Concentrated SRWC Willow and Hybrid Poplar in Ontario and Western Canada

Derek Sidders, Program Manager, Canadian Wood Fibre Centre, Prairies and NWT and Silviculture and Afforestation Innovation Group Leader

March 14, 2012  Culture of Willows and Hybrid Poplar for Energy Production

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Concentrated Short-rotation Woody Crops

- Fast-growing, high-yield area based plantations.
- Species: willow, hybrid poplar, and selected aspen
- Short Rotations: 3 Year Harvest Cycles 5-7 Cycles
Development of Short-rotation Woody Crop Systems

Concentrated Short-rotation Woody Crops
Concentrated SRWC Systems Development

Objective:

To diversify biomass supply opportunities while integrating land use options along the forest fringe using high yield, concentrated short-rotation woody crop (SRWC) systems for bio-products, bio-energy and carbon values.
**NEED:** New high-yield woody fibre source plantations designed to produce desirable attributes for developed and developing energy and fuel, bio- products and carbon capture values.
**Approach:** Establish a National Network of partners and technical development sites to develop SRWC land management designs, refine practices, validate growth trajectories and establish supply-chain variables, costs and product values.
Benefits: Diversification of the forest/agriculture land base in Canada through the introduction of innovative woody crop land management regimes in close proximity to final users, and designed to meet specific final product options and values.
Development of Short-rotation Woody Crop Systems

Short Rotation Woody Crop Options in Canada: National Network of Sites

B.N. Joss, D.M. Sidders, T.J. Keddy, Natural Resources Canada, Canadian Wood Fibre Centre

Short Rotation Woody Crops
- Purpose-grown woody crops of willow and poplar established as a means of rapidly producing lignocellulosic fiber for use in the wood products industry and for energy.
- Require appropriate site selection and preparation, suitable clonal planting stock, and intensive site management to achieve high yields (6x native yields) over short rotations (3-20 years).
- The 3 most common types of SRWC plantations are: High Yield Afforestation, Concentrated Woody Biomass and Mixedwood Afforestation.

High Yield Afforestation
- Silvotarget design (1100-1600 stems/ha).
- Designed to meet yields of 13.6-20.0 gross cubic metres NAI or 7.3-10.6 CDM/ha/yr of woody biomass.
- Uses biologically suitable hybrid poplar cultivars and superior aspen clones under intensive management regimes.
- Established on moderate to high quality agriculture land.
- 16-20 year rotations.
- Values: energy, forest products, carbon credits.

Concentrated Woody Biomass
- Short rotation (3-5 yr), high-yield biomass plantations that use high density designs (16,000 to 20,000 stems per hectare).
- Designed to meet yields of 6.0-12.0 CDM/ha/yr of biomass.
- High intensity, coppice management regime with 5-7 generations from one root system.
- Established to develop feedstock for energy conversion and carbon offsets (REPs).
- Various cultivars of hybrid willow and hybrid poplar are used.

Mixedwood Afforestation
- Designed to mimic the dynamics that exist within mixedwood forests in western Canada - the hardwood (hybrid poplar) provides the protection required by the spruce understory.
- Hybrid poplar (1,600 stems/ha) are inter-planted with white spruce (1,200 stems/ha) to meet yields of 13.6-20.0 m³/ha and 4.0-5.0 m³/ha respectively.
- A dual-crop strategy that maximizes the biomass, fibre and carbon values available from a given land base.

St. Albert, Alberta
- Type: Concentrated Woody Biomass
- Established: 2012
- Species: Hybrid Willow: Brachypodium, White Spruce
- Density: 1,500 stems/ha
- Management: High Intensity

Kamloops, Ontario
- Type: Concentrated Woody Biomass
- Established: 2013
- Species: Hybrid Poplar & White Spruce
- Density: 1,200 stems/ha
- Management: High Intensity

Legend
- Concentrated Woody Biomass
- Mixedwood Afforestation
- Site Groups
- Information Beads
Site Suitability for High-yield Concentrated SRWC
Potential to meet a minimum production of 6 ODT/ha/yr

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Figures in km²
Opportunity and Purpose
Grown Woody Biomass Options

Canadian Wood Fibre Centre
and Partner Technical
Development Sites
Development of Short-rotation Woody Crop Systems

Ellerslie Road Technical Development Site, Edmonton, Alberta

Production Stools

Species/Clone Production Trial (2005)

Willow Clone Design Trial (2007)

Clonal Trial (SUNY) (2006)
**Exhibitions and Field Tours**

The Canadian Wood Fibre Centre and the University of Guelph invite you to attend a practical and informative field exhibition showcasing high yields of short-rotation woody crops, afforestation and agroforestry management regimes, operational practices and values in carbon capture, bioenergy and bioproduct conversion.

When: Friday, November 6, 2009
Where: University of Guelph, (Guelph Turfgrass Institute, Victoria Road)
Time: 10:00-4:00 p.m. Self Guided Tour

Short-rotation woody crops are developing sources of carbon value, fibre for the forest industry and biomass for bioenergy and bioproduct conversion.

Join us for practical presentations/exhibits by researchers and developers from the Canadian Wood Fibre Centre, Canadian Forest Service, University of Guelph and their partners.

Topics include:
- Short-rotation woody crop design options
- Operational best practices development
- Carbon measuring and monitoring
- Growth and yield
- Establishment and management costs
- Equipment development
- Bio-solid and bio-liquid amelioration
- Value options (carbon, energy, products)
- Supply chain analysis

For more information, please contact:
Derek Sidders: 780-435-7355, dsidders@nrcan.gc.ca
Or Rachelle Clinch: rclinch@uoguelph.ca

Exhibitors: Derek Sidders, Tim Keddy and Brent Joss
Canadian Wood Fibre Centre, FPInnovations

Dr. Andrew Gordon, Dr. Naresh Thevathasan, Rachelle Clinch, James Simpson, University of Guelph

Dr. Barb Kishcluk and Dr. Jagtar Bhatti
Canadian Forest Service
Guelph, Ontario

Collaborator: University of Guelph: 22 ha
Short-rotation (3-5 yr), high-yield biomass plantations that use high density designs (15-20,000 stems per hectare) are being established on moderate to high quality lands across Canada to establish feedstock for energy conversion. Various cultivars of hybrid willow (Salix spp.) and hybrid poplar (Populas spp.) are being established under intensive management regimes to maximize establishment efficiency and biomass production. Initially, cultivar eco-site suitability and management practices development will be the primary focus on all demonstration study sites. All candidate lands qualify as either afforestation or reforestation under the Kyoto Protocol definition. Developmental protocols for the establishment of concentrated biomass plantations are being field refined, with biomass and carbon measuring and monitoring methodologies employed to develop and validate trajectories. Preliminary trials in Canada estimate a yield of 8-12 odt ha\(^{-1}\) yr\(^{-1}\) of woody biomass in the plant stems with estimated below ground carbon accumulations of 8.6-11.5 t CO\(_2\) e ha\(^{-1}\) yr\(^{-1}\).
Development of Short-rotation Woody Crop Systems

Species: willow and hybrid poplar
Density: 15,625 stems/ha
Spacing: 60cm X 60cm between Trees and rows and 2 metres between beds
Rotation Age: 3-4 yrs, 4-6 cycles
Biomass Yields: 6-10 ODT/ha/yr
Establishment Investment Cost: 8-12K/ha
Development of Short-rotation Woody Crop Systems

Species: willow and hybrid poplar
Density: 14,380 stems/ha
Spacing: 61cm X 76cm between Trees and rows and 1.52 metres between beds
Rotation Age: 3-4 yrs, 4-6 cycles
Biomass Yields: 6-10 ODT/ha/yr
Establishment Investment Cost: 8-12K/ha
Site Preparation to create mixed soil to a depth of 30cm

Mechanical Marking to identify planting locations

Conditioning (soaking) and planting of Hardwood Cuttings (15,625 stems/ha)

Vegetation Management to control competition

2nd Year Plantation
Vegetative Propagation of Clones/Species with Desirable Attributes
3-row Mechanical Transplanter
3-row Willow BioEnergy Beds,
2nd Week Post-Planting

$6,000 for 3-row unit
4500-6000 10 inch cuttings per operating hour
Developing Short-rotation Woody Crop Systems

3-row Willow BioEnergy Beds, Mechanical Cultivation: Split Row Rototiller
4-row Willow BioEnergy Beds,
Mechanical Cultivation: Split Row Rototiller

$4,800 for 2 row unit
0.3 -0.6 hectares/hr
3-Row Concentrated SRWC Design

H. Poplar: 1\textsuperscript{nd} Growing Season

H. Poplar: 3\textsuperscript{nd} Growing Season
2 Year-Old Willow and Hybrid Poplar
Pickering, Ontario
3-row Willow BioEnergy Beds, 
2nd Growing Season
Developing Short-rotation Woody Crop Systems

3 Year-Old Willow
Saskatoon, Saskatchewan
Developing Short-rotation Woody Crop Systems

1, 2 and 3 Year-Old Willow, Edmonton
Development of Short-rotation Woody Crop Systems

Concentrated Biomass (ODT/ha/yr*)

2009 Edmonton Harvest

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- 7 ODT
- 17 ODT
- 32 ODT
- 51.94 ODT
4 Yr-old Willow and Hybrid Poplar, Portage la Prairie
1st Cycle 4 Year Old Biomass Recovery

- Acute
- Alpha
- Charlie
- DN-17
- DN-182
- DN-34
- Hotel
- Pseudo

GREEN TONNES

GT/HA
HARVESTING OPTIONS

FLD Biomass Baler, Chesterville, Quebec

JF 192 Single Row Harvester
Ny Vraa Bioenergy, Denmark
Harvesting multi-row willow and hybrid poplar bioenergy plantations and processes into chips for handling, transportation, and conversion.
FECON Chipper Harvester
Development of Short-rotation Woody Crop Systems

FLD Biomass Baler

2008 Winter Harvest
2009 Winter Harvest
Kemptville, Pickering, Guelph: 310 bales
Developing Short-rotation Woody Crop Systems

2008/09 Winter Harvest Operational Development
Developing Short-rotation Woody Crop Systems

2008/09 Winter Harvest Operational Development
Weighing Bales to Assess Recovery Yields
Whip Harvest

India Whips

530,000 Cuttings Per Hectare
Concentrated

Site Information
Portage la Prairie, MB
DN – 182
Planted 2005
Harvested 2008
Used As Stool Bed to 2011

Volume/ha

ODT/ha/yr

Rotational ODT  Actual

Predicted ODT/ha.yr  ODT/ha.yr (Life)
Concentrated

Site Information
Portage la Prairie, MB
Acute Willow
Planted 2005
Harvested 2008 + 2011
Flooded in 2010 + 2011
Concentrated

Site Information
Edmonton, AB
India Willow
Planted 2005
Harvested 2008 + 2011

Volume/ha

ODT/HA/YR

Rotational ODT  Actual

Predicted ODT/ha.yr  ODT/ha.yr (Life)
Concentrated

Site Information
Saskatoon, SK
Hybrid Poplar
Planted 2007
Harvested 2010

Volume/ha

ODT/ha

ODT/HA/YR

Rotational ODT  Actual

Predicted ODT/ha.yr  ODT/ha/yr (Life)
Concentrated

Site Information
Univ. of Guelph, ON
SV-1
Planted 2006
Harvested 2009

Volume/ha

ODT/ha

ODT/ha/yr
Concentrated

Site Information
Pickering, ON
Charlie
Planted 2006
Harvested 2009

Volume/ha

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</table>

Rotational ODT, Actual

Predicted ODT/ha yr, ODT/ha yr (Life)
Site Preparation Operations

Proper site preparation is vital to the success of growing any type of agricultural crop. This is also true for the establishment of trees or shrubs on agricultural land. The three key components of any afforestation site preparation plan are:

1) Creating a suitable rooting environment
2) Leveling the site to facilitate future treatments
3) Initiation of the site vegetation management program

Depending on the previous use and status of the proposed planting area, the schedule for the completion of these three components may be altered. For example, sites that have been previously used for pasture or for the production of hay crops may have a heavy sod layer that will require a more rigorous site preparation plan than a site that has previously been used for cereal grains or other crops that require annual seeding.

Anyone planning to establish trees in an afforestation scenario must realize that the failure to meet the site preparation requirements outlined in this document will have a direct impact on the growth and achievable volume of the planted trees.
### Fibre Attributes: Chemical

**Concentrated SRWC**

*(composition % of oven-dried wood mass)*

<table>
<thead>
<tr>
<th>Species</th>
<th>Cellulose</th>
<th>hemicellulose</th>
<th>lignin</th>
<th>Extractives</th>
<th>Ash</th>
<th>Mean Calorific Values MJ/ODkg</th>
</tr>
</thead>
<tbody>
<tr>
<td>hybrid aspen</td>
<td>44.5-45.5</td>
<td>20.6-21.2</td>
<td>20.8-21.9</td>
<td>2.9-3.88</td>
<td>.27-.45</td>
<td>19.6</td>
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<tr>
<td>hybrid poplar</td>
<td>38.5-40.8</td>
<td>19.7-21.8</td>
<td>22.9-26.3</td>
<td>1.8-3.5</td>
<td>.52-.7</td>
<td>19.5</td>
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<tr>
<td>willow</td>
<td>38.4-42.7</td>
<td>17.3-20.2</td>
<td>21.4-27.9</td>
<td>1.2-2.8</td>
<td>.33-.83</td>
<td>19.4</td>
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</table>

* All juvenile samples of various clones/species
## Product Potential

<table>
<thead>
<tr>
<th>Opportunity Woody Residues</th>
<th>Purpose Grown Woody Crops</th>
</tr>
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<tbody>
<tr>
<td>• pellets</td>
<td>• pellets</td>
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<tr>
<td>• electricity and heat</td>
<td>• electricity and heat</td>
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<tr>
<td>• bio liquid and gas fuels</td>
<td>• pulp (aspen, hybrid poplar)</td>
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<tr>
<td>• mulch</td>
<td>• OSB (aspen, hybrid poplar)</td>
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<td></td>
<td>• bio fuels</td>
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<td>• electricity</td>
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<td>• newly developing products</td>
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</table>
Development of Short-rotation Woody Crop Systems

Biomass Value Simulator
B.N. Joss, D.M. Sidders & T.J. Keddy. Natural Resources Canada, Canadian Forest Service, Canadian Wood Fibre Centre

Objective
Create and maintain an internet-based fibre valuation system as part of the Canadian Wood Fibre Centre’s “Short Rotation Woody Crops (SRWC) and Opportunity Woody Biomass” project. The valuation system provides users with a decision support tool to determine the economical feasibility of growing and/or accessing woody biomass feedstocks for bioenergy/bioproduct development.

Future Development
Information pertaining to fibre characteristics, accessibility, availability, value-chain cost/value components and economics of purpose grown and opportunity woody biomass will be progressively added and integrated into the system to facilitate the development/refinement of the decision support tool and the optimization of the models that comprise it.

Partners
Canadian Biomass Innovation Network, EcoEnergy Technology Initiative, Canadian Forest Service (GLFC and LFC), CANMET Energy Technology Centre, Agriculture and Agri-Food Canada, FPInnovations - FERIC, FPInnovations - Paprican, University of Guelph, University of Saskatchewan, University of British Columbia and Manitoba Conservation.

Purpose Grown and Opportunity Biomass Value Chain

WOODY BIOMASS

HARVEST / COLLECT

PRE-PROCESS

LOAD

TRANSPORT

PRE-PROCESS

CONVERSION

STORAGE

2ª PRODUCT

PRIMARÝ PRODUCT

2ª PRODUCT

Canadian Wood Fibre Centre
Working together to optimize wood fibre value – creating forest sector solutions with FPInnovations
Benefit to Canadian Forest/Agriculture Community

1) New Sources of Feedstock for Bioproduct Conversion

2) Short-rotation and High-yield Focus to Fill Gaps in Specific Fibre Inventories

3) C Sequestration and GHG Offsets (New Value)

4) New Product Alternatives: Fuels, Crafts, Enviro-Barriers

5) Contribute to Environmental Movement (Climate Change Adaptation) and Bio-remediation.

6) Positioned strategically in close proximity to final user.
Points to Considered and the Future:

- Several management regimes exist: consider all
- **Hybrid poplar and willow should be considered**
- Yields for concentrated biomass systems are at or above acceptable range when suitable sites, management practices and recovery methods are deployed
- **Several output values need to be considered including bioenergy, carbon, conventional forest products and other bioproducts**
- Harvest technologies need to continue to be developed, and diversity in use needs to be considered.
Benefits and Limitations

Opportunity Woody Residues
- large volumes
- cheap, free or paid to dispose of at source
- ownership
- inconsistent fibre attributes and mediums
- low density handling
- costly transport

Purpose Grown Woody Crops
- significant land suitable
- social acceptance
- high-yields, short-rotation
- consistent fibre quality
- selective crop placement
- costly establishment and management investment
- requires supply chain technical development, and breeding
Development of Short-rotation Woody Crop Systems

Contributing Researchers:

Canadian Forest Service:

Dr. Barb Kishchuk, Soil Fertility, Sustainability
Dr. Jagtar Bhatti, Carbon Budget Modelling
Dr. Carmela Arevalo, Carbon Respiration
Dr. Dave Price, Afforestation Carbon Flux
Dr. Dan McKenney, Spatial Economic Modelling
Dr. Denys Yemshanov, Spatial Economic Modelling

Other Contributing Researchers and Partners:

Drs. Andy Black and Paul Jassel, UBC, Water Use
Dr. Naresh Thevathasan, U of G, Life Cycle Analysis
Dr. Philippe Savoie, AAFC, Harvester Development
Partner Organizations

University of Guelph                    University of Alberta
University of Saskatchewan                       University of B.C.
Alberta-Pacific Forest Industries              Millar-Western
Daishawa-Marubeni International                  Weyerhaeuser
Manitoba Conservation                  Poplar Council of Canada
Ferguson Forest Centre                     L.A. Quality Products
Alberta Innovates – Bio Solutions             C2C Reforestation
TreeCanada                                    Canadian Wood Fibre Centre
Agriculture and Agri-food Canada                Sylva Crotssance