimation of Forest Biomass with Hemispherical Photography

Joshua Clark and Glen Murphy

There are three primary objectives for this project:

(1) Investigate the correlation between above ground biomass and gap fraction measurements derived from hemispherical photography analysis.
(2) Determine whether biomass correlations are forest type dependent.
(3) Evaluate potential improvements in biomass correlation when shrub and stand measurements are included.

For this project, biomass is defined as:

(1) Total mass of all boles, limbs, and tops from trees >1 m. tall, excluding stumps.
(2) Shrubs >1 m. tall.

Three separate areas are being used for the study. Plots within two areas were destructively sampled, where limbs, tops, and shrubs were chipped and weighed, while boles were systematically measured. Bole volume was estimated by measuring diameter at specific intervals; bole mass was extrapolated by estimating the density of wood disks from select trees. 15 plots of Douglas-fir were destructively sampled near Molalla, OR. 13 plots of mixed conifer (Ponderosa pine, white fir, and incense-cedar) were destructively sampled near Burney, CA.

5 photographs were taken for each plot:

Photograph 1: Taken with plot biomass = 100% of the original biomass.
Photograph 2: Taken with plot biomass = 75% of the original biomass.
Photograph 3: Taken with plot biomass = 50% of the original biomass.
Photograph 4: Taken with plot biomass = 25% of the original biomass.
Photograph 5: Taken with plot biomass = 0% of the original biomass.

Since the biomass is also measured at 25% increments, there is a corresponding biomass measurement for each photograph. This will effectively allow me to analyze 5 photographs for each plot, which will give me more data to analyze. A key assumption to use this method is that each photograph will mimic a natural stand with a different amount of biomass. Granted, this may not be a completely accurate assumption, but cutting more plots was not physically feasible under the project's scope, and this method increases the sample size for analysis.

In addition to the destructive sampling in Molalla and Burney, approximately 50 plots were photographed with non-destructive sampling near Pringle Falls, OR. Total

biomass for all plots will be compared to biomass estimations by using the basal area from each plot, with equations derived from previous research by several others.

Gap fractions are being estimated using Winscanopy. Currently, the gap fraction used in the analysis is actually an average of 5 zenith angles(9°,27°,45°,63°,81°) – these angles were chosen because of their success in estimating canopy bulk density (Keane, et al).

A detailed statistical analysis of the data collected is currently underway for the Douglas-fir stands. At this point, it is clear that gap fraction is a significant indicator of biomass. However, the current model for Molalla sites show R^2 ~0.55, so much of the variability in biomass may not be fully described by gap fraction alone. In order to find a model that describes the variability of above ground biomass, other factors such as height will be included.

In the future, different gap fraction zenith angles will be used and compared, while similar analysis will be completed for the Burney and Pringle Falls sites. Statistical analysis will be completed by May 2009.

Road Sediment Sampling and Estimation: Oak Creek and South Fork Albion River Watersheds

Christopher G. Surfleet

I hypothesized a road storm run-off and sediment sampling approach combined with a road erosion model will yield cost effective yet accurate road sediment estimates. This study used road hydrologic and suspended sediment observations from the Oak Creek catchment, Corvallis Oregon and the South Fork of the Albion River, within managed timberland in Mendocino County, California. The road run-off and sediment observations were analyzed with 2 road erosion models, SEDMODL2 and WARSEM. Statistically significant relationships between log of storm sediment load and storm peak flow ($r2 = 0.33$, p value < 0.0001) and storm volume ($r2 = 0.45$, p value < 0.0001) were found for Oak Creek road observations. These relationships demonstrated that sediment load for roads can be estimated with road run-off data. The mean of suspended sediment samples, without storm run-off data, could also be used to estimate storm sediment load ($r2 = 0.54$, p value < 0.0001). The mean of 3 or 4 randomly selected suspended sediment samples combined with road run-off peak flow predicted the log of storm sediment load; $r2 = 0.44$, p value < 0.03 and $r2 = 0.47$, p value < 0.02 respectively. The road erosion parameters of geologic hazard, road traffic, and precipitation factors were "back-calculated" for SEDMODL2 and WARSEM from observed sediment observations in Oak Creek. Using these calculated parameters the 95% confidence interval of suspended sediment load delivered from Oak Creek roads was estimated by SEDMODL2 as 5.39 to 6.67 tons/year and WARSEM 5.25 to 6.51 tons/year. SEDMODL2 and WARSEM estimates for Oak Creek coarse and fine road sediment without the benefit of the field observations were 12.65 and 13.32 tons/year respectively. When correcting the suspended sediment load estimate by a fine to coarse sediment ratio the estimates are still less than results from SEDMODL2 and WARSEM without the benefit of field observations. These estimates were lower than SEDMODL and WARSEM estimates without field observations. Linear relationships between storm volume, peak flow, or suspended sediment samples and storm sediment load were developed for the South Fork of the Albion River based on the Oak Creek findings. These relationships had to be developed by type of road due to a more complex road network and varied road uses. SEDMODL2 and WARSEM estimated annual sediment loads of 103.2 and 129.7 tons/year respectively. The estimate of road sediment from SEDMODL2 adjusted by field observations had a 95% confidence interval of -8.7 to 26.3 tons/year for the 2007 water year. This was considerably less than the WARSEM and SEDMODL2 results without the benefit of field observations. When correcting the suspended sediment load estimates by a fine to coarse sediment ratio the estimates are still considerably less than results from SEDMODL2 and WARSEM without the benefit of field observations.

Influence of Season and Method in the Evaluation of Subgrade Strength under an Aggregate Surfaced Forest Road

Justin Pattison, Kevin Boston and Marvin Pyles

Very few studies, Hinshaw & Northrup, 1989, Vischer et al, 1971 and Linares, 1988 (unpublished) have documented the temporal and spatial variations in subgrade strength and moisture content under an aggregate surfaced forest road in the Pacific Northwest. Even with the results of previous studies little is still known about seasonal and storm scale changes within a forest road subgrade. Although poorly understood, these changes ultimately affect forest managers policy's regarding wet weather hauling, road maintenance scheduling and road construction. Thus, motivation for understanding these changes and the underlying process exists not only from a scientific and engineering perspective, but also from an operational and economical stand point. The objective of the current study was to observe the magnitude of seasonal changes in subgrade strength and moisture content under an aggregate surfaced forest road. Methods for measuring subgrade strength are evaluated. Observed changes in strength and moisture content are compared to a hypothesized model based on soil physics theory. Spatial variations in subgrade characteristics are compared to laboratory measurements.

This study was conducted in the McDonald School near Oregon State University on a stretch of forest road constructed during the summer 2006. Subgrade material consisted of a low to highly plastic silt (USCS ML & MH). Subgrade and aggregate surface data was collected periodically from May 2007 through Mid-September 2007. Subgrade strength measurements included the California Bearing Ratio (CBR) and Clegg Impact Value (CIV). The CBR was obtained using a CBR device modified to fit on a truck and the CIV was obtained using a 20 kg Clegg Hammer. Moisture content and density measurement were obtained via an impact style soil sampler. In July, temperature sensors were installed at four locations in the subgrade one location included an external temperature senor that was placed just below the aggregate surface. Soil samples were obtained to generate compaction and CBR curves.

Results showed that during the summer of 2007 no statistically significant change in subgrade moisture content occurred yielding a mean moisture content of 43.8% (ANOVA, p-value = 0.449, 95% confidence interval). CIV and CBR subgrade strength values showed similar results with no statistically significant change in CIV or CBR yielding a mean of 5.1 and 7.6 respectively (ANOVA, CIV p-value 0.96, CBR p-value = 0.89, 95% confidence interval). CIV's collected on the aggregate surface showed a statistically significant change in CIV, indicating that aggregate surface strengthened as the summer progressed (ANOVA, p-value = 0.0002, 95% confidence interval). A regression equation using subgrade CIV to predict subgrade CBR was explored and showed moderate prediction ability as indicated by a 0.73 R2. Air, surface and subgrade

temperatures were found to be tightly correlated. Diurnal temperature patterns were observed in both the aggregate and subgrade surface. However, subgrade diurnal patterns were significantly dampened, fluctuating 1oC between daily maximum and night minimum temperatures. Using aggregate and subgrade surface temperature vapor flux was estimated. Estimations of upward vapor flux showed that changes in subgrade moisture content ranged on the order of hundredths of a percent per day. The temperature data also showed similar magnitudes of movement downward when the vapor gradient changed direction. Discrepancies were observed between lab and field CBR values similar to those found by Bose & Bhattacharya 1984.

Results of this study differ significantly with those found by Hinshaw & Northrup, 1989. Discrepancies in observed changes in subgrade moisture content may be attributed to geographic location and or solar angle and aspect, where as differences in air to subgrade temperature correlations can not be explained at this time. Broad conclusions shall not be drawn from the current study. However, it may be hypothesized that changes in subgrade strength and moisture content are likely to be small following over wintering of a newly constructed forest road. It is further hypothesized that changes in moisture and strength may become more apparent with road age as transpiration becomes more of a significant part of the moisture cycle. It should be noted that preceding hypothesis is limited to the immediate geographic region.

Optimal Policies for Aggregate Recovery and Reuse on Forest Roads

Matt Thompson

To mitigate the adverse environmental impact of roads, especially degradation of endangered salmonid habitat, many public and private land managers in the western United States are actively removing roads where practical and affordable. Road decommissioning is associated with reduced long-term environmental impact. When decommissioning a road it may be possible to recover some aggregate (crushed rock) from the road surface. Aggregate is used on many low volume forest roads to reduce wheel stresses transferred to the subgrade, reduce erosion, reduce maintenance costs, and improve driver comfort. Previous studies have demonstrated the potential for aggregate to be recycled and used elsewhere on the road network, at a reduced cost compared to purchasing aggregate from a quarry. My research investigates the potential for aggregate recycling to provide an economic incentive to decommission additional roads by reducing transport distance and aggregate procurement costs for other actively used roads. Decommissioning additional roads may in turn result in improved aquatic habitat. I present real-world examples of aggregate recycling and discuss the advantages of doing so. Further, I present management models and mathematical formulations to determine optimal levels of aggregate recycling. Tested on an example road network, incorporation of aggregate recycling demonstrates substantial cost-savings, reducing management costs and increasing the likelihood of road removal. In an example problem I find that recycling can yield up to $47,000 (24%) in cost savings, and permit up to 5 additional km of road to be decommissioned.

Soil Compaction Associated with Cut-To-Length and Whole-Tree Harvesting of Conifer Forest

Sang-Kyun Han

With an increasing demand for the fire hazard reduction and for ecosystem restoration treatments in the Inland Northwest, USA, multiple entries of heavy equipment into forest stands are often required to achieve forest management objectives. Managers knowledgeable of different harvesting methods, equipment, and soil conditions want to manage their forests with minimal impact on soil physical properties to maintain soil productivity of forest soils.

In the Interior Northwest, whole tree (WT) and cut-to-length (CTL) harvesting are commonly used to harvest trees in a mechanized operation. CTL harvesting systems are increasingly popular due to less soil compaction, but much of the harvesting infrastructure in mechanized systems remains with the WT systems. Debate over the relative merits of each system have occurred over several years and have been recently renewed in relation to fuel reduction treatments and small wood harvesting.

This study was conducted to compare the degree and extent of impacts on soils from cut-to-length (CTL) and whole tree (WT) harvesting operations. A CTL harvesting system used less area to transport logs to the landings than did the WT harvesting system (20% vs. 25%). At high soil moisture levels (25 - 30%), both CTL and WT harvestings caused a significant increase of soil resistance to penetration (SRP) and bulk density (BD) in the track compared to undisturbed area ($p<0.05$). Readings of SRP in the track were consistently higher for all soil depths in CTL units than in the WT units while BD changes were greater in the WT units. There was no significant difference in SRP and BD between the undisturbed area and the center of the forwarding trails in the CTL harvest units ($p>0.05$). However, in the WT harvest units SRP and BD readings from the centerline area were significantly higher than those from the undisturbed area ($p<0.05$). Slash covered 69% of the forwarding trail area in the CTL harvesting unit; 37% was in heavy slash while 32% of the trail was covered by light slash. Heavy slash was more effective in reducing soil compaction in the CTL units. Prediction models were developed that can be used to estimate percent increases in SRP and BD over undisturbed areas for both CTL and WT harvesting systems.

Contribution of Belowground Organic Matter Source to Changes in Soil C and N Following Harvesting

Robert A. Slesak

Much effort has been spent on determining the potential for intensive forest management to negatively affect soil quality, with many studies focused on harvest intensity (i.e. biomass removal) as the most likely practice to modify long-term soil quality. We examined the short-term effect (4 yr) of varying levels of biomass retention and competing vegetation control (CVC) on soil C and N pools at two sites in the PNW that are similar in site productivity but differ strongly in soil characteristics. There was no significant treatment effect (plot scale) of biomass retention on total soil C and N to a depth of 60 cm at either site, even though stratified sampling (within plots) indicated a significant effect of logging-debris abundance on those properties. At the site (LS) with relatively low initial C and N, soil C and N increased following harvesting regardless of treatment, while at the site (HS) with relatively high C and N no change was observed.

Root exclusion cores indicated that the allocation of recently fixed C to the belowground pool may be an important contributor to soil C at HS, but not LS. The main effect of competing vegetation control supports this possibility, as soil C and N were significantly decreased in the upper 15 cm following CVC at HS, but no significant effect of CVC was observed at LS. The results suggest different mechanisms for incorporation of belowground organic matter (OM) into the mineral soil C and N pools following harvesting, with recently-fixed OM (i.e. root turnover) being important at HS, but older OM (i.e. previous stands root system) more important at LS.

Assessments of Changes in Forest Soil Quality

Terry Craigg

Forest managers must understand how changes in soil quality resulting from forest management activities affect long-term productivity and watershed health. Soil quality can be defined simply as "the capacity of a specific kind of soil to function." However, when discussing soil quality it is important to distinguish between the soils inherent and dynamic qualities. Inherent soil quality is based on stable soil attributes like soil texture, soil color, and soil depth. The inherent soil quality is typically not altered by management activities and is used to determine the capability of a particular soil for a given purpose. In contrast the soils dynamic quality can be described by the condition of the soil that may result from applied inputs. Unlike inherent soil quality, the dynamic soil quality can be easily altered by forest management activities. In 2004 an assessment was made of changes in the dynamic soil quality of a forested stand that was thinned using a harvester forwarder system. The stand is located on a volcanic ash soil type on the Sisters Ranger District of the Deschutes National Forest in central Oregon. Initially, visual soil disturbance classes and a series of transects were used to determine the areal extent of soil disturbance resulting from the thinning operation. Next a series of soil indices were measured to evaluate different soil disturbances and to determine whether these disturbances represent a detrimental soil change. Results indicated that 17% of the activity area had some level of soil disturbance following the thinning operation. In disturbed areas the bulk density of the soil increased by 8% and 15% on ghost trails and harvester forwarder trails respectively. Soil compaction also resulted in a shift in soil porosity to smaller pore sizes. And soil strength, when measured as the resistance of the soil to penetration, increased considerably following disturbance. Soil disturbances within the activity area, however, did not exceed U.S. Forest Service Regional Soil Quality Standards and therefore were determined not to be detrimentally impacted. Assessments like this can be used both as a management tool to evaluate management practices and as a measure of the sustainability of these practices over the long term.