Short-Rotation Woody Crops

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Operations Working Group NEWSLETTER

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Spotlight on Marilyn Buford

Marilyn Buford, the new chair of the Short Rotation Woody Crops Operations Working Group, is in a strategic position to contribute to the group in her current position as National Program Leader for Silvicultural Research in the USDA Forest Service. Job responsibilities also involve Co-Leading the USDA Forest Service Biobased Products and Bioenergy R&D Program and serving on many interagency working groups associated with utilization, biobased products and bioenergy.

Marilyn's academic training included training in Biology at Rhodes College (Memphis, TN) in1976, A MS in Forestry, from the State University of New York College of Environmental Science and Forestry, 1979. and a PhD in Forestry from North Carolina State University, 1983.

Before joining the Forest Service, Marilyn worked as a Post-doctoral Fellow at Virginia Tech where she quantified the impact of genetic tree improvement programs on growth and yield of Loblolly Pine. Beginning in 1985, Marilyn joined the Forest Service as a Researcher in the Southern Forested Wetlands Research Work Unit where she pursued work on several aspects of pine and natural forest management. By 1991, Marilyn was already beginning to take on leadership responsibility as Project Leader for a research unit of 5 scientists, initially and shortly thereafter, lead a group of 9 scientists. Her own work focused on forest and soil productivity.

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Marilyn's career description continues on next page.

At the USDA Forest Service Southern Station, it was likely that Marilyn began her professional collaborations with Bryce Stokes that have continued as both moved higher into the ranks of Forest Service Research Leadership. Specifically in 1998, Marilyn moved into the role of National Program Leader for Quantitative Ecology Research, and Co-Lead the Forest Service Climate Change Research Program. Between 1998 and 2006, Marilyn was also was involved in a wide variety of working groups dealing with climate change issues and biomass issues. She specifically was involved in helping to start the Short Rotation Woody Crops cooperative research effort that was initiated on the U.S. Department of Energy's Savannah River Site together with other researchers (especially Mark Coleman and others) at the Southern Station. Since that time, Marilyn has been very active in promoting short rotation woody crops research and development.

2006 Short-rotation Woody Crops Operations Working Group Meeting Summaries:

Credits:

Many organizations and individuals were responsible for the very successful and interesting Short Rotation Woody Crops Meeting in Pasco, Washington 25-28, September 2006. Organizational co-sponsors of the meeting included the U S. Poplar Council, the Poplar Council of Canada, The IUFRO Applied Temperate Short-Rotation Forestry Group (Division 1.03.02), and the Society of American Foresters Agroforestry Working Group. Much of the meeting organization work and tour planning was accomplished by the collaborative efforts of Jake Eaton of Potlatch and Steve Pottle of Boise Cascade (and several others on their staffs). Key tour hosts during the meeting included Brian Stanton and other staff of Greenwood Resources, together with Don Rice of Potlatch, and Jon Johnson of Washington State University. Jake Eaton and Tim Volk did the lion's share of the work in reviewing proposed presentations and deciding on the final meeting agenda. Judd Isebrands organized interesting post-meeting tours around Pasco and across the state of Washington.

Meeting Agenda

Tuesday, 26, September 2006
Welcome by Jake Eaton; Potlatch Corporation
Keynote presentation by Dr. Ed White; SUNY-ESF

Plenary Session Topics (Those followed by an * are summarized in this newsletter)

1. Bioenergy: Feedstocks, Economics, Production*
2. Environmental Opportunities: Phytoremediation using SRWC, Wildlife Use of SRWC
3. Genetics and Tree Improvement:Breeding and Selection Strategies.
4. Production Systems: Silviculture, Nutrition, Water Relations, Pests*

Wesnesday, 27, September
Field Tour Schedule
Boardman, Oregon

a) GreenWood Resources poplar clone trial to evaluate bioenergy attributes
b) Potlatch Clone and Cultural Test Site with experiments on nitrogen use efficiency, water use, & clone screening
c) Catered Lunch by Potlatch at office – demonstrations of satellite imagery, irrigation system control center, and western white poplar
d) GreenWood Resources and Boise infield harvesting, and chipping operation.
e) Potlatch Central Wood Processing
f) Potlatch Operational plantations with stops at first year planting, three year old planting with pruning, 10 year solid wood plantation.

Thursday, 28, September
Plenary Session Topics Continued

5. Continuation of Production Systems: Silviculture, Nutrition, Water Relations, Pests*
6. Carbon Sequestestration: dynamics of below and above ground storage, measuring, and modeling.*
7. Economic Opportunities for SRWC Development: Bioenergy Crops to Solid Wood Use, Policy Issues. *

Keynote Address: Wood Biomass Feedstock for Bioenergy and Bioproducts-A solution for the United States.

The Seventh Biennial Meeting of the Short Rotation Woody Crops Operations Working Group was enthusiastically kicked off by Dr. Ed White of the State University of New York (SUNY) at the keynote speaker. Dr. White is an esteemed member of the biomass community who began developing woody crops well before the 1970's.

Dr. White noted that President Bush established a goal in 2006 for replacing as much as 75% of our oil imports from the Middle East by 2025 to address oil supply and price concerns. Several examples of federal, state, private and university lead activities were described that are all contributing to finding solutions for reducing oil imports and increasing national security.

Ed next turned to discussing the status of biomass in the U.S. today. He re-iterated that biomass is very complex with many types of feedstock, many types of conversion technologies available and many interlinking pathways in the production of interim and final products. He quoted the recently published joint DOE and USDA study that concluded that the U.S. has the technical capability to supply more than 1 billion tons of dry biomass annually – enough to replace about 30% of the country's petroleum consumption. The study suggested the possibility of about 368 million dry tons available from forests and 998 million dry tons available from agricultural lands, including as much as 377 million dry tons from perennial crops. The crops could be either grasses or woody crops such as willows, hybrid poplars, cottonwoods, sycamore, or southern pines. Ed suggested that the wood availability from natural forests was likely a conservative number since the net annual growth of forest woody biomass on almost 500 million acres is exceeding removals by almost 50% across the whole U.S. He noted that in the state of New York growth exceeds removals by 300%.

A key point in Ed's presentation was his argument that woody biomass has several advantages over agricultural sources. These included:

(1) wood is available year round from multiple sources
(2) net energy ratios for bioenergy and bioproducts from wood are large and positive
(3) wood can be sustainably managed and produced while simultaneously providing environmental and socioeconomic benefits
(4) the physical-chemical characteristics of woody biomass are fairly consistent from multiple sources, and
(5) the forest products industry and wood-based renewable energy industry have developed technical and engineering competencies to manage woody biomass

Given the many advantages of wood, Ed argued that a Woody Biomass Coalition is needed to market the value of wood as a biomass resource and suggested the coalition should include the USDA Forest Service, Forestry Schools, Forest Industry, Woody Energy Developers and many others. He notes that woody biomass is always "on the agenda" but receiving very little support.

Dr. White next described the advantages of a pulp and paper biorefinery approach whereby with a slight modification of the pre-treatment phase to include water extraction of the hemicelluloses from cellulose and lignin, many of the standard wood products can be produced more efficiently, and several other bioproducts including ethanol, acetic acid, chemicals and biodegradable plastics can be produced.

Ed ended on an optimistic note with a statement made by Egon Glesinger in 1949 that "…forests can be made to produce fifty times their present volume of end-products and still remain a permanently self-renewing source for raw materials.." Ed added that " only forests – no other raw material resource- can yield such returns."

Summarized by Lynn Wright, WrightLink Consultants. wrightlld@gmail.com

Plenary Session Topic: Bioenergy: Feedstocks, Economics, Production

After Dr. Ed White's thought provoking keynote address that highlighted the use of woody biomass feedstock for bioenergy, this opening session provided an excellent lead in to the rest of the program. The first paper gave an overview of the willow breeding, testing, and selection program underway at State University of New York (SUNY). Dr. White's colleague Dr. Larry Smart showed how impressive gains were being made in total biomass yield (oven dry tones per hectare per year). Over the last 10 years, the willow breeding program has collected 600 clones from the upper Lake States across the upper Ohio River Valley and across into New England. Some 550 controlled crosses have been performed and the families and clones that have been produced are in various stages of testing. In 2005 and 2006 regional yield trials were established to verify field performance of selected elite clones, some of which in testing showed a 40% yield improvement over the reference clone. Concurrently, commercial nursery beds have been established by an entrepreneur in New York who is positioning his business for the large scale commercial plantations that are expected to be grown for bioenergy in the future.

Dr. Steve Strauss from Oregon State University followed with a paper on the value and obstacles of applying biotechnology and the use of genetically modified organisms (GMO) in woody crops. Dr. Strauss explained how the sequencing of the poplar genome has opened up a new horizon of research and potential application targeted at increasing yield and composition of *Populus Sp.* woody crops. Examples of the use of biotechnology in poplar include herbicide tolerance, insect tolerance, reduced lignin, and salt tolerance. However, use on a commercial scale has several obstacles. Most studies are limited to short time periods by regulatory agencies, time periods that are insufficient to determine stability of the plant material. Containment strategies are in their early phases. Strategies such as reproductive sterility are advancing, but an effective system is still a few years away. Further, social opposition to this technology remains high. A few high profile examples of genetically modified products that have been problematic have eroded scientific credibility. Dr. Strauss concludes that if society is ever going to take advantage of this tremendous opportunity then the regulatory system has to be more workable to accept GMO technology and allow applied research and breeding using genomic and GMO tools.

In the last paper of the session Dr. Naresh Thevathasan presented an overview of field applications of agroforestry and afforestation at the Guelph Agroforestry Research Station. Within the context of his paper Dr. Thevathasan made a case for these production systems in contributing to the production of woody feedstock for the burgeoning biofuels market in Canada. A time series of willow bioenergy plots grown between wind breaks showed how the area between the wind break actually complimented and enhanced production when compared to controls that were mono-cropped. Dr. Thevathasan concluded that agroforestry systems can diversify outputs and income from farms and better protect ecological values. However, if these systems are to ever gain a significant foothold in Canada then the government needs to better promote and structure incentives for the farmer to do so. At the same time short rotation woody crop establishment, harvest, and market structures need to be developed.

Summarized by Jake Eaton, Potlatch Corporation.
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Plenary Session Topic: Production Systems: Silviculture, Nutrition, Water Relations, Pests

Nine talks were presented on production systems. Studies included fertilizer and drought response, spacing studies, poplar clonal performance, and pest management. The presentations had an international flavor with presentations from Italy and Germany in addition to those from Canada and the US. Typically response to fertilization is not evident during establishment. Davin Kamelchuk reported results where fertilizer was applied to individual cuttings just after planting and found up to a 40% increase for some clones, but the fastest growing clones, which were hybrids, showed much less of a response. In another study Ken Van Rees reported a negative response to fertilization in years 1 and 3 for hybrid poplar growing in Saskatchewan. As a result, they could not recommend fertilization, but expect that over the rotation some fertilizer will be required. It would be interesting to compare the methods of Kamelchuk and Van Rees side-by-side to understand if the contrasting responses were due to method or location.

Adriana Arango identified drought sensitivity in Alberta poplar clones by monitoring physiological parameters during a dry down and recovery. Water use and photosynthesis was lower in all clones under severe drought compared to well-watered controls, indicating decreased stomatal aperture as one of the main drought response. Resistant clones had much greater stomata control over water loss than sensitive. The poor stomatal control was accompanied by more severe tissue water potentials and greater vulnerability to xylem to embolism.

Cees van Oosten synthesized information from several spacing trials and pruning studies and considered financial considerations. A full report from this very interesting presentation is included in this newsletter .

Clonal selection was the theme in the European presentations. Fabrizio Nardin described a poplar and willow selection program that included world-wide collections along the 40th parallel, selection, controlled crosses, initial screening for morphology and physiology, and selection of elite genotypes through two successive two-year field trials. Selection traits include growth, disease resistance, drought and salt tolerance, phenology and robust climate range. Fabrizio also described a well developed energy wood production system that included two-year coppice rotations deployed throughout Europe. George von Wuehlisch compared hybrid aspen clones in northern Germany. Hybrid vigor was evident in a 7 by 7 crossing scheme that involved select genotypes of *P. tremula* and *P. tremuloides.* The greatest performance occurred with *P. tremula* as the male parent. In 20-year field trials, tissue cultured clones of select aspen hybrids demonstrated large growth potential over seedling material.

Pest management was described in three separate talks from John Brown's program at Washington State University. John gave an overview of the pests assaulting poplar in the Pacific Northwest interior growing region and concludes that understanding ecological relationships and biological traits of individual pests will be required for control. One example was from Eugene Hannon's work with poplar-and-willow borer. Since there is no effective control for this pest, they use no-choice, caged screening trials to evaluate clonal susceptibility. Clones of *P. deltoidies* crossed with *P. trichocarpa* were more susceptible than were those crossed with either *P. nigra* or *P. maximowiczii*. This demonstrates that selecting for resistant clones is a viable strategy for avoiding damage in from this pest in poplar plantations. Robert Robstrom evaluated insect populations before and after harvests, which represent a catastrophic disturbance event. Common species were present both before and after harvest; however rare species before harvest were no longer found after harvest. The most dominant species prevailed both before and after disturbance. Niel Kittleson presented results from his work on pheromone saturation to control poplar clearwing moth. Moth damage in young plantings was reduced from over three quarters of trees damaged before treatment to less than 10% post-treatment. However, the treatment is expensive, so Neil reported that wind drift effectively distributes the pheromone, so they devised a strip treatment approach. Strip treatment maintained control at one-third the cost. Pest management will always be a challenge in SRWC I'd be happy to revise plantations; however these innovative approaches involving control through biological knowledge are very encouraging.

Summarized by Mark Coleman, US Forest Service Southern Station mcoleman01@fs.fed.us

Plenary Session Topic: Carbon Sequestestration: dynamics of below and above ground storage, measuring, and modeling

This session brought together a comprehensive group of presentations that ranged from soil biochemical processes relative to carbon storage, to sampling for above and below ground carbon, to ultimately the latest tool to model carbon sequestration by poplars. Dr. Mark Coleman started off the session by reviewing the carbon cycle and presenting a summary of soil organic carbon levels found under various plant communities. Using the Savannah River short rotation woody crop test plots Dr. Coleman presented soil carbon content results for two tree cover types, cottonwood and loblolly pine, and several irrigation, fertigation, and weed control treatments. Results showed that converting to the tree crops had a net loss of soil carbon initially. The results over the three year period show that carbon was lost across all treatments for the first two years, but the trend is towards becoming net carbon positive in the future. Further, the treatments resulting in the highest productivity tended to become carbon positive sooner. The timing and precise quantification of net soil carbon increases will be difficult to measure and verify in the context of monetizing future carbon sequestration credits.

In the second paper Dr. Fabio Sartori presented results from a chronosequence of Potlatch poplar plantations in eastern Oregon. Several age classes of trees were sampled for soil carbon, exchangeable cations, bulk density, and liter. For comparison adjacent agricultural fields and native shrub-steppe habitat were sampled. Results showed that these soils are 80-90% sand with very little clay and organic matter initially. Total C and N trended higher in the poplar plantations and increased with tree age. Dr. Sartori conclusions showed that the tree crops sequestered greater amounts of above and below ground carbon and that along with the higher C, came higher base contents and more exchangeable cations.

The next paper presented results from a field sampling for carbon sequestration in the Potlatch poplar plantations in eastern Oregon and the GreenWood Resources plantations in western OR. Dr. Jon Johnson sampled above and below ground biomass and carbon, sampling soil carbon to 100 cm in depth. The tree biomass was separated into branches, stems, stumps, and roots. Tree carbon increased with tree age with annual carbon sequestration for clones in eastern OR ranging from 15-20 Mg/ha/yr. Samples for soil carbon were also taken from adjacent annual crop fields and native shrub-steppe habitat. Soil carbon was much higher on the western OR sites because of greater organic matter. The tree crops showed greater soil carbon than the other land uses with greater than 50% increase in soil carbon on the eastside plantations and 10% greater soil carbon in the westside locations. In his conclusions Dr. Johnson stated that poplar tree crops can significantly increase carbon sequestration in both the soil and the biomass when compared to agricultural crops. Further, accurate prediction equations can be developed to determine biomass carbon sequestration.

In the last paper in the session Dr. Alejandro Fraga gave an introduction to CO2fix, a modeling frame in which a user builds his own (forest) data in order to simulate the long term carbon balance of a forest ecosystem. It provides annual output in terms of carbon stocks and fluxes. To highlight the models capabilities Dr. Fraga used clone productivity data provided by Potlatch. From the current annual increment data the model predicts the above ground branch, stem, root, and foliage carbon that result from user specified management scenarios. The user can simulate different silvicultural treatments, rotation and harvest scenarios. The model also has a soil carbon routine that predicts this component based on organic mater inputs and decomposition rates. The user can compare the output from the tree crop scenario to those from afforestation. In a verification comparison, the model results were compared to results from Dr. Johnson's field sampling experiment described above. The two results agreed very closely showing the promise of the model.

Summarized by Jake Eaton, Potlatch Corporation,
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Plenary Session Topic: Economic Opportunities for SRWC Development: Bioenergy Crops to Solid Wood Use, Policy Issues

- **Bioenergy crops**

Globally forests are the main source of energy for domestic use and many industries; biofuels provide 14% of the world's primary energy and 60% of wood removals are for energy. At the same time forest cover is declining by 9.4 million hectares per year (23.2 million ac./year), necessitating sustainable forestry practices. There are many regional differences. In Southeast Asia biomass is an important source of energy and, although decreasing in relative terms, it is increasing in absolute terms. Europe's forest area and volumes are increasing and there is an increased emphasis on forest residue harvesting and establishment of woody energy crops to offset reliance on fossil fuels. Fossil fuel costs are very high in Europe in contrast to those in North America, where forest management is less intensive and forest biomass use for energy is still in its infancy.

The past lack of interest in bioenergy in both Canada and the US was due to (relatively) low energy prices, lack of capital, small and widely-separated biomass sources, undeveloped supply chains, lack of knowledge and absence of policy incentives.

That has changed in the US especially, where concerns about rising energy prices, increased dependency on imported oil and need for energy security for end users have become the main drivers for commercialization of poplar and willow biomass crops. There is increased interest in cellulosic crops (e.g. poplar, willow, and switchgrass) for the production of bioenergy and bioproducts and a number of policy incentives were put in place in the US. The 'Renewable Portfolio Standard' in New York and other states recognizes SRWC ('short-rotation-woody-crops') and sustainably harvested woody biomass from forests as feedstock for bioenergy and bioproducts. The federal biomass tax credit for closed loop biomass provides a tax incentive and modifications to the Conservation Reserve Program (CRP) and the Conservation Reserve Enhancement Program (CREP) allow the growing of biomass crops on lands covered under these programs. Efforts need to be spent on overcoming non-technical barriers, such as securing support for biomass among the public, policy makers, NGOs, and industries.

The situation in Canada is not as far advanced as in the US. The lack of policy incentives remains a serious barrier to increased use of bioenergy derived from cellulosic feedstock. From the Federal perspective there is substantial emphasis on the research & development component of growing biomass crops. Several trials of purpose-grown poplar and willow biomass crops are planned or underway in Canada under a Federal Government research and development program, coordinated through the Canadian Biomass Innovation Network (CBIN). Historically Canada has had a strong research component; the '<u>EN</u>ergy from the <u>FOR</u>est' (ENFOR) program was initiated in late the 70's. ENFOR initially concentrated on both biomass production & conversion, and enhanced use of harvesting and mill residues for energy production. It was succeeded by 'Biobased Energy Systems and Technologies' (BEST), which supports CBIN and focuses on feedstock issues, such as short-rotation-intensive-culture (SRIC), biomass supply and availability and a national biomass inventory.

Acceptance of purpose-grown cellulosic biomass crops depends on the competitiveness of their production costs at the farm gate. Cellulosic-ethanol production is not yet competitive with corn-ethanol production; however, processing costs and enzyme costs are expected to decrease significantly.

Establishment of purpose-grown SRWC poplar and willow are now a reality in the US, especially in NY State with willow. A new commercial willow nursery started production in 2005 in New York State and is rapidly increasing capacity to meet demand. The first commercial willow biomass crops were planted in 2006 in NY State for combined heat & power (CHP) and biorefinery applications and there are plans to plant an additional 300-500 acres (120-200 ha) for 2007. Other projects are at various stages of development across the state.

Breeding efforts at the State University of New York-College of Environmental Science & Forestry (SUNY-ESF) have resulted in new and more productive willow clones. The Minnesota Forest Productivity Research Cooperative has a very successful poplar breeding and field testing program in Minnesota in cooperation with industry. New hybrid poplar clones show substantial yield improvements over the standard clones used to date. Breeding and selection of poplar and willow clones offer a great opportunity to not only increase yield per unit area, but it may make growing energy, pulp or solid wood crops on more expensive high quality land cost competitive with other more traditional farm crops.

Sources:

- 'A Comparison of Economics of Short Rotation Poplar and Switchgrass Energy Crops' - Bill Berguson, Lynn Wright and Don Riemenschneider (US)
- 'Developing Short-rotation Plantation/Agroforestry Systems for Bioenergy Generation in Canada: Policies, Laws, Programs and Social Factors' - Sylvain Masse and Pierre Marchand (Canada)
- 'Commercializing Willow Biomass Crops for Bioenergy and Bioproducts in the Northeastern and Midwestern United States' – T. Volk, L. Abrahamson, T. Amidon, D.J. Aneshansley, K. Cameron1, G. Johnson, E. Priepke, D. Rak, L. Smart, E. Spomer, E. White (US)
- 'Biomass for Energy from Woody Crops – Challenges and Opportunities in Canada and Internationally' – Jim Richardson and Jeff Karau (Canada)

- **Solid wood crops**

The Province of Saskatchewan has a goal to convert 10% of its arable land to agroforestry systems over next 20 years. This amounts to 1.6 million ha, or almost 4 million ac. The use of short-rotation-intensive-culture (SRIC) hybrid poplar will play an important role.

This project evaluates the commercial suitability of Prairie-grown hybrid poplars for the manufacture of high value solid wood products such as appearance grade lumber, plywood, laminated-veneer-lumber (LVL) and oriented-strandboard (OSB) in the Prairie region of Canada.

Hybrid poplar wood is light in colour, dries quickly with a low amount of drying degrade and it machines well. The wood is attractive in appearance and can be finished to take on different looks. It is suitable in applications where other softer hardwood species are used. It is also suitable for high quality veneer products (plywood and LVL) and can be mixed with native aspen and spruce. It processes similarly to aspen and for the production of OSB, hybrid poplar properties are fully equivalent to aspen. It can be substituted for aspen at any level with no apparent effect on panel properties, requiring only minor processing adjustments.

The author recommends development of silvicultural practices to grow hybrid poplar for different product applications and promotes the development of a species data base.

Source:

- 'Evaluation of Canadian Prairie-Grown Hybrid Poplar for High Value Solid Wood Products' – Robert M. Knudson (Canada)

Summarized by Cees ("*Case*") van Oosten
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Pictures and Notes on the Field Tours Associated with the Pasco, Washington SRWC-OWG meeting contributed by Lynn Wright,
Stop One – Port of Morrow, Boardman, Oregon; Site of two planned ethanol plants and varietal trials

Richard Shuran of GreenWood Resources described the varietal-site evaluation trials that are part of a Department of Energy Small Business Innovative Research project entitled "Modification of the Composition and Quality of Hybrid Poplar Biomass in the Pacific Northwest. Trials are established on 3 mesic sites and 5 xeric sites in the PNW. 36 varieties are common to all trials. Trees on this site established at 1.8 x 1.8 spacing will also be used to demonstrate productivity and harvesting operations.

Jon Johnson of Washington State University described Hybrid Poplar Nitrogen Use Efficiency (NUE) trials on this site with 6 clones. The standard (1x) treatment is 30, 50 and 70 lbs N/a for years 1, 2, & 3. Other treatments were 0.3x, 0.6x, 2x and 3x At the end of year 1, NUE was found to range from 41 to 51 g biomass/g N with a DT clone exhibiting the highest NUE and a TD exhibiting the lowest. The plots will be followed for at least 10 years.

Also at this site, a Poplar Irrigation study designed to determine the annual level of irrigation that produces the greatest volume of fiber was described. (The Field Tour Booklet says this was to be done by Andrew Bourque of Potlatch – but no picture was taken.) Treatments are 100%, 80% and 60% of field capacity resulting in average annual applications of 54 inches, 36 inches, and 5 inches respectively. All other management is the same for all treatments. In first year there were significant differences among all treatment with the highest treatment producing at a rate of 60 m3/ha/yr (900 ft3/A/yr). Study has found that highest level produces largest trees, but it is not economically practical nor operationally possible. The current goal is to manage the farm at 90% of field capacity.

The next stop was at the site of Potlatch's clone screening and refinement trials Where Jake Eaton described the process. The annual target is to screen 2000 to 2500 bareroot seedling for 2 years. Actual number screened has ranged from 400 to 5500 per year. Trial spacing is 6 x 6 feet. Selections (2 to 10%) at age 2 are taken into the refinement trials after clonal propagation. Wood properties are considered as well as growth, insect resistance, bud break & set, winter damage, stem form, and branching habit. In the refinement trial clones are selected for criteria specific to saw log production after observation for 4 to 5 years. Spacing in these trials are 10 ft by 7.5 feet. The photo of large trees shows the tour group inside of what is probably the Phase III stage of selection, or the clone verification trials. Selections are made at year 5 or 6 after spacings have been widened to 10 x 15 ft. Potlatch has 3 clone verification trials in progress scattered across their operational plantings.

Lunch at the Potlach office was a welcome relief!! Note the times on my pictures are probably in EST rather than PST.

Here we learned about how satellite imagery is being used to help manage the site and enjoyed a delicious lunch provided by Potlatch.

One of the many highlights of the tours was a chance to see an operation harvesting operation being conducted by GreenWood Resources on the Sand Lake Tree Farm originally owned by Boise Cascade. Highlights from that visit are represented below in pictures

Safety First!!

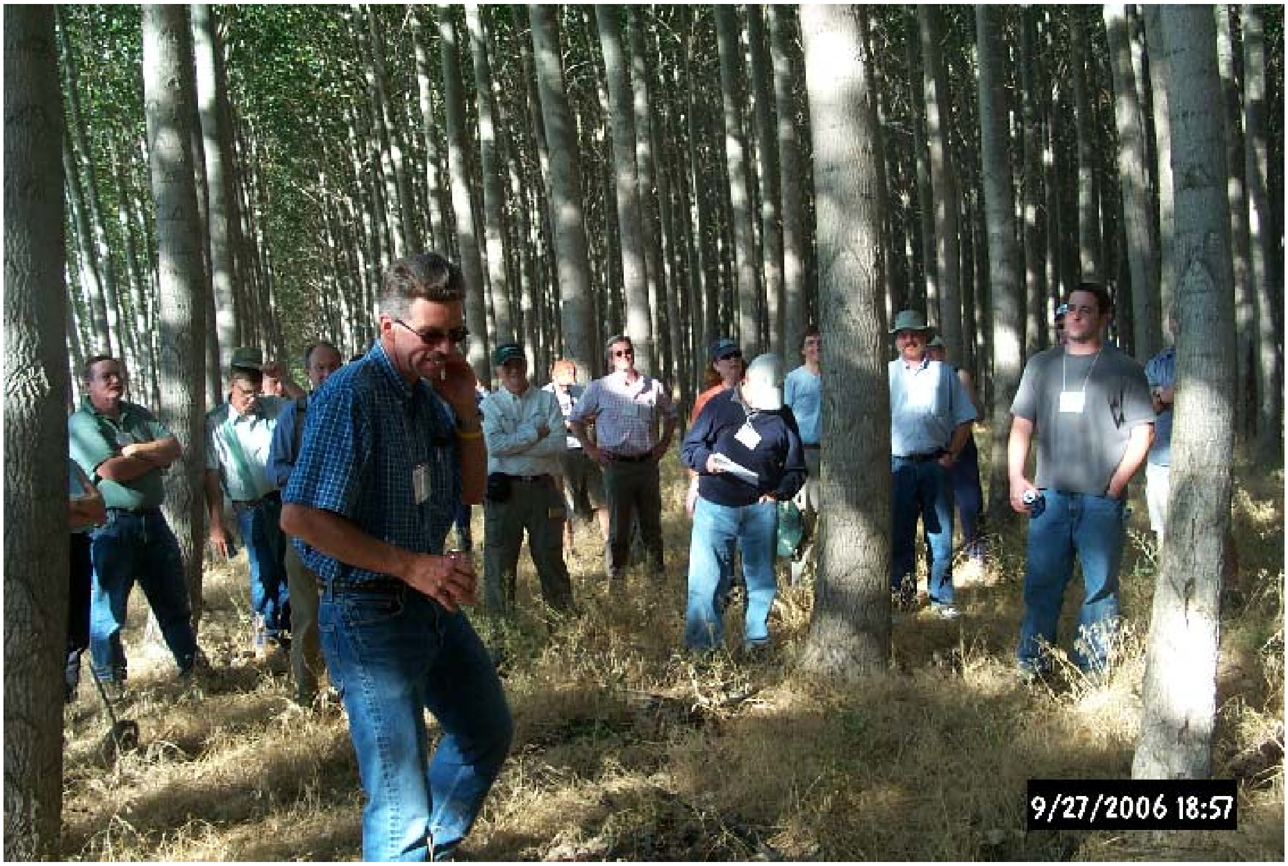
Trees before and after felling

Harvester head on a conventional John Deere Excavator.

In-field chipping

Looks like biomass energy wood to me!!

The tour ends the day back in the Potlatch plantations where we get to see very fast growing 1 year old trees, three-year old trees that have been pruned for the first time, and finally in the shade of a 10 year old planting. Apparently I missed taking photo's of the 3 year old trees!



I believe that Jake Eaton and the Potlatch team are very proud of their 10 year old saw timber hybrid poplars – as they well should be. The stand was planted at 10 x 7.5 ft in 4/1997, and thinned in 2/2000 to 10 x 11.5 feet (387 trees/acre). Pruned up to 24 feet. Stand scheduled for harvest in early 2009.

Special Report: Hybrid Poplar Crop Density and Rotation Length Consideration by Cees van Oosten

Hybrid Poplar Crop Density

Private landowners need to realize the maximum net value from their land, whatever the crop. With an SRIC[1] hybrid poplar crop, the maximum amount of merchantable wood needs to be grown in the shortest possible time to produce the highest net value per hectare. The amount of high value merchantable wood that can be grown depends, among others, on crop density. The choice of crop density and rotation length is driven by end product and by financial considerations.

❖ **Crop development and rate of growth**

Hybrid poplar crops for the production of saw and veneer logs have typically been grown at very low densities of 156-200 spha (~60-80 spac)[2] in Europe and South America. Densities between 400 and 1200 spha (~160-485 spac) remain relatively unexplored and could be of interest in North America. Pure pulpwood crops were not considered in this analysis.

The following conclusions were drawn from a review and a descriptive analysis of existing 13-year old hybrid poplar density trials in south western British Columbia and coastal Oregon:

- Differentiation of growth rates between trees in the same crop starts at age two to four years. This differentiation is independent of crop density.
- DBH growth peaks at age three to four in most trials and is independent of crop density. This was also observed by Krinard and Johnson (1984)[3] in long term density trials of eastern cottonwood.
- Rate of DBH growth depends on crop density; trees grown at lower densities have better and more sustained DBH growth (basal area growth) and thus volume growth per tree.
- Annual DBH growth rapidly declines after peaking, regardless of density.

❖ **Financial considerations**

Forintek Canada Corp.[4] conducted simulations to provide potential lumber recoveries from a range of tree sizes. Use of the simulations was restricted to reflect a more conservative lumber recovery. Trees were 'pruned' to a height of 6.7 m (22 ft.) and 'cut' into two saw log lengths, with knotty cores of 10 and 14 cm (4.0 and 5.5 in.) respectively. Each log was assumed to have a taper of 1.0 cm per meter of length (1.25 in. per 10 ft.). Lumber prices used were estimated in consultation with Potlatch Corporation and GreenWood Resources. Discount rates[5] of 2, 4, 6, 8 and 10% were used in a 'discounted cash flow' analysis. Simulation results were used to evaluate volume and value recovery for seven crop densities (see Table below) at age 13 years.

Stems per hectare	spha	1077	897	770	657	567	494	434
Stems per acre	spac	435	365	310	265	230	200	175

The saw log price (delivered to the mill) per cubic meter was assumed to be equal to 50% of the lumber value per cubic meter of saw log for each crop density. Lumber values for unpruned trees (i.e. 100% knotty core) were set at the #2 Shop grade, regardless of density. The pulpwood portion for each tree was valued at a fixed price per cubic meter (delivered).

All scenarios were evaluated against an unpruned crop at the 1077 spha (~435 spac) density, called the 'Base Case'. For each scenario the incremental net present value (npv) over the 'Base Case' was determined and ranked. Through lack of long term growth data for the Canadian Prairie region, growth was assumed to take twice as long (25 years) as on the coast. The resulting mean annual increments for the Prairie region were considered to be realistic.

- For the coastal region:

[1] SRIC stands for short-rotation-intensive-culture.
[2] Spha = stems per hectare; spac = stems per acre. One hectare is approximately 2.5 acres.
[3] Krinard and Johnson (1984) in 'Cottonwood plantation growth through 20 years' - USDA Forest Service Research Paper. Southern Forest Exp. Station, New Orleans..
[4] Forintek Canada Corp. is Canada's premier wood products research institute - www.forintek.ca
[5] Real discount rates (excluding inflation).

- For unpruned crops only, the 657-770 spha (~265-310 spac) range is superior to any other crop density at age 13.
- Pruning offers a much better return than a 'No pruning' scenario for all densities and discount rates. The best results for pruning are in the 657-770 spha (~265-310 spac) range.

- For the Canadian Prairie region:
  - For unpruned crops only, the 657-770 spha (~265-310 spac) range is also superior to any other crop density at age 25.
  - Pruning offers a much better return than a 'No pruning' option for densities of 897 spha (~365 spac) and lower. The best results for pruning are also in the 657-770 spha (~265-310 spac) range.

❖ Conclusions

- In order for the land owner or farmer to realize a sufficient return on a pruning investment, the market price for a saw log needs to be tied to its lumber value recovery. This needs to be supported by well documented pruning records.
- A sensitivity analysis for a saw log price reduction by 50% for the unpruned scenarios indicates that 1077 spha may be too dense, even for a pulp wood crop.
- The success of an SRIC hybrid poplar crop is determined by the choice of crop density and by early establishment success, which is a function of the intensity of crop management.

This project was completed under contract with the Saskatchewan Forest Centre. It was made possible through the generous access to density data from Potlatch Corporation, GreenWood Resources (both of Oregon) and Scott Paper Limited (British Columbia).

A full version of the report can be downloaded from the following websites:

1. Saskatchewan Forest Centre: http://www.saskforestcentre.ca/ (under Agroforestry Reports, or under Forest Development Fund - Agroforestry Reports).
2. Poplar Council of Canada: http://www.poplar.ca/whatsnew.htm (follow the link 'Hybrid poplar reports for the Prairies - Hybrid Poplar Manual now available'; this will show 2 reports, one of these is the crop density report).

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Special Report : Development of a Willow Biomass Crop Harvester Based on a New Holland Forage Harvester and Specially Designed Cutting Head

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Willow shrubs have several characteristics that make them an ideal feedstock for biofuels, bioproducts and bioenergy. They provide high yields that can be obtained in three to four years, are easily propagated from dormant hardwood cuttings, have a broad genetic base, have potential for significant improvements from traditional breeding, can be planted once and harvested multiple times, will provide a uniform feedstock, and have limited pest and diseases problems. Despite the numerous environmental and rural development benefits associated with willow biomass crops, they have not yet been widely adopted, primarily due to the current cost of production and delivery, which is $47 to $57 per ODT.6 The main economic factors are crop yield, and the cost of harvesting and transportation. Harvesting and transportation can account for 39-60% of the delivered cost of willow biomass[1]. SUNY-ESF has been working with Case New Holland and Cornell University to design a more efficient and effective harvester for willow biomass crops to lower harvesting costs and improve chip quality.

Willow is planted using 8 – 10 inch long dormant hardwood cuttings at a density of about 6,000 plants/acre. Site preparation uses a combination of chemical and mechanical weed control. The crop is coppiced after the first year during the dormant season to promote the production of multiple stems. The first harvest typically occurs three to four years after coppicing. The willow crop resprouts the following spring and is harvested again three to four years later. Seven or more harvests are anticipated from a single planting. Yields have ranged 3-5 oven-dry tons/acre-year or about 18-30 green tons/acre at harvest with a three-year rotation. Increases in yield of 20-40% are anticipated from planting new willow varieties from breeding and selection efforts7. The average number of stems per plant ranges from 4.5 to 12.5 among varieties, resulting in up to 75,000 stems/acre. Variability in number of stems per plant and corresponding variation in stem size means that the harvesting equipment being developed needs to be able to manage a range of stem numbers, sizes and heights.

A 140 HP tractor and harvester (called the Bender) that cut and chipped willow biomass crops in one pass was tested over two growing seasons (2002 – 2003). It had several advantages for the willow crop system being developed in the U.S. However, the unit produced chips of inconsistent size and quality, some of which were long and stringy. These pieces formed "bird nests" that jammed the chip handling systems in the field and at some of the bioenergy facilities where the willow chips were tested. Further, the machine was not mechanically robust and failed numerous times, especially in willow crops with yields >25 green tons/acre. Despite implementing a number of design modifications, the new model Bender was not suitable for willow crop harvesting and was discontinued from further testing in 2004.

During the summer of 2004 Case New Holland (CNH) expressed interest in developing a harvesting system for willow biomass crops based on their New Holland FX forage harvesters. During the fall of 2004, CNH purchased and modified a row independent corn head to determine if this type of cutting head could effectively harvest willow crops with smaller stem diameters (<1.5 inches) and to assess the capability and efficiency of the FX45 forage harvester (450 HP engine) to chip willow stems and produce high quality willow chips. Field trials in December 2004 and January 2005 (Figure 1) showed that the FX45 forage harvester could effectively and efficiently chip willow biomass crops and produce a consistent size, high quality product with >95% of the chips being less than one inch in size. Adjustments to feed roller speeds and the number of knives on the drum provides options for changing the size distribution of the chips that are produced. The modified corn head was able to harvest willow crops up to 1.5 inches in diameter, but was not robust enough to harvest more than about 0.5 acre at a time without stoppages for repairs or adjustments.

These initial field trials provided valuable information on the flow and chipping of willow stems. It was clear that a different cutting head would be required. A review of willow cuttings heads that have been designed and tested indicated that a head made by Coppice Resources Ltd. (CRL) in Doncaster, U.K. was probably the most robust for the size of willow produced in the U.S. Several versions of this cutting head have been built and operated by CRL. Modifications were made to the latest design including changing the drive mechanism for the cutting blades from mechanical to hydraulic. Two large diameter saw blades run at about 1200 rpm to cut the

6 Tharakan, P.J., T.A. Volk, C.A. Lindsey, L.P. Abrahamson, and E.H. White. 2005. Evaluating the impact of three incentive programs on cofiring willow biomass with coal in New York State. Energy Policy 33(3): 337-347.
7 Smart, L.B., T.A. Volk, J. Lin, R.F. Kopp, I.S. Phillips, K.D. Cameron, E.H. White and L.P. Abrahamson. 2005. Genetic improvement of shrub willow (*Salix* spp.) crops for bioenergy, bioproducts, and environmental applications. Unasylva. 56:51-55

willow stems and feed them into the forage harvester to be chipped. Support from Congressman James T. Walsh (NY-25th) was vital in moving this project forward and in acquiring a new cutting head. Congressman Walsh has been a short rotation woody crops advocate since the mid-1990s, securing vital and repeated federal project funding in the Agriculture, Interior, and Energy and Water Development appropriations bills.

Initial field trials with the new head mounted on the FX45 forage harvester were run in willow crops during summer of 2006 with support from the New York State Energy and Research Development Authority (NYSERDA). NYSERDA has been a long-term supporter of various aspects of willow biomass crop research, development and deployment. The chipped material produced continued to be consistent and high quality, but there were problems in the flow of material through the harvester. This problem was complicated by the foliage, which caused the cut willow stems to hang up rather than fall down and feed into the harvester. Field trials during the dormant season in the late fall of 2006 (Figure 2) indicated that material flow was improved, but was still not optimal. The harvester was able to operate at ground speeds of 3-4 miles/hour (1.9-2.5 acres/hour with 70% field efficiency) if stem diameters were less than 3 inches. A wet and warm start to the winter in upstate NY has severely limited the amount of running time in the field. The arrival of cold weather has allowed a resumption of field trials and the opportunity to begin testing the harvesting system in snow.

Figure 1: New Holland FX45 forage harvester with a modified row independent corn head harvesting 3-year-old willow biomass crops during field trials in December 2004 and January 2005 at the SUNY-ESF Genetic Research Station in Tully, NY.

Figure 2. Harvesting willow biomass crops with a New Holland FX45 forage harvester and a specially designed Coppice Resources Ltd. (CRL) willow cutting head in NY during fall 2006 and a close up view of the CRL willow cutting head.