POPLAR AND WILLOW CULTIVATION AND UTILIZATION IN CANADA
2008-2011 Canadian Country Progress Report

Canadian Report to the 24th IPC Session, Dehradun, India – International Poplar Commission for the Period 2008-2011

Prepared for: Poplar Council of Canada/Conseil du Peuplier du Canada

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1 FOREWORD

This Report covers the period from 2008 to 2011 (inclusive). The information collected in this report summarizes the activities during this period, any changes from the previous 2008 report[1] and highlights areas of new development and research, particularly in the area of environmental utilization. Some of the content completed for this report, 'Activities Related to Poplar and Willow Cultivation and Utilization in Canada', remains unchanged where no updates have been reported or occurred since the previous report. Where significant updates were needed, the original text has been altered; deleted or new text has been inserted to reflect such updates. No new Canadian Forest Inventory, which represented the sole basis of previous reports, has been published since 2001; therefore no new information from this source was available for this report[2]. Canada's National Forest Inventory is only available on-line in topic specific data sets and it is only based on data up to 2006; none of the *Populus* tree species are separately identified in the data. Other more recent sources available for this report include the "The State Of Canada's Forests Annual Report 2011" and the "The National Forestry Database (NFD)" that was last updated in January 2012, but only contains partial information for 2010 and 2011 in relation to a very limited number of topics. However, these sources do not treat any of the *Populus* tree species separately. Overall it was extremely challenging to make use of the more recent statistical national data as the basis for this report.

[1] *Canadian Report to the 23rd Session, Beijing, China – International Poplar Commission for the Period 2004-2007*.

[2] *National Forest Inventory Reports*, Chapter 4, Canada, Mark D. Gillis, Paul Boudewyn, Katja Power, and Glenda Russo. 2009

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3 Message from the Chair of the Poplar Council of Canada

2008-2011 was a progressive and exciting time for poplars in Canada. Breeding and research programs developed, expanded and emerged as interest in species such as balsam poplar (*Populus balsamifera*) gained notice. As such, significant funds have been obtained for research through Genome Canada and other Genome centres across Canada, the forest industry and other government agencies such as the Natural Sciences Engineering Research Council of Canada.

In December of 2011, the Chair of the Poplar Council of Canada was requested to make a presentation to the Standing Senate Committee on Agriculture & Forestry titled: Poplar Plantations – A Canadian Opportunity. This presentation afforded the Poplar Council of Canada the opportunity to put forward the current advancements and opportunities as well as the challenges holding up development and utilization of poplars and willows across the county.

Within the council we have an active and committed pesticide working group who have worked with partner companies and obtained registration for several chemicals (see www.poplar.ca) to assist growers in yield production, competition and disease control. The genetics working group is developing fact sheets for released clones, a national breeding strategy document for poplars and willows and it will soon be time again to update our electronically available clone and seed directory for Canadian material.

In 2010, the PCC undertook a 2-day Strategic Planning meeting which set new direction for the council for the next 3-5 years. The meeting was well attended and areas of development identified included: communication and education; production and stand health; environmental services; genetics and breeding; carbon credits; bio-energy; administration. Teams currently work in each area and conference calls are held every 3-4 months to review and discuss advancements.

Our international meeting held in Edmonton Alberta in September of 2011, in conjunction with the IPC Environmental Applications working group and the Poplar Council of United States had participants from around the world and included 2 full days of field trips, 2 days of seminars and a 2-day post-meeting field tour to the oil sands region of north-eastern Alberta. The immense reclamation challenges of oil sands operations were discussed, viewed and debated.

As this document concludes its preparation, the cycle of growth appears to be waning. Genetic resources amassed over the last few decades may be at risk and new avenues must be sought to preserve these resources until the tide turns again regarding environmental, economic and industrial relevance. Canadian populations of both native and exotic poplars are unique and worthy of preservation for scientific, practical and industrial uses. The PCC will continue to promote the wise use and conservation of these species especially considering their wide range of application throughout the world.

Barb Thomas, PhD
Chair, PCC

4 INTRODUCTION

4.1 General Information

The words *Populus* (in this report *Populus* refers to the genus and not section, unless specifically mentioned), poplar or aspen can be used interchangeably in this report; however, where appropriate this report distinguishes between:

Poplar (non-aspen) species, such as *P*. *balsamifera*, *P*. *trichocarpa* (both native to North America), *P*. *maximowiczii*[3]) and *P*. *laurifolia* in the Tacamahaca section (Balsam poplars), and *P*. *deltoides* (native to North America) and *P*. *nigra* in the Aigeiros section (Cottonwoods and black poplar). Hybrid poplar thus refers to the natural or artificial interspecific and/or intersectional hybrids. *P*. *deltoides* and *P. trichocarpa* are frequently referred to as eastern cottonwood and black cottonwood respectively, or just cottonwoods and *P*. *balsamifera* is known as balsam poplar.

Aspen species, such as *Populus tremuloides*, *P*. *grandidentata* and *P*. *tremula* (not native to North America) in the Populus section, formerly Leuce (Aspens and *P. alba*). *Populus tremuloides* is commonly known as trembling or quaking aspen, or just aspen and is by far the dominant *Populus* species in Canada. It occurs mainly in the boreal region of Canada. Hybrid aspen thus refers to the artificial interspecific hybrids of *P*. *tremuloides* and *P*. *tremula* (including the variety *P. davidiana* or Chinese or Korean poplar).

Willow (*Salix* spp.) species, such as *Salix viminalis* (Basket willow) have seen use as sound and visual barriers and *Salix nigra* (black willow) as a fibre source for a while, a wider spectrum of species, including *Salix dasyclados*, *Salix exigua* (Coyote or Sandbar Willow, native to North America) and hybrids (e.g. *Salix viminalis* L.*)* have seen an increased use in bio energy and environmental application in a variety of habitats including riparian areas, wetlands, open forests and disturbed areas. Canadian research and development work with *Salix* is ongoing in the Prairie region, Québec and New Brunswick. The names *Salix* and willow are used interchangeably in this report.

The main regions with economically significant *Populus* stands are located from the Province of British Columbia to the Province of Québec. In the four Atlantic Provinces east of Québec (Newfoundland & Labrador, Nova Scotia, Prince Edward Island and New Brunswick), natural *Populus* stands are less common and less economically significant than in the remaining provinces of Canada and form only a minor source of industrial wood. This is even more the case for Nunavut, the Yukon and Northwest Territories in northern Canada.

Aspen and poplar have, in particular, seen an increase in cultivation for use as sources of fibre for the pulp and paper industry and for the composite wood industry, primarily Oriented Strand

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[3] *Populus maximowiczii* is also colloquially referred to as 'Max'.

Board (OSB). However, because of economic, regulatory and environmental reasons, this development has seen a sharp reversal very recently in spring 2012 with the closure or scaling down of fibre-oriented plantations. However at the same time the utilization of aspen and poplar for environmental purposes is seeing slow but steady growth. Therefore, this report contains sections dedicated to the different environmental applications, such as remediation, use in riparian areas and carbon sequestration.

This report frequently refers to short-rotation-intensive-culture or SRIC (hybrid) poplar and willow crops. These SRIC woody crops are established and managed using an agronomic approach to crop management on cleared (usually) agricultural land, requiring a short rotation (usually less than 25 years for poplar and 5 to 6 years for willow). SRIC woody crops could be compared to the 'trees-outside-forests' or TOF, a term used by the International Poplar Commission.

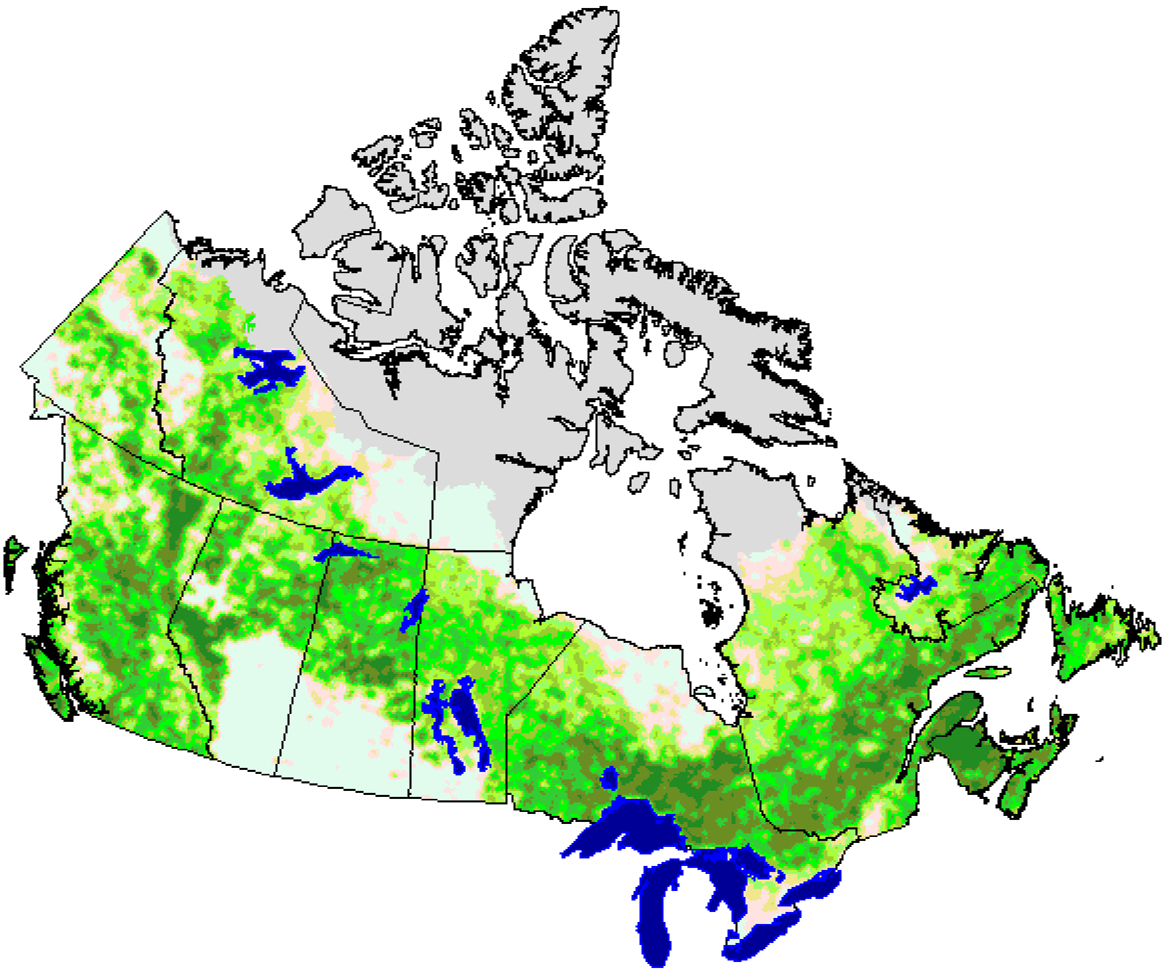
The use of the word 'crop(s)' refers to short-rotation-intensive-culture (SRIC) crops of (hybrid) poplar (or aspen) and/or (hybrid) willow. The words 'plantation' or 'forest plantation(s)' refer to plantations on forestland.

For readers not familiar with the term 'Crown' land: Crown land is owned and managed by the respective provinces or, in some cases, by the federal government. Any references to Crown and/or public land in this report are to Provincial Crown land.

There is frequent reference to the Prairie Provinces, which include Alberta, Saskatchewan and Manitoba. The Prairie region refers to these three provinces, as well as the northeast corner of British Columbia, located to the east of the Rocky Mountains.

An extensive listing of publications by authors residing in Canada and/or publications published in Canada and/or covering projects located in Canada complements this report; it includes articles, research papers as well as theses and technical reports. These listing have been compiled by a systematic search approach that has been documented in detail at the beginning of the section.

4.2 Map of Forest Cover in Canada



Map Legend

Percent Forest (%)

- -
- 0 - 10
- > 10 - 20
- > 20 - 30
- > 30 - 40
- > 40 - 50
- > 50 - 60
- > 60 - 70
- > 70 - 80
- > 80 - 90
- > 90 - 100

Source: National Forest Inventory 2006

5 SUMMARY

Canada has 10 percent of the world's forests that cover 397.3 million hectares (ha) of forest, other wooded land and other land with tree cover, which represents 53.8 percent of its total surface area. Canada's forest, other wooded land and other land with tree cover are made up of 347.7 million ha (87.5 percent) of forest, 41.8 million ha (10.5 percent) of other wooded land and 7.8 million ha (2 percent) of other land with tree cover. The predominant tree species on forest land are spruce (53.2 percent), poplar (11.6 percent) and pine (9.3 percent)[4]. The vast majority of the *Populus* inventory in Canada consists of natural stands[5].

Provinces in Canada have full jurisdiction over forest management and agriculture regulations, thus taxation on property and various forest and agriculture regulations are strictly a provincial affair. These provincial regulation and legislation if in existence at all vary widely across Canada in their approach and nature. Only the Province of British Columbia recognizes intensively-managed *Populus* and *Salix* plantations. The Province of Saskatchewan offers the most favourable property valuation and taxation rate that applies to rural, mostly agricultural land, regardless of what crop is grown; this includes tree or woody crops. As the provinces have jurisdiction over forest resources, provincial agencies carry out and maintain forest inventory systems. Standards for data collection and compilation differ between provinces and are not necessarily compatible. In addition, most inventory systems with the exception of the Province of Québec, do not specifically track any of the *Populus* tree species in their data systems.

The main regions with economically significant natural and plantation *Populus* stands are located in the Province of British Columbia, Alberta, Saskatchewan and Québec. The plantation stands have been mostly planted to serve as sources of fibre for the pulp and paper industry and for the composite wood industry. However because of economic, regulatory and environmental reasons this development has seen a sharp reversal in the last half year with the closure or scaling down of fibre-oriented plantations. At the same time, environmental research and the utilization of poplars for environmental purposes (such as remediation, use in riparian areas and carbon sequestration) are seeing slow but steady growth. In addition, a fair amount of consideration has been given to research and project development as it relates to poplars, including biomass production from Short-Rotation-Intensive-Culture plantations using hybrid poplar and willow trees.

[4] Natural Resources Canada.

[5] Canada's Forest Inventory 2001.

6 POLICY AND LEGAL FRAMEWORK

Provinces in Canada have full jurisdiction over forest management and agriculture regulations, thus taxation on property and various forest and agriculture regulations are strictly a provincial affair. Federal income tax rules apply nationwide and are administered by the Canada Revenue Agency (CRA). The federal income tax rules will not be discussed in this report, as there are no specific policies or federal tax incentives pertaining to *Populus* or *Salix*.

Two provinces, British Columbia[6] (BC) and Alberta[7], have regulations and standards that govern the deployment of (hybrid) clonal material and/or genetically improved material on Crown lands.

The only province with a specific property tax policy and supporting regulations pertaining to *Populus* and *Salix* management is BC, where intensively-managed *Populus*[8] or *Salix* crops can be recognized as primary agricultural production. The incentives and regulations in BC apply to private land. Besides the policy for intensively-managed *Populus* and *Salix* on private land, BC also has property tax regulations that apply to privately-held managed forests and/or woodlots, as do Ontario and Quebec. The three Prairie Provinces, Alberta, Saskatchewan and Manitoba do not have specific tax policies for privately-held managed forestland or woodlots. The report will review the various policies and property tax arrangements for each of the western and central provinces and provide an overview of the Atlantic Provinces.

Property tax law and regulations generally do not apply to Crown land, except in BC for Crown lands leased for the purpose of farming or grazing, which theoretically could include poplar farming.

6.1 British Columbia

6.1.1 *Populus* and *Salix* as Primary Agricultural Production

Since 1995, BC's *Standards for the Classification of Land as a Farm Regulation*[9] under the Assessment Act[10] recognize "*Populus* species and *Salix* species intensively cultivated in plantations"[11] as primary agricultural production.[12] Land that is privately owned or leased and is growing *Populus* or *Salix* species can be classified as a developing farm when:

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[6] See http://www.for.gov.bc.ca/hti/publications/misc/legs&standards.htm.

[7] See http://www.abtreegene.com/images/STIA.pdf.

[8] This includes SRIC aspen crops.

[9] B.C. Reg. 411/95 (the "Regulation").

[10] R.S.B.C. 1996, c. 20.

[11] Schedule A of the Regulation.

[12] See also Farm Classification in British Columbia brochure (http://www.bcassessment.ca/public/Documents/10-055%20BCA%20Farm%20Classification%20Brochure.pdf or http://www.bcassessment.ca/public/Documents/farm_brochure.pdf).

"...*in the case of products produced from primary agricultural production that…require 7 to 12 years to establish after planting, there is a sufficient area prepared and planted to meet the requirements of this regulation when harvesting occurs and the assessor determines that there is a reasonable expectation of profit from farming*"[13].

The latter criterion of "*a reasonable expectation of profit from farming*" is similar to that used by the Canada Revenue Agency to allow certain deductions for farm expenses.

The regulations cover a variety of products and uses and are aimed at providing tax incentives for legitimate farming operations. For land to be classified as a farm, the owner must submit an Application for Farm Classification to the local assessment office. With his or her application, the landowner or lessee must submit a development plan and a map outlining crop details, area to be planted, date of planting, expected yields, anticipated selling prices and a date of harvest.

Populus and *Salix* species managed beyond the 12-year window do not technically qualify as primary agricultural production and neither do plantations that are not intensively managed, nor do natural stands.

Through an Order-in-Council, the Assessment Commissioner, who is the Chief Executive Officer of the British Columbia Assessment Authority, sets the valuation rates for farm use. These rates reflect the land capability and land use. The assessed value of farm land is usually lower than market value, especially in the more populated areas of the province, where market values are driven up by non-farm market pressures on the land base. In some rural areas, farm valuation rates are similar to assessed market values.

The tax rate for farm land is in a separate rate class. The farm rates are usually one of the lowest tax rates. Apart from a lower valuation and tax rate, there are several important exemptions from taxation of the school and hospital tax. An additional advantage for legitimate poplar or willow farms is the eligibility for an exemption from provincial sales tax[14].

Although the regulations are beneficial to poplar and willow planting, the restriction of the rotation to 12 years has now proven problematic for poplar plantations. Yield plots in south-western British Columbia[15] show that SRIC hybrid poplar crops planted at 1,100 or fewer stems per hectare do not culminate mean annual increment (MAI) within the 12-year period, especially when grown to produce saw logs or veneer logs at a reduced crop density. For the independent crop owner this may jeopardize the "reasonable expectation of profit from farming", which is a key provision in both the Federal Income Tax regulations and the provincial farm assessment regulations. To change the restrictive rotation length to a more appropriate length can only be implemented through a political process; there is currently no regulatory mechanism to allow for such a change.

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[13] *Ibid*., pp. 28-29.

[14] See Ministry of Finance Tax Bulletin SST 023 (http://www.sbr.gov.bc.ca/documents_library/bulletins/sst_023.pdf).

[15] Information provided by Cees van Oosten.

A major advantage of classifying *Populus* and *Salix* species as primary agricultural production has been the flexibility of managing the crop without the regulations that apply to a more traditional forest crop. As a farming operation, there is also the added protection through BC's *Farm Practices Protection (Right to Farm) Act*[16]. Under this act 'farm operation' means any of the following activities involved in carrying on a farm business:

a) growing, producing, raising or keeping animals or plants, including mushrooms, or the primary products of those plants or animals;
b) clearing, draining, irrigating or cultivating land;
c) using farm machinery, equipment, devices, materials and structures;
d) applying fertilizers, manure, pesticides and biological control agents, including by ground and aerial spraying; and
e) conducting any other agricultural activity on, in or over agricultural land, including *"intensively cultivating in plantations, any (i) specialty wood crops, or (ii) specialty fibre crops"* (emphasis added).

This protection does not apply to forests in the Managed Forest Land class (discussed in further detail below).

One regulation that applies to more traditional forest crops also applies to SRIC woody crops grown on private farmland. All 'timber' produced in BC must be scaled and measured under the provisions of the *Forest and Range Practices Act*[17] ('timber' includes logs and chips), regardless of its origin (Crown or private land). Owners of SRIC hybrid poplar and willow crops grown on farm land must obtain a private 'timber mark'[18] and must make provisions to have their harvest scaled by a licensed scaler[19]. What is unclear at this point is how biomass crops on very short coppice rotations will be handled under the *Forest and Range Practices Act*.

6.1.2 Managed Forest Land

Managed Forest Land[20] (MFL) is privately-owned forest land subject to an acceptable and approved forest management commitment that complies with the *Private Managed Forest Land Act*[21]. Property owners in this class are obliged to provide good resource management practices such as reforestation, stand tending, protection from fire and disease and sound harvesting methods. The assessed forest land value is based on its capability for tree growth and therefore recognizes the land for its forest use value. The assessed value is not subject to other market

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[16] R.S.B.C. 1996, c. 131.
[17] S.B.C. 2002, c. 69.
[18] A timber mark is an identifying mark that must be marked onto cut timber before it may be removed from the land where the timber was cut. A timber mark identifies the timber so that Forest Service
personnel can determine the origin of the timber, whether stumpage payments are due to the government on that timber, and whether the timber may be exported. For more information, see "Timber Marks for Private Land" (http://www.for.gov.bc.ca/ftp/HTH/external/!publish/web/timber-tenures/private-timber-marks/brochure-jul-24-2003.pdf).
[19] Personal communication with Bruce Walders by Cees van Oosten. No further updates have been provided.
[20] As defined in section 24 of the *Assessment Act*.
[21] S.B.C. 2003, c. 80.

forces, such as its true market value for possible other uses. The valuation takes places in a two-step process:

1. BC Assessment determines the value of the land without trees, including other factors, such as growth capability, location, topography and accessibility. The assessor applies a schedule of regulated values to the bare land. At this stage, trees are not assessed a value.
2. After the trees are harvested, BC Assessment will add the assessed value of the harvested trees to the bare land value of the land. The value of the trees harvested in any year is added two years later to the property's assessed value.

Poplar or willow crops not recognized as primary agricultural production, i.e. stands that exceed the 12-year rotation or stands that are not intensively-managed as a farm crop, can still qualify under the MFL class. Natural poplar stands could also qualify, provided they meet the above-mentioned conditions. There are size restrictions and to be classified as MFL, "the land must be at least 25 hectares and be managed as a single unit, or, if the land is 50 hectares or less, at least 70% of the land must be productive during the year ending on October 31. If the land measures more than 50 hectares, at least 50% of the land must be productive during the year ending on October 31"[22].

Forest land classed as MFL offers several benefits:

a) owners are assured the right to harvest trees;
b) assessments are reasonably stable through years of no harvesting; and
c) increased assessments will apply only following a year in which tree harvesting occurs.

6.2 Alberta

There are no specific policies or tax measures promoting the management of *Populus* or *Salix* species in Alberta.

Rural land is generally valued as either agricultural, based on productive capability rather than market value, or as non-agricultural land, valued at market value. Privately-held forest land and woodlots are not considered agriculture and are generally assessed at market value, rather than productive capability. Property value assessment of forest land and woodlots at market value frequently leads to accelerated liquidation of the standing timber inventories in order to reduce the property tax burden.

Much of the private wood purchased by various companies thus comes from forests that are being liquidated for agricultural or other industrial development. This liquidation process reduces the opportunity to obtain fibre from these sources in the future. With projected increases in mill production and forecast reductions in land committed to sustainable fibre

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[22] See "Managed Forest Classification in British Columbia" (http://www.bcassessment.ca/public/Fact%20Sheets/Managed%20Forest%20Classification%20in%20British%20Columbia.aspx).

production, the hardwood[23] (i.e. aspen and poplar) fibre shortage is expected to increase. There are opportunities to retain and manage private forest lands and woodlots for sustainable fibre production by offering incentives to landowners through a more appropriate valuation and tax process. This will encourage sustainable management, rather than liquidation, of forested private land, and also afforestation of cleared farmland. This latter category is of increasing importance to several land owners and corporations, who are planning to establish or are currently establishing aspen and poplar plantations.

Alberta is divided into two main administrative areas, the White Area and the Green Area. Both areas are managed in a multiple use context; however, there are important differences between the primary uses of the two areas[24]:

a) The White Area, covering approximately 39% of Alberta (three-quarters of which is privately owned), is generally settled or suitable for settlement and is associated with uses such as agriculture, oil and gas development, tourism and recreation, urban centres, conservation of natural spaces, and fish and wildlife habitat. The authority to set regulations and make decisions with respect to the White Area rests primarily with municipal governments on private land and with the provincial government on public land.
b) The Green Area, covering approximately 61% of Alberta (most of which is publicly owned), is largely permanent forest and is associated with uses such as timber production, oil and gas development, tourism and recreation, conservation of natural spaces, watershed protection, and fish and wildlife habitat. Authority to set regulations and make decisions with respect to the Green Area rests primarily with the provincial government.

Much of the privately-held forest lands, woodlots and agricultural lands suitable for afforestation to aspen and poplar are located in the White Area, where several land owners and corporations are planning to establish or are currently establishing SRIC aspen and poplar crops. Alberta-Pacific Forest Industries Inc. (Al-Pac) is the only corporation in Alberta currently engaged in establishing and managing large-scale operational SRIC hybrid poplar crops on farmland. Ainsworth Engineered Canada LP has also started to establish SRIC hybrid poplar crops to provide a sustainable supply of wood for its OSB plant in Grande Prairie (Alberta).

Several years ago, Alberta was contemplating changing its property tax laws to recognize managed private woodlots, which would have had a positive impact on sustainable management of aspen and poplar. These proposals were part of an omnibus of legislative changes pertaining to agricultural assessment regulations, including regulations for intensive livestock operations. The unfortunate occurrence of a single cow with bovine spongiform

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[23] The term hardwood is used throughout this report and refers to the deciduous or broadleaved species present in the inventory; it does **not** include deciduous species such as *Larix*. The terms hardwood and deciduous are used interchangeably.

[24] For more information, see https://landuse.alberta.ca/Planning/WhyLandusePlanning/UnderstandingLandUseAlberta/Pages/GreenandWhiteAreas.aspx.

encephalopathy (BSE) changed all that, cancelling all of these legislative initiatives[25]. Changes to Alberta's property tax laws have yet to take place[26].

Land ownership rules in Alberta put restrictions on foreign-owned corporations leasing or owning land[27]. A foreign-owned corporation can only lease less than 5 acres (2 hectares) for a period not exceeding 20 years. A 2004 Order-in-Council allowed Al-Pac to lease 25,000 hectares for up to 30 years, provided the land classification did not exceed a certain value, restricting such leases to lower farmland classes. In the fall of 2007, the Government dropped the restriction in land classification, thereby allowing Al-Pac to lease any and all classes of land[28]. The Order-in-Council and the 2007 ruling only apply to Al-Pac; however, it sets a precedent for other foreign-owned corporations, should they be interested in leasing land for the purpose of growing a SRIC woody crop.

6.3 Saskatchewan

As in Alberta, there are no specific policies or tax measures promoting the management of *Populus* or *Salix* species in Saskatchewan.

Treating trees as a crop, particularly hybrid poplars, is relatively new to Saskatchewan. While the potential is large, constraints to implementation exist, including[29]:

- The length of time it will take (from 15 to 20 years) to develop a mature wood supply with the requisite high front end costs. Loan programs and other financial risk sharing programs need development.
- The need to establish critical mass in production in any given region to ensure that the range of services, expertise, and local markets are available.
- The need for research and development into new commercial species.

For woodlots or other privately-held forest land there are no incentives for properties classified as "forest property" or managed as woodlots or tree plantations[30].Saskatchewan's forest is not fully utilized. Canadian industry prefers long-term land tenure and secures wood supplies from

[25] Personal communication with Byron Grundberg and Larry Collins by Cees van Oosten, 2004. No further updates have been provided.

[26] Personal communication with Al Bertschi by Cees van Oosten. No further updates have been provided.

[27] Pursuant to the *Agricultural and Recreational Land Ownership Act* (Alberta) (Chapter A-9, R.S.A. 2000), no ineligible person or foreign controlled corporation may take or acquire an interest in certain controlled land, subject to various exceptions. Generally, controlled land includes all privately owned land outside urban boundaries (usually farm land or rural recreational land). Furthermore, any corporation that acquires or attempts to register an interest in Alberta land must be registered in Alberta (either as an Alberta corporation or as an extra-provincially registered corporation).

[28] Personal communication with Randy McNamara by Cees van Oosten. No further updates have been provided.

[29] "Saskatchewan Short Rotation Woody Crops Economics and Benefits", Saskatchewan Forest Centre (January 2007), p. 10 (http://www.environment.gov.sk.ca/fic/9618.pdf).

[30] Gary Coghill - Saskatchewan Agriculture, Food and Rural Revitalization: "Income tax and property tax implications for woodlots and tree plantations" – undated.

Crown forests, therefore Saskatchewan does not yet have a scarcity of wood supply which would create a competitive market for privately held wood.

The Saskatchewan Assessment Management Agency (SAMA) assesses woodlots using agricultural land valuation. Rural land is assumed to be for an agricultural purpose, capable of agricultural crop production and proper tillage, and is assessed as such. Arable (cultivatable) land is assessed at 55% and non-arable (non-cultivatable) land at 50% of the assessed value, resulting in rural forestlands being in one of the lowest property tax classes. A recent change lowered the assessment rate for land growing grain that is converted to treed land (including SRIC woody crops) from 55% to 50%; the same applies to grain land converted to grassland. The actual tax savings are insignificant[31]. A 2004 study in Saskatchewan concludes that "*results of the economic analysis in this study suggest that the actual impediment to afforestation and agroforestry arising from the cost of property taxation to the producer is very small relative to other economic disincentives that include high establishment costs and the substantial time lag until harvest. Property assessment for taxation purposes generally rates agricultural land at the lowest valuation rates*". The same study recommends "*If property taxation incentives are to be applied, they should encourage producers to incorporate good management practices in their afforestation or agroforestry operations. Such practices develop long-term, sustainable industry and have demonstrable environmental benefit. Accordingly, we can conclude that a move towards a vigorous Management Plan regime for private land forestation in conjunction with target-specific property taxation adjustments that direct incentives to producers will lead to better profitability and resource management than is presently the case*" [32].

To date there are no new developments on this issue.

6.4 Manitoba

As in Alberta and Saskatchewan, Manitoba has no specific policies or tax measures promoting the management of *Populus* or *Salix* species. That situation has not changed since 2004[33].

Land taxes for forest land are lower than for agricultural land and there are no incentives available for management of woodlots[34].

6.5 Ontario

As in the Prairie Provinces, Ontario does not have specific policies or tax measures promoting the management of *Populus* or *Salix* species, but Ontario does offer a Managed Forest Tax Incentive Program to eligible forest land owners.

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[31] Personal communication with Douglas Currie by Cees van Oosten. No further updates have been provided.

[32] Ken Belcher, Richard Edwards, Hayley Hesseln, Richard Marleau - Centre for Studies in Agriculture, Law and the Environment: 'Developing Saskatchewan Property Taxation Policies for Afforestation and Agroforestry Systems: A Legislative and Economic Overview' – 29 April 2004.

[33] Information provided by Shane Tornblom. No further updates have been provided.

[34] Information provided by Patricia Pohrebniuk, 2004. No further updates have been provided.

6.5.1 Managed Forest Tax Incentive Program

"The Managed Forest Tax Incentive Program (MFTIP) is designed to encourage landowner participation in natural resource stewardship on private forest land in Ontario"[35]. The Ontario Woodlot Association defines the goal of the MFTIP program as bringing *"greater fairness to the property tax system by valuing forestland according to its current use"*[36]. The MFTIP allows for a reduction in property taxes to forest land owners who prepare an approved management plan and commit to good stewardship of their property. Recently, the term of the program was increased from five to 10 years on a renewable basis[37]. A five-year progress report needs to be filed in order to continue qualification under the program. The MFTIP is meant to remove financial barriers to good management by valuing the land for its current use. Eligible land is taxed at 25 percent of the municipal tax rate set for residential properties.

In Ontario, the Ministry of Natural Resources (MNR) administers the MFTIP and the Municipal Property Assessment Corporation (MPAC) is responsible to carry out property assessments, while the municipalities are responsible for the administration of the property tax system, including billing. Areas planted to and managed for *Populus* species are considered managed forests, provided there is an approved management plan; this applies to poplars planted on farmland (SRIC crops) and on forest land. It is unclear how this incentive program would affect SRIC willow crops.

Managed forest must meet several conditions:

a) The land owner must be a Canadian citizen, corporation, partnership or conservation authority;
b) The forest area must cover at least 4 hectares (10 acres) excluding all residences;
c) The forest must all be on one property with one municipal roll number;
d) There must be a minimum number of trees on each hectare (acre), depending on size;
e) The land cannot be subject to a 'Registered Plan' of subdivision or be licensed under the Aggregate Resources Act (*note the recent change*[38]).

From a poplar-management perspective, the criterion of a minimum number of trees per hectare could cause some grief. The minimum number of stems per hectare (spha) is 1,000 at any time, but does decline as the diameter-at-breast-height (dbh) increases. A grower, who intends to establish e.g. 500 stems per hectare (spha) to manage the stand for the saw log or

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[35] http://www.mnr.gov.on.ca/en/Business/Forests/Publication/MNR_E000245P.html.

[36] http://www.ont-woodlot-assoc.org/forman_mftip.html.

[37] Ontario Managed Forest Tax Incentive Program (MFTIP) Guide (January 2012), p. 4 (http://www.mnr.gov.on.ca/stdprodconsume/groups/lr/@mnr/@forests/documents/document/mnr_e000245.pdf).

[38] Effective January 1, 2007, the regulations of the Act state that if "property is in a newly designated area under the *Aggregate Resources Act* or was previously zoned for extraction, but is not licensed (i.e., you are not extracting aggregate), your property may now be eligible for the program, subject to other program eligibility requirements" – source: http://www.ont-woodlot-assoc.org/forman_mftip.html.

veneer log market, runs the risk of the plantation not meeting the eligibility criteria until the average dbh is in excess of 12 cm [39].

The new assessment method caused numerous complaints of property taxes actually increasing and led to calls for the assessed value to revert to the subset of farm values as used before. The complaints resulted in a formal review under the *Environmental Bill of Rights*[40] (EBR), which provides that Ontario residents may apply to the Environmental Commissioner to request a review of a policy, act, regulation or instrument[41]. The report summarizing the review made eight recommendations and certain changes were implemented as a result, including that "Managed Forest (MF) properties will be assessed in a manner similar to the method used for farmland, which is based on land productivity rates"[42]. Under the new assessment approach, it is estimated that more than 80% of the MFTIP properties will experience lower assessments when compared to the previous assessment procedure[43]. Other changes to the MFTIP included: (i) increasing the term of MFTIP plans from five to 10 years; (ii) modifying the definition of eligible open area to better recognize the variability of the forested landscape, and (iii) requiring that purchasers of MFTIP properties wishing to keep a property in the program to have their plan approved by a Managed Forest Plan Approver[44].

6.6 Québec

The Province of Québec does not have specific policies for the establishment and management of *Populus* or *Salix* species on either public or private land. Most poplar is planted on private and public forestland with only approximately 3-4% planted on cleared agricultural land[45]. Public lands are governed by the *Forest Act*[46] («Loi sur les forêts»), which states that forests must be managed in a sustainable fashion and must meet several important criteria. Approximately 90% of Québec's forests are under public ownership and are managed on its behalf by the provincial government[47]. Although the *Forest Act* is not very explicit about how the rules affect private forestland, management criteria also apply to private forests and woodlots. Woodlot owners can obtain financial and technical assistance from the government to develop their forests. The private forest development agency programs provide the framework for

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[39] The criteria are: 1,000 spha any size of tree; 750 spha with dbh > 5 cm; 500 spha with dbh > 12 cm; 250 spha with dbh > 20 cm. See *Ontario Managed Forest Tax Incentive Program (MFTIP) Guide* (January 2012), supra note 43 at p. 6.

[40] O. Reg. 73/94.

[41] Ministry of Natural Resources and Ministry of Finance – Managed Forest Tax Incentive Program (MFTIB), June 2004 – file name: EBR Review R2003005 (http://www.ontla.on.ca/library/repository/mon/8000/245333.pdf).

[42] See Ministry of Natural Resources' Managed Forest Tax Incentive Program (MFTIP) Program Enhancements: http://www.ontla.on.ca/library/repository/mon/11000/255087.pdf.

[43] *Ibid*.

[44] *Ibid*.

[45] P Information provided by Pierre Gagné. No further updates have been provided.

[46] R.S.Q., chapter F-4.1.

[47] http://www.mrn.gouv.qc.ca/english/forest/understanding/understanding-system.jsp.

assistance to private forest producers. The Assistance Program for the Development of Private Woodlots contributes on average 80% of afforestation expenses. However, only part of the agencies fund afforestation projects involving block plantations of hybrid poplar. Further, the program does not subsidize short-rotation intensive culture of willow, particularly because of the novelty of this type of crop and financial constraints[48].

Following the Private Forest Summit of 1995, the *Forest Act* was amended to establish 17 private forest development agencies («Agence régionale de mise en valeur des forêts privées»). According to the Act, the purpose of the agencies is to guide and enhance the development of private forests in their region, especially through (i) preparation and implementation of a private forest protection and development plan (PPMV), and (ii) financial and technical support for the protection and development of private forests. The 17 regional private forest development agencies are therefore responsible for administering the assistance programs to certified forest producers in each of Québec's administrative regions. Some of these regions have more than one agency[49]. These agencies are composed of representatives of the private forest land owners, forest companies (forest companies are official members of the agency), local municipalities and the Ministry of Natural Resources and Wildlife, «Ministère des Ressources naturelles et de la Faune» (MRNF)[50].

6.6.1 Managed Forest Land

Planning of forest management activities on private land is scrutinized by the regional agency and is subject to public consultation. Regional agencies for private forest land (development) are responsible for forest protection planning and forest development planning that meet objectives of the Regional County Municipalities (RCMs). Agencies submit their plans to the RCM in whose jurisdiction they operate in order to reach an agreement. The regional agencies have nothing to do with the management of public land. Planning of all forest management is subject to public consultation for both private and public forest lands[51].

Private forest land owners qualify for subsidies for site preparation, planting, tending and various silvicultural activities such as pruning, and these subsidies equally apply to forest land owners who plant and manage poplars; however, the number of treatments allowed for subsidies, the percentage paid by the landowner, the pruning height, etc. does vary from agency to agency[52]. The subsidies include free-of-charge planting stock, including hybrid poplar,

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[48] See "Short-rotation Afforestation and Agroforestry.
on Quebec Private Land: Review of Laws, Regulations, Policies, and Programs" (Information Report LAU-X-130E 2007) prepared by Natural Resources Canada, Canadian Forest Service and Laurentian Forestry Centre, pp. 35-36 (http://www.agrireseau.qc.ca/Agroforesterie/documents/Report(LAU-X-130E).pdf).
[49] *Ibid*., p. 13.
[50] http://www.mrn.gouv.qc.ca/english/forest/quebec/quebec-system-management-act.jsp.
[51] Information provided by Gisèle Bélanger, 2004. No further updates have been provided.
[52] Information provided by Pierre Périnet. No further updates have been provided.

supplied by the MRNF. One of the restrictive conditions of receiving these subsidies is that forest land owners cannot apply herbicides to control competing vegetation.

6.6.2 Real Estate Refund Program

Private forest land owners can also qualify for a reduction in land taxes under the Real Estate Refund Program. This includes private forest land owners who plant and manage poplars. Eligible owners can qualify for a tax credit equivalent to 85% of the amount of real estate tax (municipal and school taxes) payable on forest land. Forest producers who are not Québec residents are also eligible to receive a real estate tax reimbursement[53]. Forest land qualifies if registered by the certified forest producer who owns it. A "*Forest Producer's Certificate*" is issued by the MRNF[54].

6.6.3 Farmland for Woody Crops

Few poplar growers contemplate establishing SRIC poplar or willow crops on private farmland. One of the main reasons is that transfer of farmland to grow a woody crop, rather than a traditional agricultural crop, is regulated in Québec and the practice is strongly discouraged on prime farmland. Agricultural land is protected for agricultural crops by law[55] and SRIC poplar or willow crops are not considered agriculture. There are ongoing discussions in Québec that could lead to SRIC willow biomass crops being considered an agricultural crop production system[56]. In December 2007, the «Union des producteurs agricoles» (UPA) adopted a resolution to be presented to the Department of Agriculture, Fisheries and Food, «Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec» (MAPAQ) to recognize willow biomass crops as agricultural production[57].

Before planting trees, landowners need to obtain authorization from MAPAQ to get an exemption from the act that regulates agriculture and agricultural zoning; this is negotiated at a regional level and both MRNF and MAPAQ are involved. It is interesting to note that the definition of agriculture specified in the *Forest Act* includes, among other things, "the cultivation of the soil and plants, leaving land uncropped or using it for forestry purposes…". So according to the Act itself, agriculture does not automatically exclude use for forestry purposes[58]. Despite substantial interest from private land owners to plant hybrid poplar on farmland, obtaining authorization from MAPAQ to plant trees on agricultural land is very difficult[59].

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[53] http://www.mrn.gouv.qc.ca/english/forest/reimbursement/reimbursement-faq.jsp.

[54] http://www.mrn.gouv.qc.ca/english/forest/reimbursement/index.jsp.

[55] «*Loi sur la protection du territoire et des activités agricoles, ou zonage agricole*» (personal communication with Gisèle Bélanger by Cees van Oosten, 2004. No further updates have been provided.).

[56] Personal communication with Michel Labrecque and Charles Provost by Cees van Oosten. No further updates have been provided.

[57] Information provided by Charles Provost. No further updates have been provided.

[58] *Supra* note 54, p. 16.

[59] Information provided by Pierre Périnet. No further updates have been provided.

6.7 Atlantic Canada

In Atlantic Canada, agroforestry is still in its early stages. While there is growing awareness of agroforestry practices, none of the Atlantic Provinces has specific policies or tax measures promoting the management of *Populus* or *Salix* species. Interest is different in each province depending on local issues and emerging initiatives. The Eastern Canada Soil and Water Conservation Centre[60] (ECSWCC) have been actively involved in developing and promoting agroforestry in the region. Along with its partners, the ECSWCC has encouraged the adoption of two important agroforestry systems for the Maritimes: windbreaks and forested riparian buffers.

[60] ECSWCC web site: http://www.ccse-swcc.nb.ca/index2.cfm?title=1&lg=en.

7 STATISTICS & TECHNICAL INFORMATION

7.1 Forest Inventories – Canada

Canada has 10 percent of the world's forests that cover 397.3 million hectares (ha) of forest, other wooded land and other land with tree cover, which represent 53.8 percent of its total surface area. Canada's forest, other wooded land and other land with tree cover are made up of 347.7 million ha (87.5 percent) of forest, 41.8 million ha (10.5 percent) of other wooded land and 7.8 million ha (2 percent) of other land with tree cover. The predominant tree species on forest land are spruce (53.2 percent), poplar (11.6 percent) and pine (9.3 percent)[61]. The vast majority of the *Populus* inventory in Canada consists of natural stands[62].

As the provinces have jurisdiction over forest resources, provincial agencies carry out and maintain forest inventory systems. Standards for data collection and compilation differ between provinces and are not necessarily compatible. On a federal level, no new Canadian Forest Inventory has been published since 2001. Canada's National Forest Inventory is only available on-line in topic specific data sets and it is only based on data up to 2006 and none of the *Populus* tree species are separately identified in the data. The other more recent sources available for this report include the "The State Of Canada's Forests Annual Report 2011" and the "The National Forestry Database (NFD)", which was last updated in January 2012 but only contains partial information for 2010 and 2011 in relation to a very limited number of topics. Unfortunately, the various data tables are not broken down by species and only list the species groups 'Softwoods' and 'Hardwoods'. Therefore, production data for aspen and poplar are not available on a national or provincial basis from these sources.

There is also little consistency between provinces in how they keep records and report on forest inventories, if at all. This unfortunate situation has been made worse by federal and provincial budgetary cuts, especially in British Columbia. Therefore with the exception of Québec, no meaningful updated information from the last report is available.

7.2 Québec[63]

Significant hybrid poplar cultivation began nearly 15 years ago in Québec with forest companies that are now actively managing poplar plantations. Besides forest companies, some small private landowners have also gotten involved in hybrid poplar cultivation in Québec.

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[61] Natural Resources Canada.

[62] Canada's Forest Inventory 2001.

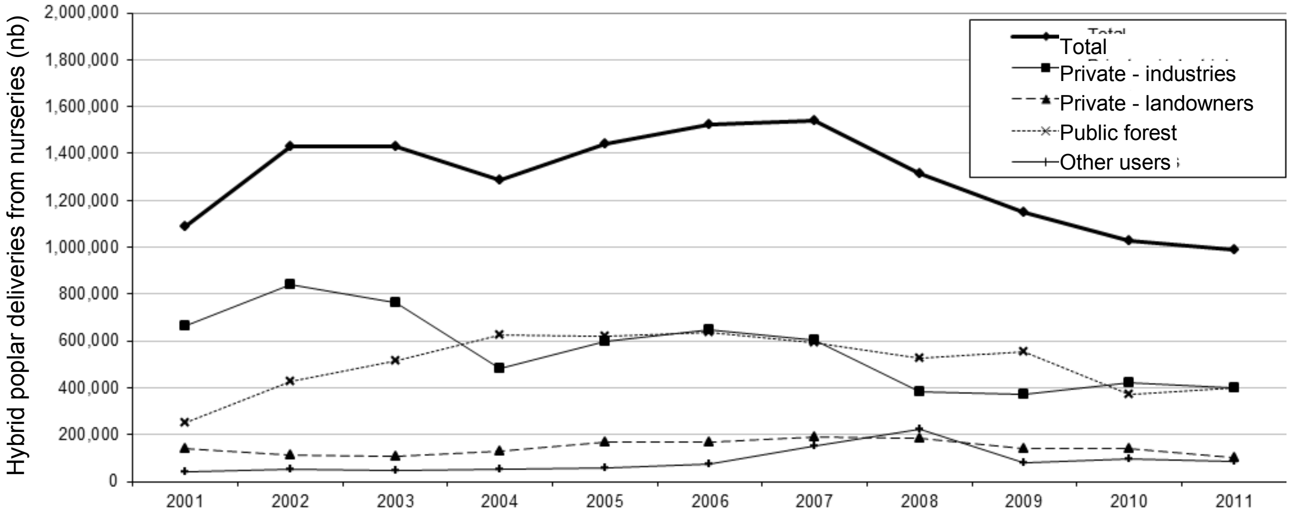
[63] This section is excerpted with edits from the paper *Hybrid Poplar Yields in Québec: Implications for a Sustainable Forest Zoning Management System*, by Julien Fortier, Benoit Truax, Daniel Gagnon and France Lambert. 2012

In the province of Québec, approximately 9000 ha of fast-growing poplar plantations are industrially managed, while small private landowners have planted only 1000 ha. Most of these poplar plantations are established on clearcut forest sites (approx. 8000 ha). […] Yields as high as 39.6 $m^3 ha^{-1} year^{-1}$ were observed after 6 years in a riparian agroforestry system (2222 stems ha^{-1}) along a stream in a fertilised pasture in southern Québec. Very high yields were also observed in the St. Lawrence Valley, on abandoned farmlands (22.4 $m^3 ha^{-1} year^{-1}$ after 8 years, Montérégie region; 16.4 $m^3 ha^{-1} year^{-1}$ after 6 years, Lanaudière region) at intermediate stem density (833 stems ha^{-1}). Available data from four clearcut site hybrid poplar plantations show yields varying from 0.5 to 1.4 $m^3 ha^{-1} year^{-1}$. These yields are lower than the mean yield of natural trembling aspen regeneration (3.4 $m^3 ha^{-1} year^{-1}$). In addition, forest conversion to "exotic" poplar plantations is generally perceived as detrimental to biodiversity and soil carbon sequestration. In southern Québec, three factors are highly correlated to yield for clones of various parentages: NO_3 supply rate in riparian soils, elevation (or climate) and soil P availability in abandoned farmland soils. Many Québec forest sites, particularly in the boreal shield ecozone, have acidic soils and harsh climate, with low mineralization rates. These sites generally cannot fulfill the very high nutrient requirements of hybrid poplars. Within a forest zoning management system, hybrid poplar plantations and agroforestry should be located on priority sites in the southern Québec landscapes, with low remaining natural forest cover, and where intensive agriculture is the dominant land-use. Elsewhere, intensive trembling aspen regeneration silviculture could be a sustainable alternative to forest conversion into hybrid poplar plantations.

Since 2001, 1 to 1.5 million hybrid poplars have been delivered annually in Québec to establish new plantations, but also to create some agroforestry systems (riparian buffers, shelterbelts, windbreaks, intercropping systems). An important decline in hybrid poplar deliveries has been obvious since 2007 (see also Figure 1). This is not surprising given the economic recession that strongly affected the United States economy at the end of 2007. As with other Canadian provinces, Québec's forest sector is strongly dependant on the US housing market[64]. The recent collapse of the US housing market, along with the sharp decline in newsprint sales and the rise of the Canadian dollar[65] are all potential explanations for the decrease of investments in fast-growing plantations in Québec. Another important fact is that the vast majority of hybrid poplar plantations are established by the forest industry, whether on private or public land. Hybrid poplar deliveries to small private landowners represent only a very small fraction of total deliveries over the last 10 years. *As part of this trend an* overall decline in usage can be observed and the under harvesting below allowable cut levels continues from previous years (See Figure 2).

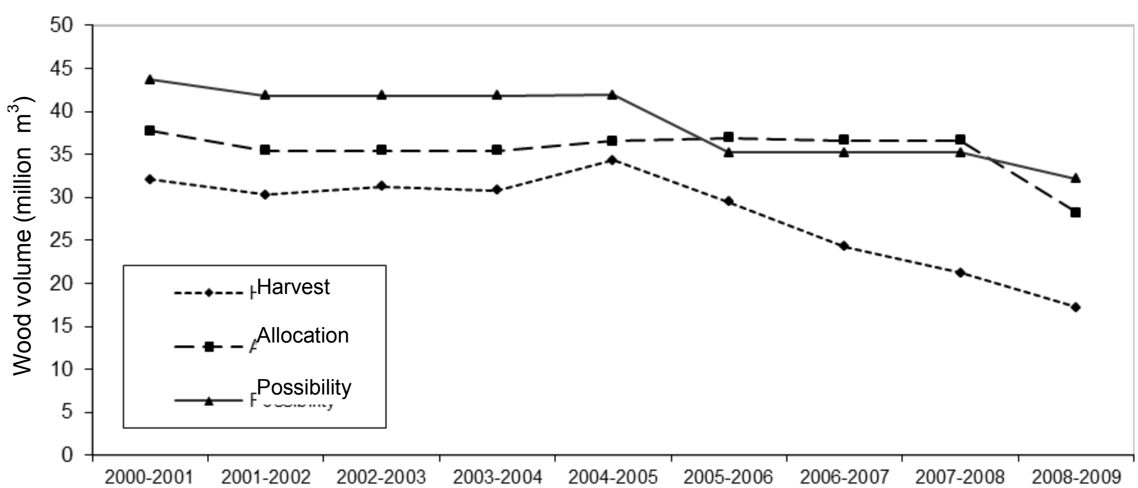
[64] Natural Resources Canada 2011.
[65] Natural Resources Canada 2011.

Figure 1



Evolution of hybrid poplar deliveries from nurseries (nb) to different users: industries that own private land (private - industries), small private landowners (private - landowners), industries operating in public forests (public forest) and all other users including watershed organisations, scientists, agro-environmental consultants, etc. (other users). Data obtained from the DPSP, MRNF.

Figure 2



Evolution of forest possibility, wood volume allocation and wood volume harvested in public forests of Québec during the 2000-2009 period (MRNF 2001-2010).

7.3 Identification, Registration and Control of Clones

Canada has no national regulations for the identification, registration or control of *Populus* or *Salix* clones. Although Canada has the 1990 *Plant Breeders' Rights Act*[66], it only applies to certain species prescribed by its regulations. Neither *Populus* nor *Salix* are on this list. *Populus* and *Salix* clones can and are widely propagated vegetatively for various purposes without any legal protection of intellectual property rights for the breeder, unless specific contractual arrangements are in place. There is no regulatory mechanism to ensure the origin and clonal identities of *Populus* or *Salix* clones. However DNA fingerprinting is available to check clone identity and it has been used. Individuals, companies or nurseries can have it done. There is also a clone directory on the PCC site that although voluntary – digitized all material from a much older 1988 version and includes most material in Canada. Because of the lack of regulatory framework nursery-produced clonal planting stock has been known to be contaminated with unknown clones. This continues to be a common occurrence, primarily stemming from a lack of quality control at the nursery level. Several provinces in Canada have regulations pertaining to deployment of exotic species, e.g. hybrid *Populus* clones on Crown land.

7.3.1 Province of British Columbia

Hybrid poplar stock to be deployed on Crown lands in British Columbia must be registered[67]. The registration standards exempt hybrid poplar from the genetic diversity requirements, which permits it to be deployed in pure clonal blocks not exceeding 10 hectares in size[68]. Hybrid poplar can therefore be deployed on Crown lands in British Columbia, provided it meets the Ministry of Forests and Range recommendations for specified geographic areas[69]. The regulations do not cover *Salix* species as these are not considered a commercial forest species in British Columbia. There are no standards for private land and landowners can plant exotic and hybrid poplar and willow trees without restrictions.

7.3.2 Province of Alberta

Alberta Sustainable Resource Development introduced a 'Standards for Tree Improvement in Alberta' manual in 2003 (revised in 2005), covering planting and regeneration of genetically improved tree stock on Provincial Crown land. A further revision in 2009 saw a change in the name to 'Alberta Forest Genetic Resource Management and Conservation Standards'[70]. The manual covers all reforestation genetic requirements – not just tree improved stock. There are

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[66] See http://laws.justice.gc.ca/en/P-14.6/ for the Act.
[67] http://www.for.gov.bc.ca/hti/treeseed/tech.htm
[68] Information provided by Dan Carson.
[69] Guidebook Update #2 - http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/veg/seedtoc.htm.
[70] http://www.srd.alberta.ca/LandsForests/ForestManagement/documents/FGRMS-AlbertaForestGeneticResourceManagementAndConservationStandards-May2009.pdf.

clear standards for all wild collections and deployment to seed zones as well. It also covers conservation requirements for any tree improvement programs. It lists specific standards for tree improvement and deployment for *Populus* – both aspen and poplar –, as well as *Picea* and *Pinus* species. The standards apply to Crown lands in the so-called Green Area. Hybrid poplars are not allowed to be planted on an operational scale on Provincial Crown land in the so-called Green and White Areas[71]. This restricts deployment of hybrid poplar and hybrid aspen to private lands only. Planting of monoclonal blocks (even of native material) is not permitted on Crown land; clones of native material can only be deployed in intimate clonal mixes, consisting of a minimum of 18 clones[72]. There are no such restrictions on private land.

7.3.3 Province of Québec

The Ministry of Natural Resources and Wildlife, «Ministère des Ressources naturelles, de la Faune et des Parcs» (MRNFP) in Quebec has been actively breeding and selecting hybrid poplar for use in the province since 1969 and keeps firm control of the hybrid poplar resource under its jurisdiction. Since the MRNFP provides free-of-charge hybrid poplar planting stock to companies that operate on Provincial public lands, as well as to eligible private forestland owners, it controls the production of planting stock and thus the deployment of hybrid poplar clones on both public and private land. Hybrid poplar clones are not made available to clients from outside the Province.

7.4 Conservation of *Populus* and *Salix* Genetic Resources

Several government agencies have been actively involved in the collection and conservation of genotypes of *Populus trichocarpa* (black cottonwood), *Populus balsamifera* (balsam poplar) and *Populus deltoides* (var. *monilifera*, a.k.a. *P. deltoides* var. *occidentalis* or Plains cottonwood).

7.4.1 *Populus trichocarpa*

The British Columbia Ministry of Forests and Range (MOF), Research Branch in Victoria (British Columbia) completed a common-garden trial with coastal *P. trichocarpa*, and selected material that was subsequently planted in three distinct locations in British Columbia. The trials include selections from eight populations from Oregon, Washington and coastal British Columbia[73]. The MOF also collected *P. trichocarpa* from the interior of British Columbia and that collection was planted in one of the three locations in the Province[74]. The material will be utilized in the future for environmental purposes, such as riparian restoration, and will also be available for future breeding purposes.

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[71] Information provided by Barb Thomas.
[72] Information provided by Tim Gylander.
[73] Information provided by Chang-Yi Xie.
[74] Information provided by Michael Carlson.

7.4.2 *Populus balsamifera* and *Populus deltoides*

The Agroforestry Development Centre, AAFC Agri-Environment Services Branch formerly called The Shelterbelt Centre of the Prairie Farm Rehabilitation Administration (PFRA) (combined AAFC-PFRA) at Indian Head, Saskatchewan made a range wide collection of *P. balsamifera* from across Canada and Alaska (the AgCanBaP collection). Clonebanks are being established at four locations across the country. The plan is to make selections from this collection based on local outplanting trials (clonal trials), followed by intra-specific hybridization between distinct populations. In early 2008 AAFC-PFRA collected *P. deltoides* var. *monilifera* (a.k.a. *P. deltoides* var. *occidentalis* or Plains cottonwood) along the South Saskatchewan River drainage in the southern Canadian Prairie Region. This collection was augmented with *P. deltoides* var. *monilifera* from the US Great Plains. Selections from this *P. deltoides* collection will be used for intra-specific hybridization between distinct *P. deltoides* populations. Besides the need for genotype conservation in both species, one of the objectives is to use the material for environmental projects, such as riparian restoration and shelterbelt use. This material will also be made available as breeding stock for SRIC hybrid poplar crops and poplar plantations.

7.4.3 *Salix* Species

Since 2004 the Canadian Forest Service (CFS), Atlantic Forestry Centre in Fredericton, New Brunswick has collected material of seven native willow species and has been studying the genetic variation between and within species populations[75]. The objectives are mainly aimed at ecological uses of native willow species in riparian zone restoration and phytoremediation. One interesting use is in bee pollination in blueberry production. The CFS is making willow clones available to blueberry farmers for bee pollination; willows are largely insect-pollinated and provide an early food source for bees. Also of great interest are traits related to biomass production. The Canadian Forest Service has exchanged material with several interested parties for field testing and further work, including future breeding and hybridization. The CFS is pursuing additional research objectives with the species and is very interested in cooperating with industry to advance the species as a source of biomass.

[75] Information provided by Alex Mosseler.

8 CULTIVATION

8.1 History of Growing Poplars in Canada[76]

There is a long history of growing poplars in Canada, dating back from before the time of European settlement. People who came to Canada in the 17th and 18th centuries brought with them trees such as Lombardy poplar (*P. nigra L.* cv. Italica) and silver poplar (*P. alba L.*). They also took eastern cottonwood back with them to Europe where they hybridized spontaneously with the European black poplar (*P. nigra* L.) creating a hybrid that became known as 'Canadian poplar' (*P. ×canadensis* Moench). Much later, in the early 20th century, this hybrid was introduced to Canada and gave rise to the very widely planted 'Carolina poplar' grown in Ontario, Québec and the Lake States.

Selection and breeding of poplars for wood production in Canada began in the 1930s, largely stimulated by Carl Heimburger in Ontario. By the 1970s, there were active breeding programs in Ontario, Québec and to a lesser extent in British Columbia. They followed classical breeding procedures, making numerous crosses of promising native and introduced clones, and testing and selecting the best progeny, showing the beneficial effects of heterosis, for further crossing and testing. The Ontario and Québec programs had close associations with similar programs in the United States and Europe and there was considerable interchange of reproductive material (cuttings, pollen and seeds). Meanwhile, similar strategies were followed at the Prairie Farm Rehabilitation Administration (PFRA) Shelterbelt Centre in Saskatchewan with breeding goals of improved suitability and vigour for windbreak plantings on the Prairies. The Shelterbelt Centre program has a history which is now more than 100 years old. The program has developed numerous poplar hybrids and has released several which have been widely planted across the prairies and have proved exceptionally well-suited for the purpose for which they were originally selected.

Although poplar breeding has been conducted in Canada for decades, significantly more activity has taken place in […] *the more recent past* (edit). This has occurred as forest companies look to secure fibre sources to meet future needs while recognizing that current fibre sources are coming from an ever-diminishing land-base. MacMillan Bloedel (now Weyerhaeuser) on Vancouver Island and Scott Paper (now Kruger) in the Fraser Valley of BC both relied heavily on earlier breeding work of Drs. Reinhard Stettler and Paul Heilman for their sources of hybrid planting stock. […]Scott Paper has been looking at developing new hybrids for the Fraser delta region. New breeding efforts began on the Prairies when the PFRA Shelterbelt Centre reactivated their breeding program at the end of the 1990s after it had lain dormant for over a decade. A year later, a joint effort between Alberta-Pacific Forest Industries Inc. (Al-Pac) and

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[76] This section is excerpted from the paper *Poplar Genomics to Poplar Production: Bridging the Gap for Best Use of our Resources and Knowledge*, http://www.poplar.ca/pdf/g2ppaper.pdf

PFRA also commenced with the mandate to complete 3-4 years of new hybrid breeding based primarily on crosses between Aigeiros (cottonwood poplars) and Tacamahaca (balsam poplars) and their associated hybrids. In addition, Al-Pac has conducted some hybrid aspen breeding on its own, and the Western Boreal Aspen Corporation, also in Alberta, has also been actively breeding aspen and hybrid aspen since the late 1990's. The Prairie Shelterbelt Program is now administered out of the AESB Agroforestry Development Centre and is part of the Agriculture and Agri-Food Canada's Agri-Environment Services Branch (AAFC-AESB) (combined AAFC-PFRA). AAFC-PFRA is currently completing a range-wide collection of balsam poplar, and pure species programs for both aspen and balsam poplar have been undertaken by a number of companies in Alberta. In BC, a range-wide collection of black cottonwood has also been made by the BC Ministry of Forests. The most extensive long-term poplar breeding program in Canada is that of the Québec Ministry of Natural Resources (MRNFP), aimed at producing hybrid poplars suited to each of the different regions throughout Québec.

Canadian poplar breeding programs have specific mandates which range from producing shelterbelt trees for farm fields and riparian stabilization along stream edges, to intensive plantations of pure stands for deployment on private lands, to using in a mixed planting strategy with conifers on public lands. In addition, with the increase in interest in bioenergy, programs in the adjacent Pacific Northwest, e.g. Greenwood Resources, are working with the US Department of Energy to determine the energy values of different hybrid poplar clones and how best to develop breeding strategies to meet energy needs in the future.

8.2 Genomics

In Canada, the *Populus* resource represents an enormous source of economic and environmental potential and many in the poplar breeding and nursery community have high hopes that advances in *Populus* genomics will eventually lead to opportunities to develop techniques to assist in the selection and breeding of *Populus* clones with desirable traits. There are three main research groups focusing on tree genomics in Canada, Treenomix[77] and the BC Genome POPCAN Project both at the University of British Columbia and Arborea[78] at Laval University in Québec City, Québec, Canada. Treenomix concentrates on conifer forest health, and spruce (*Picea*) is its main interest, some projects also have considered *Populus* in the past. Genome BC also located at the University of British Columbia completed one *Populus* project called Optimized *Populus* Feedstocks and Novel Enzyme Systems for a British Columbia Bioenergy Sector[79]. The researchers aimed to use genomics to optimize breeding and selection of fast growing poplars to improve their potential as a biofuel resource. As a continuation, the POPCAN[80] project looks at genetic improvement of poplar trees as a Canadian bioenergy

[77] www.treenomix.ca.
[78] www.arborea.ulaval.ca/en/.
[79] http://www.genomebc.ca/portfolio/projects/bioenergy-projects/completed/optimized-populus-feedstocks-and-novel-enzyme-systems-for-a-brit/.
[80] http://www.poplar.ca/pdf/edmonton11popcan.pdf.

feedstock with a specific focus on *P. trichocarpa* and *P. balsamifera*. Arborea concentrates on identifying "genes that govern naturally occurring phenotypic variation of commercially valuable traits in breeding populations of white spruce trees (*Picea glauca*)." From an operational viewpoint, the main emphasis of *Populus* tree selection and breeding is to create useful clones that realize significant heterosis (hybrid vigour), are very resistant or tolerant to diseases and pests, and are able to successfully withstand the rigours of the Canadian climate. Also considered in the clonal selection and testing are characteristic like fast growth, adaptability and potential for reforestation and reclamation in the energy sector. Other potentially important criteria, such as improved wood quality to meet specific demands for processing, are at this time still secondary considerations.

8.3 Nursery Stock Types and Production

Populus stock types vary depending on the region, the general availability of clones and the *Populus* species. For poplar (non-aspen), ease of rooting is one of the criteria that determine the choice of stock type for poplar. It varies with species; for instance *P. deltoides* is usually a problematic rooter, whereas *P. trichocarpa* is a very prolific rooter. Many of the hybrid clones are reasonable rooters; however, ease of rooting does vary by clone.

In British Columbia, the stock type of choice is a 1-year old unrooted, dormant cutting or whip. Cuttings (approximately 30 to 90 cm long) are used when establishing SRIC hybrid poplar crops, where site preparation and weed control can be optimized in a farm setting. For plantations that cannot be managed as intensively, e.g. forest plantations, unrooted whips (1.5 to 1.8 m long) are best when some height is needed to dominate the weed competition.

In the Prairie Provinces, Al-Pac is the corporation that has embarked on a large-scale SRIC hybrid poplar crop operation, using an agronomic approach to poplar crop farming. The company relies on rooted stock, preferably dormant bareroot stock and container-grown rooted stock (in that order). Experience with unrooted cuttings has been poor due to low soil moisture conditions after planting in the spring and early summer; this stock type is no longer in use. All stock is produced by private nurseries under contract with Al-Pac.

In Québec, the « ministère des Ressources naturelles et de la Faune » (MRNF) controls hybrid poplar nursery production and distribution. Since the vast majority of planting in Québec takes place on forestland and there is a 'no-herbicide' policy in place, large stock is required to ensure survival. The preferred stock type is a steckling, which is essentially the same as a set or rooted whip and varies from 1.2 to 1.8 m in length. The trees are grown in bareroot nurseries for one year from small unrooted cuttings. In the fall the stock is lifted, processed and cold-stored for outplanting the following spring. During the processing the roots are trimmed back to resemble a rough 'bottle brush'.

Salix species are generally planted in high density SRIC biomass crops and are established using unrooted dormant cuttings. For aspen the stock type has to be a rooted plant, either a bareroot or container plant. Aspen does not root from an unrooted stem cutting and this is a distinct disadvantage from a tree improvement and an operational perspective. For tree improvement and subsequent planting trials, it is critical to have access to uniform clonal material. To fully benefit from the yield gains through heterosis of selected hybrid clones, an efficient and low-cost vegetative mass propagation technology is required to allow operational clonal plantings.

8.4 Selection and Breeding

Hybrid poplars have been featured in a number of corporate selection and breeding programs. Examples of those companies are: Ainsworth Engineered Canada LP in Alberta, Al-Pac in Alberta and Kruger Products Limited in British Columbia. While these programs make very important contributions to the breeding stock they are shut down as fast as they are started based on market and corporate requirements. The orientation on practical application makes them an excellent resource for proven and reliable hybrid poplar clones. However their market orientation makes them long-term an unreliable resource to preserve and maintain hybrid poplar species. In terms of governmental organizations in Canada two organizations have been involved in the breeding of hybrid poplar clones, the Provincial Ministry of Natural Resources and Wildlife, «Ministère des Ressources naturelles, de la Faune» (MRNF) in Québec and the Agri-Environment Services Branch (AESB) Agroforestry Development Centre, formerly known as the Prairie Farm Rehabilitation Administration (PFRA) Shelterbelt Centre in Saskatchewan.

8.4.1 Ministère des Ressources naturelles, de la Faune

The MRNF has been involved in a hybrid poplar breeding and improvement program since 1969. The program has been producing superior hybrid poplar clones for deployment on both provincial public and private lands. Selected clones are suited to the highly varied growing conditions in Québec. The following selection criteria are used: Growth, cold tolerance, tree form, disease and insect resistance, site adaptability and wood quality. Five poplar species are used for hybridization: *Populus deltoides*, *P. balsamifera*, *P. maximowiczii*, *P. trichocarpa*, and *P. nigra*. Several hybrid aspen clones were also produced: *P. alba* × *P. grandidentata* and *P. tremula* × *P. tremuloides*. The MRNF has in excess of 5,000 clones under evaluation and the program has more than 40 operational hybrid poplar clones (Aigeiros-Tacamahaca hybrids) available for deployment. To maintain genetic diversity, the MRNF strives for 6-19 clones per planting region. For southern Québec the presence of *Septoria musiva* (stem canker) drives the breeding and selection of new clones. Eighteen clones of clone types[81] DN, TD, DNxM, NM and BM have been identified due to their resistance to *Septoria musiva*. Unfortunately, the fast-growing DM hybrid type is too susceptible to *Septoria musiva* to be planted in southern Québec and it is not cold tolerant enough to be planted in the northern regions where *Septoria musiva* is (still) absent. For the northern regions *P. maximowiczii* hybrids with *P. balsamifera* and *P. trichocarpa* are suitable.

[81] DN = *P. deltoides* × *P. nigra*; TD = *P. trichocarpa* × *P. deltoides*; DN×M = DN × *P. maximowiczii*; NM = *P. nigra* × *P. maximowiczii*; BM = *P. balsamifera* × *P. maximowiczii*; DM = *P. deltoides* × *P. maximowiczii*.

8.4.2 Prairie Shelterbelt Program

The Agri-Environment Services Branch (AESB) Agroforestry Development Centre[82] promotes the environmental and economic benefits of integrating trees with agricultural systems through research, extension and provision of seedlings to prairie farmers and other eligible clients. As a component of Agriculture and Agri-Food Canada's Agri-Environment Services Branch (AAFC-AESB), the Prairie Shelterbelt Program (PSP) (combined AAFC-PFRA) provides technical services and tree and shrub seedlings for establishment of shelterbelts and other agroforestry, conservation and reclamation projects on agricultural and eligible lands in Manitoba, Saskatchewan, Alberta and in the Peace River region of British Columbia. The seedlings provided are an incentive to producers adopting beneficial management practices and environmental stewardship. The aim of the Prairie Shelterbelt Program is to improve the performance and sustainability of the agricultural sector by helping to achieve the social, economic and environmental benefits of agroforestry. Tree and shrub seedlings are provided to eligible landowners at no charge [83]. AAFC-AESB has also been involved in breeding programs to create new hybrid poplars for SRIC hybrid poplar crops. The recent initiatives of genotype conservation of *P. balsamifera* and *P. deltoides* (var. *monilifera*) will eventually lead to intra-specific hybridization between distinct populations (within the species) as a first step.

AAFC-PFRA development strategy[84] aims to develop a diverse pool of 10-15 operational genotypes within 10 years of breeding. These clone mixes are developed as dynamic groups into which new selections are regularly infused. The traits targeted are classified as either: *Agronomic* (e. g. biomass, stem form, pest resistance, tolerance of cold and drought, wind firmness, adventitious rooting) or wood quality (e. g. specific gravity, fibre length, cell wall thickness, lignin content). All these traits have exhibited varying magnitudes of genetic variation and respond well to clonal selection. Disease resistance plays a universal role of singular importance in defining all *Populus* ideotypes. The pathogens of most significant impact include *Melampsora* leaf rust and *Septoria* canker. The AAFC-AESB mandate is also to develop varieties for ecological applications. However, genetic variation is sufficiently broad that elite varieties are likely to be found in the same population for both agroforestry and poplar farming applications. Partnerships with Al-Pac and others are helping to facilitate development of a gene pool for poplar farming clones numbering currently more than 10,000 genotypes in field trials. New genotypes from the breeding program include: *P. deltoides x P. maximowiczii*, Walker *x P. maximowiczii*, Walker *x P. nigra*.

AAFC-AESB also engages in selection and breeding work with willow material originating from the Canadian Forest Service (CFS), Atlantic Forestry Centre in Fredericton, New Brunswick. AAFC-AESB interest in willows is focused on well adapted to the drier upland sites of riparian

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[82] http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1186517615847&lang=eng.

[83] Source: Agri-Environment Services Branch (AESB) Agroforestry Development Centre.

[84] This section is excerpted with edits from Richard Hall, Iowa State University, Pierre Perinet, Ministère des Ressources naturelles et de la Faune, Québec and Brian Stanton, Greenwood Resources Inc. Conference presentation: *North American poplar breeding: good news/bad news* (http://www.poplar.ca/pdf/edmonton11perinet.pdf).

areas. Selection emphasis will be on growth performance, drought tolerance, cold tolerance and disease resistance (especially *Melampsora* leaf rust resistance or tolerance). The willow breeding program[85] follows traditional strategies of selecting superior individuals from genetically diverse populations. The first step of the program will identify appropriate parent material by selecting native and introduced *Salix* species. The second step is to generate genetic variability and hybrid vigour within the breeding population through controlled breeding. The third stage is to subject progeny to testing and selection. Testing is done through observation and measurement of the progeny growing in field environments as well as laboratory screening. Selection is based on the observation of multiple traits. The last stage is increase of selected clones through vegetative propagation. Under the willow breeding domain, based on three years of screening in the field, superior individuals of *S. eriocephala* and *S. discolor* are being used to do crosses. In the ongoing breeding work we will generate a series F_1 hybrids of E x E, D x D. Beginning in spring 2013 the F_1's planted into the field will be subjected to screening for growth, yield, phenology and pathogen resistance. Since 2008, the breeding program has generated 37 families with 1800 genotypes. In 2009, 118 of the best genotypes were selected on the basis of early biomass and planted in nursery trials.

8.4.3 Atlantic Forestry Centre

The Canadian Forest Service, Atlantic Forestry Centre in Fredericton, New Brunswick[86] is providing seeds for *P. balsamifera* (balsam poplar), *P. grandidentata* (largetooth aspen) and *P. tremuloides* (trembling aspen). In addition, the organizations are also involved in the selection of willow and research into willow seedling handling. Since 2004 they have collected material of seven native willow species and have been studying the genetic variation between and within species populations. The objectives are mainly aimed at ecological uses of native willow species in riparian zone restoration, biomass and phytoremediation. Research topic examples are "Five years' storage of seeds from three willow species" [87] and "Collecting and processing Salicaceae seeds"[88]. The CFS's Atlantic Forestry Centre is cooperating with the AAFC-AESB collecting native willow species, primarily *Salix discolor* (a.k.a. pussy willow) from across Canada, and *Salix eriocephala* (heartleaf willow) over a range from Saskatchewan to the Atlantic Provinces. This collection is co-located at the CFS's Atlantic Forestry Centre in Fredericton and the AAFC-AESB Shelterbelt Centre in Indian Head and is managed in common gardens.

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[85] Source: AAFC-AESB Salix Breeding Program, William Schroeder, Raju Soolanayakanahally.
[86] http://www.lib.unb.ca/Texts/Forest/english/.
[87] http://nofc.cfs.nrcan.gc.ca/publications?id=30094.
[88] http://nofc.cfs.nrcan.gc.ca/publications?id=30093.

9 FORESTRY

9.1 Planting

Depending on the region, the availability of stock and suitable clones for *Populus* stands – whether a dormant unrooted cutting, bareroot stock or container-grown stock – is planted in a systematic pattern on properly prepared farmland. In the Prairie region rooted stock is preferred due to dry soil conditions at planting time. Bareroot stock is preferred over container-grown stock due to lower costs and a higher proportion of coarse roots. In Québec the preferred stock type is a steckling, which is a rooted whip or set of 1.2 – 1.8 m in length. This stock type is particularly useful where weed control is not feasible, such as in forest plantations. Unrooted, dormant cuttings are typically 30 to 90 cm long and are used in British Columbia. The increase in cutting length to 90 cm is a fairly recent development adopted by Kruger Products Limited and is particularly useful in situations where complete site preparation is not possible (e.g. on second rotation crops on farmland) and weed control cannot be complete.

9.2 Short-Rotation-Intensive-Culture (SRIC) Crops

SRIC hybrid poplar crops are almost exclusively grown on existing farmland or newly-cleared agricultural class lands in private ownership, using agronomic methods (Table 1). The land is either owned or leased. Except for a few small private crops of hybrid poplar, currently almost all SRIC hybrid poplar crops in Canada are for the purpose of supplying pulp fibre or logs for engineered wood products, such as panel board or OSB. The cultivation approach for SRIC willow does not differ much from the cultivation of an SRIC hybrid poplar crop, in particular poplar stoolbed production systems. However most willow production is still in an experimental phase and the majority of applications fall under an environmental application.

Table 1 - Area of hybrid poplar short-rotation-intensive-culture (SRIC) crops in Canada that are reported to PCC by Operator.

	Planted 2004-2007	Total crops to and incl. 2007	Planted 2008 to 2011	Reported total for 2011
	Hectares	Hectares	Hectares	Hectares
Kruger Products Ltd. - BC	70	1,070	123	3,411
Catalyst Paper Corp. - BC	0	200	0	Unknown
Alberta-Pacific Forest Ind. Inc. - AB	4,940	5,640	4,000	9000
Ainsworth Engineered Canada LP - Alberta	215	215	390	605
AAFC-AESB (*)– SK	Unknown	9,030	1,470	10,500
Domtar Inc. – QC	0	2,500	suspended	4,000
Agro Énergie inc. - QC				43
MRNF – QC	200	350	0	Unknown
Total	**5,425**	**19,005**	**5,9834**	**27,559**

(*) Agri-Food Canada's Agri-Environment Services Branch Prairie Shelterbelt Program.

9.3 Yield, Crop Density and Rotation Length

Crop (stand) density of SRIC hybrid poplar crops depends on the end product. Most crops to date are intended to produce pulp fibre; however, one company has started planting SRIC hybrid poplar for the production of OSB feedstock. Pulp crops are planted at fairly high densities, usually around 1,111 stems per hectare (Table 2). Poplar growers make allowances for a percentage of crop mortality to arrive at the right number of stems per hectare at harvest. In British Columbia, Kruger Products Limited requires a larger piece size for its conversion facility, hence the lower stand densities.

Table 2 - Yield, crop Density and rotation length - Short-rotation-intensive-culture (SRIC) crops.

	Mean Annual Increment – MAI $m^3\ ha^{-1}\ yr^{-1}$	Crop Density stems per ha (spha)	Rotation Length Year	Comments
Kruger Products Ltd. - British Columbia	25	550	15	Pulp wood
Alberta-Pacific Forest Ind. Inc. - Alberta (*)	16	1,111 changed to 1,275 in 2011	18-20	Pulp wood
Ainsworth Engineered Canada LP - Alberta(**)	Unknown	816	Unknown	OSB feedstock

(*) These values are for hybrid poplar.

(**) Ainsworth recently decided to adopt a 3.5x3.5 m crop spacing for a crop density of 816 stems per hectare.

Source: Personal communication by Cees van Oosten with Kruger and Ainsworth in 2008 and personal communication with Barb Thomas for Alberta-Pacific in 2012.

In the Prairie Provinces, Al-Pac changed its planting density to 1,275 (2.8m x 2.8m) from 1,111 stems per hectare, making an allowance for approximately a 15% mortality during establishment and recognizing the columnar form of the Walker clone which does not close canopy nor fully capture the site at a 3m x 3m spacing. Al-Pac has also begun deployment of hybrid aspen on selected sites across their plantations. Ainsworth Engineered Canada LP in Alberta is a recent newcomer to the field of SRIC hybrid poplar crops. The company started planting at 1,111 stems per hectare at 3 × 3 m crop spacing. They recently changed this to 3.5 × 3.5 m crop spacing or 816 stems per hectare and based this on a crop density report[89] commissioned by ForestFirst in Prince Albert, Saskatchewan[90].

[89] Crop Density for Hybrid Poplar in the Prairie Provinces - authored by Cees van Oosten – SilviConsult Woody Crops Technology Inc.; http://www.saskforestcentre.ca/uploaded/200501_-_Crop_Density_for_Hybrid_Poplar.pdf.

[90] Information provided by Fred Radersma, 2008.

9.4 Forest Plantations

The vast majority of poplars planted on forestland are hybrids. This planting is classed as a reforestation activity. The establishment of the main forest plantations with *Populus* species takes place in British Columbia and Québec. In British Columbia Kruger Products Limited uses tall (1.5 to 1.8 m) dormant unrooted whips that are planted in the spring. It is the only company establishing significant hybrid poplar forest plantations in the province. Kruger Products refers to these plantations as 'extensive' plantations. The company frequently uses a small hydraulic excavator to create 440-450 individual planting spots per hectare by removing harvest debris, competing vegetation and mixing up the humus and mineral soil layers. Where soil conditions are unfavourable (wet ground), planting mounds are created to improve drainage and soil temperature; the stand density could be as low as 280 stems per hectare in this case. Shortly following planting, planters place a small amount of NPK (9-40-4, plus minor elements) fertilizer close to the root zone at shovel depth. Weed control is done as needed and registered herbicides may be used on plantations located close to the pulp mill near Vancouver. This plantation system has proven successful over time. The company manages about 3,300 hectares of these forest plantations in coastal British Columbia and plants an average of 75-85 hectares per year. In Québec hybrid poplar planting occurs on private and provincial public forestlands. The preferred stock type is a steckling (rooted whip or set) of 1.2 to 1.8 m in length. Plantations are established to augment wood supplies for pulp and paper mills or OSB plants.

9.5 Disturbances

A total of 13.7 million ha of all forested land in Canada were affected by insect defoliation in 2008 and 0.8 million ha were lost due to forest fires in 2009[91]. For the *Populus* stands the increasing use and expansion also comes with the effect that diseases and insects affecting those stands are expanding at the same rate if no counter measures are taken. This is especially apparent in intensive monocultures. One prominent example is *Septoria musiva* (stem canker), which has been steadily spreading across the Prairie region, due to an increase in the amount of established SRIC hybrid poplar crops. Also the northward shifting and changes in climate and eco-zones that are part of the climate change development, put additional pressure on *Populus* stands with challenges from insects and diseases that they previously where not exposed to, with devastating consequences. In light of these specific challenges, it is unfortunate that no systematic attempts have been made so far in Canada to use biological means to control agents of plant diseases and so besides breeding and selection for resistance, mostly traditional chemical-based approaches are used.

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[91] Natural Resources Canada.

Table 3 – Main *Populus* and *Salix* Diseases and Pests in Canada

	Name	Common name	New Area or Area of Persistent Problem
Diseases	*Septoria musiva*	Septoria stem canker	Québec, Ontario, Prairie region and British Columbia
	Melampsora ×columbiana	(Hybrid) Leaf rust	British Columbia
	Melampsora larici-populina	Eurasian rust	Québec
	Marssonina	Leaf spot fungus	Alberta/Prairies
	Melampsora (unidentified)	Leaf rust spp.	Québec, BC
Insects	*Cryptorhynchus lapathi*	Poplar willow borers	Saskatchewan (southern) and coastal British Columbia
	Hamamelistes spinosus	Witch hazel gall aphids	Alberta
	Lygus lineolaris	Tarnished plant bug	Quebec (southern Quebec) - nursery
	Popilla japonica	Japanese beetle	Quebec (southern Quebec) - nursery
	Caelifera	Grasshopper	Alberta, Saskatchewan
	Nematus sp	Sawfly	Alberta
	Aphid spp.	Aphid / Plant lice	Quebec (southern Quebec) - nursery

9.5.1 *Septoria musiva*

Septoria musiva causes leaf blight and, more importantly, necrotic lesions (cankers) that often result in stem breakage. In 2006, *Septoria musiva* stem canker was positively identified in southwestern and south coastal British Columbia (Fraser Valley and one coastal river drainage about 100-200 km north of Vancouver). This new disease in British Columbia has affected several SRIC hybrid poplar crops as well as stoolbeds at one nursery in the eastern Fraser Valley. This was the first documented presence of the disease west of the Rocky Mountains in North America. *Septoria musiva* is thought to have been present for at least 11 years[92]. A survey in 2007 by the BC Ministry of Forests, Lands and Natural Resource Operations, in cooperation with the University of BC (UBC) Department of Forest Sciences, conducted field surveys to assess the extent of the distribution of *S. musiva* on hybrid and native *Populus spp*. This survey identified several 'epicentres' and determined that most hybrids with a *P. maximowiczii* parent are at risk; however, there were notable exceptions (clone NM6, *P. nigra* × *P. maximowiczii* and clone 265-

[92] Wrap-up Report "11 December 2007 – *Septoria musiva* survey". Internal Ministry of Forest and Range report authored by Cees van Oosten – SilviConsult Woody Crops Technology Inc.

28, *P. trichocarpa* × *P. maximowiczii*). The survey work is continued with roadside collections from black cottonwood. Results of the 2008 and 2009 roadside collections resulted in two important findings; 1), *S. musiva* leaf spots occurred outside of the hybrid nursery, and 2), *S. musiva* occurred on native *P. trichocarpa*, however, the incidence appears very low[93].

Septoria musiva stem canker infections are on the rise in the Prairie region as a result of increasing number of SRIC hybrid poplar crops. One of the issues there is the heavy reliance on one female clone ('Walker', a three-way cross between a *P. deltoides* female and a hybrid male clone of *P. nigra* × *P. laurifolia*). 'Walker' has been seen in the past as having a susceptibility to the disease. However more recent reports from Alberta indicate greater resistance as compared to performance in Saskatchewan. Besides steadily spreading across the Prairie region *Septoria musiva* is also present in Québec, in some areas of that province representing a major selection criteria and in Ontario, where it has shut down most projects in that province.

9.5.2 *Marssonina*

It is difficult to quantify the impacts of *Marssonina*. Each year it is present in Alberta plantations although the incidence and severity of infection varies by clone as well as based on weather conditions. *Marssonina*, especially in combination with additional stresses, can contribute to reduced growth. Negative impacts of *Marssonina* are often most evident in nursery stoolbeds where infection levels are regularly high.

9.5.3 *Melampsora* Rust Species

Melampsora larici-populina has been reported in at least one nursery and several stands of hybrid poplar in Québec[94]. After a temporary absence, the hybrid rust *Melampsora ×columbiana*, a hybrid rust between *M. occidentalis* and *M. medusae*, is continuing its onslaught in southwestern coastal British Columbia and therefore rust resistance has become the primary selection criteria for disease in the Pacific Northwest region. It is primarily affecting *P. trichocarpa* × *P. deltoides* hybrids. The area of SRIC willow crops is still small and most crops are still experimental in Canada. Disease and insect problems have yet to get established; however, one willow farmer in Québec reports that *Melampsora* leaf rust (exact species unknown) has become a problem[95].

9.5.4 Insects

Poplar willow borers (*Cryptorhynchus lapathi*) have been reported in southern Saskatchewan[96] and southwestern coastal British Columbia. The borers in British Columbia affected a crop of eight-year old SRIC hybrid poplars, which turned out be an inadvertent mix of three clones of *P. trichocarpa* × *P. deltoides*. One of these clones was very susceptible and was killed by the borer

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[93] Septoria musiva On Poplar In The Upper Fraser Valley Of British Columbia , S. Zeglen, S. Beauseigle , H. H. Kope, R. C. Hamelin.
[94] Information provided by Pierre Périnet.
[95] Information provided by Francis Allard.
[96] Information provided by Larry White.

attack; the crop was harvested prematurely in 2007 to recover the wood. Alberta-Pacific Forest Industries Inc. reported that several young SRIC hybrid poplar crops in Alberta were affected by Witch hazel gall aphids (*Hamamelistes spinosus*); however, damage appears to be limited[97]. The aphids were also present in poplar nurseries in Alberta. Québec reported a problem with Japanese beetle (*Popilla japonica*) in one of their poplar nurseries[98]. This insect is not normally associated with poplar. Other nursery problems were reported with the tarnished plant bug (*Lygus lineolaris*) and aphid species. Sawfly and grasshopper have been deemed to have a significant enough impact on plantations to warrant EUR (Emergency Use Registration) of insecticides for their control. In 2009, 13% of the spring planted hectares at Al-Pac were destroyed by grasshoppers. In 2011, under EUR, about 500 hectares of plantations were treated immediately prior, or just after, planting to limit crop damage. In 2010, a 52 hectare plantation experienced 70% defoliation as a result of sawfly. In 2011, under EUR, about 200 hectares of plantations were treated to limit crop damage (M. Sulz, Pers. Com.).

9.5.5 Pesticides

The Poplar Council of Canada (PCC) has established the Pesticide Working Group (PWG) with the objective of expanding the range of available pesticides and fungicide products for use in SRIC (hybrid) poplar crops, including aspens, poplars and their hybrids and willow. The PWG has been successfully promoting SRIC (hybrid) poplar and SRIC willow crops on farmland as agronomic crops. The goal is to apply for 'User Requested Minor Use Label Expansion' (URMULE) applications to the Pest Management Regulatory Agency (PMRA)[99] of Health Canada, to obtain labeling for useful pesticides and fungicide. Since 2004 the PWG partnership joined the Prairie Pesticide Minor Use Consortium (PPMUC) as a member. The PPMUC is a consortium of various agricultural crop producer organizations and provides administrative, technical and analytical services to its members. The PPMUC deals with all the chemical companies (called the product 'Registrants'), obtains their agreement to support minor use labeling of their products for our uses, and handles all the business dealings with the PMRA. Almost all PWG work dealing with pesticide registration runs through the PPMUC.

PCC has also established a Disease Working Group as a sub-group of the Pesticide Working Group (PWG); it was founded in 2010. It has 2 primary objectives:

- To establish a network of pathology labs across Canada able to provide disease identification services to the exact species level, using DNA technology where required. This service will be offered on a 'fee-for-service' basis to poplar and willow growers, breeders etc.
- To ensure disease identification methodology for poplar and willow uses standardized protocols and results meet certain quality standards.

It is expected that the first pathology lab to offer this service will commence in 2012.

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[97] Information provided by Al Bertschi.
[98] Information provided by Roger Touchette.
[99] PMRA is part of Health Canada. PMRA regulates the registration and use of pesticides in Canada.

10 HARVESTING AND UTILIZATION

In most cases, *Populus* stands are harvested by clear-cutting using all-tree harvesters in plantations and specially constructed machinery for short rotation biomass plantations.

10.1 Pulp & Paper

The value of naturally growing native aspen (*P. tremuloides*) in pulp and paper manufacturing is well recognized in North America. Currently, aspen is used by several large pulp mills in Alberta and pulp & paper mills in Québec[100]. Most pulp mills accept a certain percentage of poplar (balsam poplar and cottonwood) in their wood supply. Aspen pulp is manufactured using the Kraft (chemical) process; or CTMP[101] process.

Use of *Populus* species for pulping requires less bleaching chemicals in the Kraft process and less brightening chemicals in the CTMP process. The end products are many and include high quality paper, for use in photographic grades and high gloss magazines. One mill in British Columbia makes groundwood pulp for its tissue business[102], using black cottonwood (*P. trichocarpa*), balsam poplar (*P. balsamifera*), as well as hybrid poplar from its forestlands and SRIC hybrid poplar crops from leased farmlands. Plantation or SRIC (hybrid) aspen and hybrid poplar prove to be very suitable replacements for the aspen stock currently used. FPInnovations[103] – Paprican (Pulp and Paper Research Institute of Canada) has carried out research into the use of SRIC hybrid poplar fibre in the manufacturing of pulp and paper. The results are very encouraging and the fibre offers similar advantages to that of naturally growing native aspen.

10.2 Solid Wood & Composite Wood

There has been a growing interest in use of naturally growing native aspen (*P. tremuloides*) for higher-value lumber products and several small entrepreneurs have been experimenting with lumber recovery, drying and manufacturing. Previous National Reports to the IPC[104] reported on the developmental work with hybrid poplar for products ranging from tongue & groove wall paneling, window and wall mouldings, to furniture and decorative boxes. FPInnovations - Forintek[105] was involved in much of the wood-technical assessments. Native aspen is the preferred stock for the manufacture of Oriented Strand Board (OSB) and TimberStrand®

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[100] Daishowa-Marubeni International Ltd., Alberta-Pacific Forest Industries Inc. and Millar Western Forest Products Ltd. in Alberta; Catalyst Paper Corporation in British Columbia; Domtar Inc. in Quebec.

[101] CTMP = Chemi-thermo-mechanical pulp.

[102] Kruger Products Limited.

[103] FPInnovations "brings together FERIC, Forintek, Paprican, and the Canadian Wood Fibre Centre of Natural Resources Canada, to create the world's largest private, not-for-profit forest research institute". http://www.fpinnovations.ca/index.htm.

[104] The Canadian Reports to the 21st and 22nd Sessions of the International Poplar Commission in Seattle (Wa), USA and Santiago, Chile respectively.

[105] http://www.forintek.ca/.

laminated strand lumber (LSL)[106]. OSB has largely displaced plywood as a building product used in sheeting in North American construction; TimberStrand® is used for structural (indoor) use. As in the pulp and paper business, there has been increased interest in use of SRIC hybrid poplar wood for composite wood products. Much of this development work was carried out by FPInnovations - Forintek. Several products were manufactured from SRIC hybrid poplar and the test results were very encouraging. Products made and tested include OSB, Laminated Veneer Lumber (LVL), Medium Density Fibreboard (MDF) and plywood. High quality aspen and poplar veneers can be covered with expensive veneers for cabinetry.

10.3 Biomass

Biomass refers to biological material that comes from living or recently living plants, including trees. Biomass provides the basis for renewable bio-energy, bio-fuels and other bio-products that are increasingly being used in place of fossil-fuel based products. With its vast resources, Canada's forests represent an abundant source of biomass, including the following:

- residues or by-products left over from manufacturing processes;
- biomass plantations (for example, poplar or willow species);
- harvest residues;
- trees killed by natural disturbances such as fire, insects or disease.

Canadian research is underway to develop new products and technologies to maximize the value derived from forest biomass along the entire forest industry value chain. Through initiatives such as the Transformative Technologies Program (being delivered by FPInnovations on behalf of Natural Resources Canada), new and innovative products are being developed.

As one of the fastest-growing species of trees, hybrid poplars (*Populus* spp.) are well suited for the production of bio-energy (e.g. heat, power and transportation fuels), fibre (e.g. pulp and paper) and other bio-based products (e.g. organic chemicals and adhesives). While Canada's largest source of biomass energy is waste from sawmills and pulp and paper mills, governments and industry are looking at the potential of fast growing plant crops such as poplars and willows to boost the availability of biomass-derived energy in Canada.

In 2011, a project was announced to enhance the development of clean energy by using genomics to enhance breeding and selection of poplar trees to improve their potential as a bio-fuel resource. To help meet new federal and provincial requirements for renewable fuel content in gasoline, Genome Canada, Genome BC, and other partners have funded a $9.8-million research project known as "POPCAN: Genetic Improvement of Poplar Trees as a Canadian Bioenergy Feedstock".

[106] http://www.weyerhaeuser.com/Businesses/WoodProducts/TimberStrand. Timberstrand was a product innovation by MacMillan Bloedel Limited of Vancouver, B.C., Canada. MacMillan Bloedel was obtained by Weyerhaeuser in 1999.

The current production of bio-fuels, which are almost exclusively derived from agricultural residues, is insufficient to produce the requisite volume. Researchers at the University of British Columbia are using genomics to study tree growth at the molecular level, as well as wood traits associated with bio-fuel suitability in *P. trichocarpa* and *P. balsamifera.* Their aim is to develop short-rotation, fast-growing trees that can grow in a variety of climates across Canada and produce wood that can be more readily converted to biofuel while minimizing the ecological footprint. Concurrent with the genomics research, a team of economists led by Dr. Marty Luckert at the University of Alberta is looking into the economic benefits of changing forestland to fast-rotation poplar plantations. The potential payoff from a new energy crop could include job creation and stability in rural communities.

At the Murdoch Lake Agroforestry Demonstration Site in Northern Alberta, a number of research and demonstration projects have taken place since 2002. Among the projects is a planned silvopasture system in one of Al-Pac's hybrid poplar plantations, which was started in 2011 by a group of agrologists and foresters.

Beyond energy production, researchers are also studying how poplars might be turned into liquid fuel, or ethanol. Currently, ethanol is primarily produced using sugars in corn that are fermented to produce alcohol, which is then blended with petroleum products. Researchers are looking to use cellulosic feedstocks, which include not just corn stover, but also wood chips. Findings from such research could help advance the fledgling cellulosic ethanol industry. The process for producing cellulosic ethanol involves extracting sugars from the cell walls of plant material, otherwise known as biomass. As most plants contain more biomass than grain, cellulose could potentially provide more ethanol than grain. With trees, the biomass volume is even larger than it is with most row crops. Poplar trees offer advantages over other species as a cellulosic ethanol feedstock. In particular, poplars can be vegetatively propagated and poplar trees are very efficient at photosynthesis. To address some of the challenges of growing poplars as an ethanol feedstock – including the removal of sugars from cell walls and large-scale planting and harvesting – U.S. researchers are looking to develop genetically modified poplar varieties that have altered lignin composition and content[107].

[107] In May 2011, Purdue University began a five-year study to determine to determine the viability of poplar species as an ethanol feedstock and cash crop for Indiana farmers. (http://www.purdue.edu/newsroom/research/2011/111020MeilanPoplar.html).

11 ENVIRONMENTAL APPLICATIONS

11.1 Remediation

The use of poplar and willow trees in environmental remediation applications continues to be studied and explored in Canada. By planting vegetation such as poplar and willow on site, pollutant concentrations from contaminated sources can be removed and this process is referred to as phytoremediation. Although phytoremediation has been successfully tested in many locations, full-scale applications are still limited in Canada.

11.1.1 Selected Current Projects

One area of application has been the remediation of abandoned contaminated mine sites. In eastern Ontario, the Provincial Ministry of the Environment is using hybrid poplar trees to help remediate the tailings area of the Deloro Mine Site. This tailings area is 13 hectares in size and is contaminated with arsenic, cobalt, copper, nickel, and low-level radioactive materials. The remediation strategy is to cover the existing limestone cap with an engineered cap measuring 1.75 metres, and to plant 20,000 hybrid poplar trees as well as grasses. It is anticipated that these measures will prevent 90 percent of precipitation (surface water) from infiltrating the tailings area[108].

A non-governmental organization in Saskatchewan called HELP International has installed the first forestation landfill caps and landfill forest filters in Canada in the City of Weyburn, as well as in the towns of Halbrite and Stoughton, among others. The project involves planting high water usage trees in urban communities to decontaminate soils and waters before they reach water sources[109].

In Alberta phytoremediation has been used in the reclamation of oil sands mining sites. For example, Syncrude has successfully reclaimed a mining operation site, which initially consisted of a 30 meter deep hole from the top of the oil sands down to the limestone. Twelve years ago Syncrude replaced the over-burdened back to the mine site, contoured the land and put reclamation soil on top, and as part of their standard reclamation process, planted trees including poplar about two years later. The result has been the creation of a wetland complete with naturally forming bulrushes and willows[110].

Two phytoremediation projects by Passive Remediation Systems (PRSI) in British Columbia have focused on using poplar trees in the remediation of landfill sites. In Armstrong, a poplar plantation now in its seventh growth season, remedies on well over one acre effluent/leachate

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[108] www.ene.gov.on.ca/environment/en/local/deloro_mine_site_cleanup_project/index.htm.
[109] www.help-international.com/~-Forestry--and--Phytoremediation.php.
[110] www.capp.ca/energySupply/peopleWorkforce/Pages/RonLewko.aspx.

every year from the North Okanagan Regional District landfill operation. The plantation is utilizing five different clones: D-TAC7, D-TAC8, TXD 52-229, TXD 53-242 and NM 6. The best varieties of the five have emerged. D-TAC7 (from older stocks), is the top performer, but has the highest incidence of *Septoria* canker. They seem however to own the best root system as none have blown over in wind storms. They have lesser brittleness causing top and branch breakage. The NM6 clone has also developed a good root system, but are brittle and show the most breakage of any clone on that site. The next best performer was the TXD 53-242 clone. They are somewhat brittle and suffer some blow over but seem to handle stress of the untreated landfill leachate quite well or equally as well as D-TAC7. D-TAC8 lack consistency in their growth patterns. TXD 52-226 performed poorly in height and size. They showed stress and are weak.
In Salmon Arm, 1100 hybrid poplar trees were planted in 2011 at the Columbia Shuswap Regional District decommissioned landfill. This phytoremediation system has treated around 1.1 million liters of leachate, and the plantation is irrigated with recycled leachate. In addition, there is a methane gas recovery system underneath the cap which provides natural gas heating in hundreds of homes in Salmon Arm[111].

11.1.2 Selection of Phytoremediation Service Providers

Nature Works Remediation Corporation with offices in British Columbia and Ontario specializes in the treatment of contaminated wastewater through bioremediation technologies[112].

RPM Ecosystems Canada based in Toronto offers RPM trees, which are trees grown under a process that nurtures individual plants to optimize root growth. Because of their extensive root systems, the RPM trees are able to survive in the poorest soil conditions, making them ideal for remediation projects[113].

LandSaga Biogeographical Inc. based in Ontario, offers remediation services of contaminated soils and groundwater for landfill and industrial site management[114].

Waterloo Environmental Biotechnology Inc. in Ontario offers phytoremediation services of soils impacted by organic contaminants, salt and metals. Their remediation systems are based on multiple complementary techniques and target petroleum and salt impacted soils[115].

Pollutech Group of Companies also out of Ontario, offers phytoecology assessments of polluted sites, and as part of their approach they investigate the potential role of plants in the remediation of these contaminated sites[116].

Passive Remediation Systems based in British Columbia, is applying phytoremediation technology to landfill leachate by way of irrigating hybrid poplar orchards in the landfill buffer zones. It also offers remediation of old mine sites and stream side remediation.

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[111] www.prsi.ca.
[112] www.nature-works.net.
[113] www.rpmecosystems.ca/phytoremediation-and-phytostab.
[114] www.landsaga.com/phytoremediation.php.
[115] www.waterlooenvironmentalbiotechnology.com/services.html.
[116] www.pollutechgroup.com/Page/11314/0-1/Phytoecology+Assessments.aspx.

11.1.3 Selected Research Projects:

In Québec, Bergeron, Lacombe, Bradley, et al. (citation 23) examined the effects of tree-based intercropping systems using hybrid poplars to capture nutrients in alley crops thereby reducing soil nutrient leaching. Two study sites were used, one in Saint-Rémi, Québec where three hybrid poplar clones (*P. trichocarpa x P. deltoides* TD-3230*, P. nigra x P. maximowiczii* NM-3729*, P. deltoides x P. nigra* DN-3308) along with black walnut and white ash trees were studied. The second site was located in Saint-Édourd-de-Maskinongé, Québec where two hybrid poplar clones (*P. deltoides xnigra* DN3333*, P. deltoides x P. nigra* DN3579) alternating with red oak, red ash, and white ash were studied.

Guidi and Labrecque (*citation 97*) studied the effects of varying water supply levels on 1-year-old potted willow and poplar plants in order to assess, among other things, their performance in removing N and P from contaminated wastewater. The research was done at the Montreal Botanical Gardens, and *P. maximowiczii x P. nigra* (clone NM5) and *S. viminalis* (clone SQV 5027) were used.

A trial test by Teodorescu, Guidi, and Labrecque (*citation 286*) experimented with a new planting technique for willows being used to remedy environmental problems. The experiment was conducted on former agricultural land owned by the Municipality of Boisbriand, Québec, and the three willow clones were: *Salix miyabeana* clone SX64, and clone SX67, and *Salix viminalis* clone Sv 5027.

In Hendon, Saskatchewan, Gunderson, Knight, and Van Rees (*citation 100*) conducted an experiment which studied the relationship between hybrid poplar (*P. deltoides* X *P.* x*petrowskyana* C.V. Griffin) fine root production, and soil nutrients across a hydrocarbon-contaminated site.

In Saskatchewan, afforestation projects on former agricultural lands are being advanced. Hybrid poplar plantations offer remedies to environmental problems on these lands as well as the potential to provide timber for the forest industry. In support of such projects, Pinno and Bélanger (*citation 222*) examined the response of hybrid poplar plantations to competition from weeds. The study took place in central Saskatchewan near the cities of Saskatoon and Prince Albert, and used three different, genetically related clones: Assiniboine, Hill, and Walker.

11.2 Riparian Areas

11.2.1 Riparian Buffer Areas

Hybrid poplars are being studied for their ability to protect water sources in riparian habitats. Riparian areas are the buffer zones between soil and water sources, and play a vital role in healthy landscape ecology. The trees and shrubs provide soil stability, and keep potential pollutants from entering water sources. Riparian buffer areas offer a microclimatic zone where shade and lower temperatures attract diverse wildlife, and help keep healthy algae levels in the water, things which are important to maintaining water quality levels and providing fish habitats. Hybrid poplars are uniquely qualified for the creation, restoration, and enhancement of riparian buffer zones. Hybrid poplars are quick growing, offer rapid biomass accumulations of nutrients from the soil, have been shown to be able to break down certain pesticides and denitrify nitrogen, and can quickly stabilize soil. When used in buffer strips poplar roots, stems and leaves are effective nutrient sinks. They are also a flood tolerant species, and are able to efficiently absorb water from the soil, offering further defences in maintaining water source nutrient levels. These characteristics of hybrid poplars qualifies them to be preferred in riparian areas adjacent to agricultural lands in order to both improve these environments and also to provide biomass for energy production as an additional revenue crop. Riparian buffer zones keep non-source pollutants specific to agricultural lands, such as pesticides, fertilizer, and manure, from travelling out of the soil and into the aquatic environment. Poplars offer the additional possibility of being used as a source of biomass for energy production because they can be harvested after 5-10 years compared to 15-20 years for lumber. This can be a mitigating factor in the potential prohibitive costs of creating riparian zones on agricultural lands. In addition these buffers have the potential to offer both water quality and carbon sequestration objectives to the agricultural industry in general.

11.2.2 Current Projects and Selected Research

In the Eastern Townships of southern Québec, a riparian hybrid poplar buffer system model, which was implemented in 2003, continues to be studied and assessed. Fortier, Gagnon, Truax and Lambert (*citation 84*) compared the C and nutrient sequestration by five unrelated hybrid poplar clones growing in the riparian zones of four agroecosystems with free-growing (unmanaged) herbaceous buffer strips. The four buffer sites were located in Magog, Bromptonville, St-Isidore-de-Clifton, and Roxton Falls, and in the year of study, the buffers had accumulated 6 years of growth. The five hybrid clones used in the study were: *P. trichocarpa* Torr. & Gray x *P. deltoides* cv. Boelare (*P.* x*generosa,* TxD, 3230), *P. deltoides* Bartr. ex Marsh. x *P. nigra* L. (*P. xcanadensis* Moench, DxN, 3570), *P.* x*canadensis* x *P. maximowiczii* (DNxM, 915508), *P. nigra* L. x *P. maximowiczii* A. Henry (NM6, NxM, 3729) and *P. maximowiczii* x *P. balsamifera* L. (MxB, 915311). The same scholars (*citation 85*) also measured understory plant biomass and species richness, along with canopy openness in the hybrid poplar riparian buffer strips of two unrelated clones: [*P. deltoides x P. nigra* (DxN-3570)] and [*P. maximowiczii* x *P. balsamifera* (MxB-915311)].

Duchemin and Hogue (*citation 71*), also in Québec, evaluated both the initial efficacy of grass/tree filter strips in terms of enhancing runoff and drainage water from grain corn plots fertilized with liquid swine manure. They also investigated the use of vegetative filter strips as a mitigation measure for agricultural non-point source pollution. This experiment was located in Saint-Lambert-de-Lauzon on the IRDA's (Institut de Recherche et de Developpement en Agroenvironnement Inc.) experimental farm, and used the hybrid poplar tree (Clone 3230 *P. trichocarpa x P. deltoides* cultivar 'Boelare') along with a variety of grasses.

The Canadian Forest Service[117] has an ongoing project investigating the key barriers to large-scale use of short-rotation plantations and agro-forestry energy systems. In one aspect of their analysis of these barriers, they looked at studies of willow or poplar based riparian buffer systems which provide not only protection to water sources but also a source of biomass feedstock.

Concerned about fish habitat, the Cottonwood Project, run by Trout Unlimited Canada[118] seeks to protect and enhance existing riparian areas along the Bow River in Alberta to ensure fish habitats are not destroyed. As part of the enhancement project, Cottonwood trees were wrapped with wire mesh to protect them from overgrazing by beavers, which can cause soil instability and lead to erosion. In addition the Cottonwood Project workers removed weeds along with any unwanted debris.

11.3 Shelterbelts[119]

Shelterbelts at the edge of pastures, near feedlots, and near dairy, hog and poultry facilities provide a variety of significant benefits to the farming industry and in the area of environmental protection while at the same time representing important eco systems habitats for many species. When planted as shelterbelts, trees can reduce wind velocity, greatly diminishing the effect of cold temperatures on livestock. This can significantly lower stress on animals and, consequently, reduce feed energy requirements. The benefits to livestock producers and ranchers include better animal health, lower feed costs, and greater financial gain. During the summer months, trees can reduce livestock stress by providing cool shade and protection from hot winds. The benefits to the landowner will last throughout the life of the shelterbelt. [...] Crop yield increases in fields adjacent to shelterbelts have been reported in many studies. These increases occur because of reduced wind erosion of topsoil and wind damage to crops, improved microclimates and better snow (moisture) retention. [...] Trees filter dust from tillage operations or roads, and buffer traffic or machinery noise. Shelterbelts also provide essential habitat for wildlife. Many species of birds and animals will benefit from the added protection trees provide. By planting a variety of tree and fruit-bearing shrubs, a diversity of wildlife will be attracted to the farm or ranch.

By far the most important and prominent shelterbelt program in Canada is the AAFC-AESB[120] Prairie Shelterbelt Program that is administered out of the Agroforestry Development Centre at Indian Head, Saskatchewan. The program has been on-going since 1901. The AAFC-PFRA Prairie Shelterbelt Program produces trees and shrubs that are provided at no cost for agroforestry plantings on agricultural land in Alberta, Saskatchewan, Manitoba and in the Peace River region

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[117] http://cfs.nrcan.gc.ca/projects/134/2.
[118] http://www.tucanada.org/index.asp?p=2101, http://www.tucanada.org/index.asp?p=2093.
[119] This section is excerpted with edits and additions from the Agri-Environment Services Branch (AESB) Agroforestry Development Centre on-line documentations http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1186517615847&lang=eng.
[120] http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1286907236630&lang=eng.

of British Columbia. While a great variety of tree and shrub species is desirable in shelterbelts for environmental reasons, single tree species plantings are easier to establish and to maintain. Hybrid poplar feature prominently among the tree species utilised for shelterbelts in the AAFC-PFRA Prairie Shelterbelt Program. The clone and species recommended and offered by the program for shelterbelt plantations from within the *Populus* group are: Assiniboine Poplar, Mixed hybrid Poplar, Walker Poplar, and for *Salix* include: Acute Willow and Silver-leaf Willow.

11.4 Carbon Sequestration

Climate change is having, and will continue to have, a profound impact on forest ecosystems. As a result, governments are starting to recognize that climate strategies must address the role of globally significant forest assets. Internationally, strategies under development include a number of voluntary, and some regulatory, frameworks. Many of them contain carbon trading measures that enable the transfer of offset credits from project developers to entities seeking to offset their emissions. Most of these systems include forests. According to Ecosystem Marketplace, as of 2010, forest carbon transactions now represent more than 40% of the total voluntary over-the-counter carbon market by volume[121]. The average price for offsets across the primary forest carbon markets[122] rose from \$3.8/tCO_2e (tons of carbon dioxide equivalent) in 2008, to \$4.5/tCO_2e in 2009, and up to \$5.5/tCO_2e in 2010.[123] Prices continue to vary widely across both voluntary and regulatory markets, as each market deals with unique supply- and demand-side drivers along with distinct project-level characteristics.

Given Canada's wealth of forestry resources, forest carbon is becoming an increasingly significant component of climate action. In the absence of a national strategy to deal with climate change, many provinces have made commitments to reduce their greenhouse gas emissions through various initiatives, including reductions through afforestation, avoided deforestation and reforestation projects. To quantify the amount of carbon that can be attributed to forestry-related activities and that would therefore be eligible to receive credits, the use of an approved quantification protocol is required. Both BC and Alberta have introduced forestry-related protocols to facilitate the creation of carbon offset credits. In addition, not-for-profit organizations are starting to recognize the need for high quality forest carbon offsets. For example, Tree Canada has developed its own offset protocol for forestry projects – *Tree Canada Afforestation, Reforestation and Urban Tree Planting Projects*[124] – to be able to provide greater assurance to individuals and organizations of the GHG impact of its plantings.

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[121] *State of the Forest Carbon Markets 2011: From Canopy to Currency*, Ecosystem Marketplace, at p. 5: http://www.forest-trends.org/documents/files/doc_2963.pdf.
[122] The primary market refers to original transactions of credits directly from a project; the secondary market refers to all ensuing transactions.
[123] *Supra* note 122.
[124] Available online: http://www.treecanada.ca/site/resources/pages/files/Carbon%20Protocol%20English.pdf.

11.4.1 British Columbia

In August 2011, the Government of British Columbia issued the *Protocol for the Creation of Forest Carbon Offsets*[125] to guide the design, development, quantification and verification of BC forest carbon offsets from a broad range of forest activities on private and public land in the province. Four project types are eligible under the protocol:

1. *Afforestation Projects*. Afforestation means the direct human-induced conversion of land that has not been forest land for at least 20 years prior to project commencement to forest land through planting, seeding and/or restoration. Areas that may be suitable for afforestation projects include marginal productivity land, urban land, or degraded industrial lands such as mine sites.

2. *Reforestation Projects*. The re-establishment of trees on land through planting, seeding of natural seed sources. The project lands must have been forest land in the recent past (i.e. within the last 20 years; otherwise, see the afforestation project definition) or must still be forest land, and must have reduced tree cover as a result of significant natural disturbance or harvesting. There can be no legal requirements to reforest the project lands. If reforestation is part of an overall improved forest management approach, then it should be considered an improved forest management project.

3. *Improved Forest Management Projects*. "Improved Forest Management" means a system of practices for stewardship and use of forest land which reduces GHG emissions and/or increases GHG sinks/carbon pools. Eligible management activities may include one or more of a variety of approaches:

   - increasing long-term carbon storage in forests (e.g. through conservation areas, reduced harvesting);
   - increasing sequestration rates (e.g. through restoration practices); and
   - reducing emissions (e.g., through reducing burning, reducing new road widths).

4. *Conservation/Avoided Deforestation Projects*. Conservation or avoided deforestation means preventing the direct human-induced conversion of forest land to a non-forest land use. Avoided land uses could include, but are not limited to, residential, commercial, industrial, and agricultural uses. Avoided harvesting or conservation of forest lands is not included in this category; it comes under improved forest management projects.

In January 2012, the Pacific Carbon Trust submitted the protocol for formal recognition under the Verified Carbon Standard (VCS). Recognition of the protocol as an approved methodology under the VCS program will increase opportunities for BC forest carbon offset project developers to sell offsets internationally. It is anticipated that the protocol will reach VCS final review and approval by June 2012.

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[125] Available online: http://www.env.gov.bc.ca/cas/mitigation/pdfs/Forest_Carbon_Offset_Protocol_v1_0_Web.pdf.

11.4.2 Alberta

In September 2007, Alberta Environment produced a protocol for afforestation projects[126] to assist in the process of defining and quantifying the opportunity for generating carbon offsets that arise from the reduction of GHG emissions through carbon sequestration by increasing the carbon stock (planting trees) on traditionally non-forested lands such as cropped or forage land, urban land, agro-forestry operations and possibly industrial lands that have been reclaimed. More detailed protocols from other jurisdiction, e.g. BC, specify land with no forest stand for the last 20 years (see above). However because of the less specific nature of this Alberta quantification protocol it is currently under review. In general the Alberta Offset System rules allowed for projects to claim credit for past action (from 2002 onwards) and there was no deadline for accounting for past offsets as long as they could be verified. However a new go-forward date for crediting was brought into place for January 2012. In addition, Alberta Environment released the *Quantification Protocol for Direct Reductions in Greenhouse Gas Emissions Arising from Changes in Forest Harvesting Practices*[127] in June 2011. This protocol describes the process for quantifying annual GHG emission reductions/removals arising from a change in forest harvesting practice from full tree harvesting with tree length hauling and chipping in a wood room at the mill to chipping using portable chippers. Emissions reductions are achieved by improving harvest and transportation efficiency as well as reducing the amount of harvest debris disposal when compared to the baseline condition.

11.4.3 Program of Activities

The Program of Activities (PoA) is a modality of project development under the Clean Development Mechanism (CDM) of the United Nations Framework Convention on Climate Change (UNFCCC). Traditionally, the CDM has used a project-by-project process for registering and verifying projects. This approach involves very high transaction costs, a long time to market, and a high risk of non-registration. In order to reduce transaction costs and to expand the CDM's applicability to smaller project activities, the CDM Executive Board launched the Program of Activities modality. Under this modality, a PoA coordinating entity (which may include a government agency, NGO or business) develops a PoA which defines broad parameters for project activities (referred to as CDM Program Activities or CPAs) which are eligible for inclusion in the PoA. Whereas standalone CDM projects must be approved individually by the CDM Executive Board (CEB), a PoA needs to be registered only once. Following registration, an unlimited and unspecified number of individual CPAs can be included without recourse to the CEB.

In an effort to further expand the BC carbon market and to enable the development and realization of future offsets from a large number of similar small GHG reduction projects, the

[126] Available online: http://www.assembly.ab.ca/lao/library/egovdocs/2007/alen/164684.pdf. Please note that as of April 2012, this protocol is under revision.
[127] Available online: http://environment.gov.ab.ca/info/library/8390.pdf.

Pacific Carbon Trust (PCT) has developed a draft guidance document[128] to support the creation of programmatic offset projects, thereby allowing for and supporting the grouping of small−scale projects. Programmatic offset projects facilitate large-scale reductions by allowing for multiple, small emission reduction and/or removal enhancement activities that are similar in nature to join a program over time. As poplar tree projects are often small scale in nature, and yet have the potential to general large-scale emission reductions, the development of a guidance document for programmatic offset projects will provide greater opportunities for poplar tree projects to realize offset credits in the future, particularly in the BC market.

The first project of this kind is currently being developed in BC by GHG Accounting Services Ltd.[129], a GHG quantification and carbon management service provider, on phytoremediation projects established by Passive Remediation Systems Inc. (PRSI). The projects involve the sequestration of municipal land fill effluent and leachate in hybrid poplar plantations. The current project sites are located within the north Okanagan region, but the program provides the opportunity to expand to similar phytoremediation projects in other regions of BC. During the second phase, the program is expected to expand to certain kind of shelterbelts (Knicks[130]) with additional environmental and habitat benefits[131].

Aerial Photo of Award Winning project with phytoremediation poplar stand set up by Passive Remediation Systems Inc. on top of a land fill[132].

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[128] *Program of Activities Guidance Document*, draft dated February 21, 2012 (available online: http://www.pacificcarbontrust.com/assets/Uploads/Public-Consultation/Draft-for-Discussion-PoA-Feb-27-2012-1.pdf).
[129] www.GHGAccounting.ca.
[130] http://schleswig-holstein.nabu.de/naturvorort/knicks/knickpflege/02852.html.
[131] http://schleswig-holstein.nabu.de/naturvorort/knicks/lebendigerknick/02789.html.
[132] http://www.prsi.ca/salmon_arm_landfill.html.

12 POPLAR COUNCIL OF CANADA/CONSEIL DU PEUPLIER DU CANADA

12.1 General Information

The Poplar Council of Canada (PCC) was established in 1978 and is an incorporated not-for-profit organization that functions as the National Poplar Commission of Canada. PCC is representing the Canadian perspective nationally and internationally in all matters dealing with growth, production and utilization of poplars and willows. PCC's work is committed to the wise use, conservation and sustainable management of Canada's poplar resources. The PCC Secretariat is located in offices of the Canadian Forest Service, Natural Resources Canada in Edmonton, Alberta.

PCC contact information is as follows:

Address:	Poplar Council of Canada Office of the Secretariat c/o Canadian Forest Service 5320 - 122nd Street, Edmonton Alberta, Canada T6H 3S5
Phone:	+1 780 430-3843
Fax:	+1 780 435-7356
E-mail:	poplar@poplar.ca
Website:	www.poplar.ca

12.2 PCC Administration

The work of PCC is governed and carried out by an elected Board of Directors assisted by two part-time staff members, an Executive Assistant and a Technical Director. The Board of Directors and the Executive Council coordinate programs and services. The Board of Directors is made up of the Executive Council; Working Group Chairs; and Directors at Large.

The Executive Council:

Chair	*Barb Thomas*	Genstat Consulting	Edmonton, AB	chair@poplar.ca
Past Chair	*John Doornbos*	Canadian Forest Service	Edmonton, AB	pastchair@poplar.ca
Vice-Chair West	*Cees van Oosten*	SilviConsult Woody Crops Technology Inc.	Nanaimo, BC	silviconsult@telus.net
Vice-Chair East	*Annie Desrochers*	Université du Québec en Abitibi- Témiscamingue	Rouyn-Noranda, QC	annie.desrochers@uqat.ca
Secretary-Treasurer	*Dan Carson*	Kruger Products	New Westminster, BC	dan.carson@krugerproducts.ca
Executive Assistant	*Deb Brenton*	Poplar Council of Canada	Edmonton, AB	poplar@poplar.ca
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Working Group Chairs:

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Director at large	*Jared LeBoldus*	North Dakota State University	Fargo, ND, USA	jared.leboldus@ndsu.edu

12.3 PCC Activities

The information and services provided by the PCC cover all aspects of the poplar and willow resource. The PCC undertakes studies and reviews of poplar resources, management and utilization. A newsletter is published twice a year with highlights from coast to coast, special research notes, fact sheets, a clone directory, member profiles, and general interest articles. Special publications, annual meeting proceedings, field tours, and workshops are among the activities arranged by the PCC and its members. Some of the publications are available on its website. The PCC also assist in the process of research on poplar issues through contract administration, lobbying for funding, member contacts, and technological committees to evaluate projects and knowledge gaps. Although not a research agency, the PCC regularly publishes current information from research for its members. The PCC is a full member of the International Poplar Commission (IPC) and participates in their meetings and elected boards of officials. The International Poplar Commission (IPC) is a Statutory Body of the Food and Agriculture Organization (FAO) of the United Nations. Through IPC, PCC has links with poplar and willow scientists throughout the world.

Specific events that the PPC has organized or participated-in included:

Poplar Council of Canada Genetics Workshop and Annual Business Meeting, Quebec, August 21-23, 2012

Organized by the Genetics Working Group of the Poplar Council and the Direction de la recherche forestière, Ministère des Ressources naturelles et de la Faune du Québec, this event will include a 1-day workshop meeting in Ste-Foy focused on genetics (followed by the PCC Annual Business Meeting of members) and 2 days of field tours to the Chicoutimi and Rimouski areas.

Boreal Mixedwoods 2012, "Ecology and Management for Multiple Values" Edmonton, Alberta, June 17-20, 2012.

Hosted by the Canadian Wood Fibre Centre, the University of Alberta and the Western Boreal Growth and Yield Association, the conference will involve invited keynote speakers, volunteer papers, discussion session, volunteer poster session and an optional 2-day post-conference technical field tour.

Poplar Council of Canada Conference & Annual Meeting, 'Poplars and Willows on the Prairies: Traditional Practices meet Innovative Applications', Edmonton, Alberta, 18-22 September, 2011, Post-conference field tour to Fort McMurray Oil Sands, 23-24 September, 2011

A joint event of the Poplar Council of Canada, International Poplar Commission 'Environmental Applications' Working Party (WP6) and the Poplar Council of the United States. The program included technical presentations, discussion and several days of field visits.

8th Biennial Meeting of Short Rotation Woody Crops Operations Working Group (including Poplar Council Annual Meeting 2010), Sheraton Syracuse University Hotel and Conference Centre, Syracuse, NY, 17-21 October, 2010

This meeting was hosted by the State University of New York willow biomass group. The theme was 'Short Rotation Woody Crops in a Renewable Energy Future: Challenges and Opportunities'. Poplar Council of Canada held its 2010 annual meeting in conjunction. The meeting included a day and a half of plenary and concurrent technical sessions, and field visits in the Syracuse area, as well as a 2-day post-conference field tour of biomass establishments, and poplar and willow plantations in Northern New York State and eastern Ontario.

Selected examples of national and international conference contributions of PCC members:

Pharis, RP, LV Kurepin, R Zhang, L Janzen, RD Guy, SD Mansfield, V Pointeau, F Unda, B Thomas, SN Silim, RJN Emery, L Fung and S Hurst. 2009. Plant growth hormones as useful markers and causal factors for inherently rapid stem volume growth in poplar (Populus spp.) selections & progeny from controlled crosses and across a range of hybrid genotypes. Oral Presentation, Poplar Council of Canada Annual Mtg., Regina, Sept. 28 – 30, 2009.

Pharis, R.P. 2010. Plant Growth Hormones as Causal Factors for Stem Growth Productivity in Poplar (Populus spp.) Selections Across a Wide Range of Genotypes. Invited Presentation at the: International Symposium on Plant Productivity, Sponsored by Trent University & RIKEN Plant Science Ctr. Held at Trent U., Peterborough, Ontario, Canada, October 24 – 26, 2010.

Pharis, R.P., R.Y. Soolanayakanahally, C-Yi Xie, L.V. Kurepin, R. Zhang, L. Janzen, R.D. Guy, S.D. Mansfield, V. Pointeau, F. Unda, B. R. Thomas & S. Silim. 2011. Plant Hormone Markers for Inherently rapid Stem Diameter & Height Growth in Balsam Poplar and Hybrid Poplar Genotypes Growing in Canada's Prairie Provinces. Oral Powerpoint Lecture at "Poplars & Willows on the Prairies" .Ann Mtg Poplar Council of Canada, Intl Poplar Commission, Environmental Applications Working Party & Poplar Council of the United States. Edmonton, Alberta, Canada Sept 18-22, 2011, Abstract, p. 34

Morris, Jeremy, John Kort and Richard Pharis. 2011. Enhancing biomass in *Salix* spp. with gibberellin A3. Poster Presentation at "Poplars & Willows on the Prairies". Ann Mtg Poplar Council of Canada, Intl Poplar Commission, Environmental Applications Working Party & Poplar Council of the United States. Edmonton, Alberta, Canada Sept 18-22, 2011, Abstract, p. 62

13 GLOSSARY

Glossary of frequently used terms

AAC	See - Allowable annual cut
Agroforestry	Agriculture in which there is integrated management of trees or shrubs along with conventional crops or livestock.
Allowable annual cut	Allowable annual cut - The regulated amount of annual harvest.
Aspen	Aspen is the common name for *Populus* species, such as *Populus tremuloides*, *P. grandidentata* and *P. tremula* (not native to North America) in the Populus section – formerly Leuce – (Aspens and white poplars). Hybrid aspen thus refers to the artificial interspecific hybrids of *P. tremuloides* and *P. tremula* or *P. davidiana* (Chinese or Korean poplar).
Clone	An individual or group of individuals reproduced asexually from a single organism, and therefore genetically identical to the parent.
Cutting	Unrooted stem or root section originating from a plant and used for vegetative (asexual) propagation. Cuttings are usually dormant when used.
Hybrid aspen	Aspen plant (or group of plants) created by crossing two distinct species of aspen.
Hybrid poplar	Poplar plant (or group of plants) created by crossing two distinct species of poplar (or two individuals within one species with very distinct characteristics).
Intersectional hybrids	Interspecific hybrids created between species from different sections. For instance between the eastern cottonwood (*Populus deltoides*) of the Aigeiros section and the balsam poplar (*Populus balsamifera*) of the Tacamahaca section.
Interspecific hybrids	Hybrids created between different species, e.g. between black cottonwood (*Populus trichocarpa*) and eastern cottonwood (*Populus deltoides*), designated as *Populus trichocarpa* (♀) × *P. deltoides* (♂), or simply TxD or TD; ♀ is the symbol for female and ♂ is the symbol for male.
Intraspecific breeding or improvement	Crosses created between trees from the same species, e.g. between *Populus trichocarpa* trees, designated as *Populus trichocarpa* (♀).× *P. trichocarpa* (♂), or simply T × T or TT.
Poplar	Poplar is the common name for all non-aspen species, such as *P. balsamifera*, *P. trichocarpa* (both native to North America), *P. maximowiczii* and *P. laurifolia* in the Tacamahaca section (Balsam poplars), and *P. deltoides* (native to North America) and *P. nigra* in the Aigeiros section (Cottonwoods and black poplar). Hybrid poplar thus refers to the natural or artificial interspecific and/or intersectional hybrids.
Populus	The genus *Populus*, which includes poplars, aspens and cottonwoods
Salix	The genus *Salix* (willows).
Set	Rooted whip. Also referred to as stecklings in Quebec.
SRIC	Short-rotation-intensive-culture. Poplar crops that are established and managed using an agronomic approach on cleared (usually agricultural) land.
Steckling	A set, or rooted whip used in Québec or rooted aspen cuttings
TOF	Trees outside forests.
Whip	Unrooted stem or shoot originating from a plant and used for vegetative propagation. The size is usually between 1.5 and 2.0 m (5.0-6.5 ft.). A set is a rooted whip.
Willow	Trees in the genus *Salix*, including its many hybrids

14 LITERATURE REVIEW AND REFERENCES

General note: search term results were reviewed and those that did not meet the specified search criteria for this report were eliminated from the final results list.

14.1 2008-2011 Publication Search Methodology

Database	Searches	Search Terms	
Summon	1	Title:	Poplar
		Publication years:	2008-2011
			AND Canad*
		Exclude:	Book Review
			Newspaper articles
		Subject Terms:	Forestry
		Include:	Results beyond library collection
	2	Title:	Populus
		Publication years:	2008-2011
		Terms:	AND Canad*
		Exclude:	Book Review
			Newspaper articles
		Subject Terms:	Forestry
		Include:	Results beyond library collection
	3	Title:	Aspen
		Publication years:	2008-2011
		Terms:	AND Canad*
		Exclude:	Book Review
			Newspaper articles
		Subject Terms:	Forestry
		Include:	Results beyond library collection
	4	Title:	Salix
		Publication years:	2008-2011
		Terms:	AND Canad*
		Exclude:	Book Review
			Newspaper articles
		Subject Terms:	Forestry
		Include:	Results beyond library collection
	5	Title:	Willow

		Publication years:	2008-2011
		Terms:	AND Canad*
		Exclude:	Book Review
			Newspaper articles
		Subject Terms:	None
		Include:	Results beyond library collection
Agricola	6	Key words:	Poplar AND Canad*
		Publication years:	2008-2011
	7	Key words:	Populus AND Canad*
		Publication years:	2008-2011
	8	Key words:	Aspen AND Canad*
		Publication years:	2008-2011
	9	Key words:	Willow AND Canad*
		Publication years:	2008-2011
	10	Key words:	Salix AND Canad*
		Publication years:	2008-2011
CAB Abstracts	11	Article title	Poplar
		Geographic location	Canada
		Publication years:	2008-2011
	12	Article title	Populus
		Geographic location	Canada
		Publication years:	2008-2011
	13	Article title	Aspen
		Geographic location	Canada
		Publication years:	2008-2011
	14	Article title	Willow
		Geographic location	Canada
		Publication years:	2008-2011
	15	Article title	Salix
		Geographic location	Canada
		Publication years:	2008-2011
BIOSYS previews	16	Title	Poplar

		Publication years:	2008-2011
		Refine results topic:	Canad*
	17	Title	Populus
		Publication years:	2008-2011
		Refine results topic:	Canad*
	18	Title	Aspen
		Publication years:	2008-2011
		Refine results topic:	Canad*
	19	Article title	Willow OR Salix
		Publication years:	2008-2011
		Refine results topic:	Canad*
Natural Resources Canada website: forests	20	Title contains:	Poplar
		Publication between	2008-2011
	21	Title contains:	Populus
		Publication between	2008-2011
	22	Title contains:	Aspen
		Publication between	2008-2011
	23	Title contains:	Willow
		Publication between	2008-2011
	24	Title contains:	Salix
		Publication between	2008-2011
Canadian Forest Service Publications	25	Keyword:	Poplar
		Publication dates:	2008-2011
	26	Keyword:	Populus
		Publication dates:	2008-2011
	27	Keyword:	Aspen
		Publication dates:	2008-2011
	28	Keyword:	Willow
		Publication dates:	2008-2011

		29	Keyword: Publication dates:	Salix 2008-2011
Thesis Canada	30-33		Title Keyword: Dates	Poplar OR Populus OR Aspen 2008, 2009, 2010, 2011
	34-37		Title Keyword: Dates	Willow OR Salix 2008, 2009, 2010, 2011
Ecology Abstracts		38	Title Keyword Abstract Keyword Publication Dates	Poplar OR Populus OR Aspen AND Canada OR Canadian 2008-2011
		39	Title Keyword Abstract Keyword Publication Dates	Willow OR Salix AND Canada OR Canadian 2008-2011

14.2 Summary Listings of all Searches by Author:

1. Alexander, M. (2010). Surface fire spread potential in trembling aspen during summer in the boreal forest region of Canada. Forestry Chronicle, 86(2), 200-212.

2. Ally, D. (2008). The cost of longevity: Loss of sexual function in natural clones of Populus tremuloides. (Ph.D., University of British Columbia).

3. Ally, D., Ritland, K., & Otto, S. P. (2008). Can clone size serve as a proxy for clone age? An exploration using microsatellite divergence in Populus tremuloides. Molecular Ecology, 17(22), 4897-4911.

4. Almeida Rodriguez, A. M. (2009). Aquaporins in poplars: Characterization, transcript profiling and drought stress. (Ph.D., University of Alberta).

5. Alsos, I. G., Alm, T., Normand, S., & Brochmann, C. (2009). Past and future range shifts and loss of diversity in dwarf willow (Salix herbacea L.) inferred from genetics, fossils and modelling. Global Ecology and Biogeography, 18(2), 223-239.

6. Amichev, B. Y., Hangs, R. D., & Van Rees, K. C. J. (2011). A novel approach to simulate growth of multi-stem willow in bioenergy production systems with a simple process-based model (3PG). Biomass and Bioenergy, 35(1), 473-488.

7. Amichev, B. Y., Johnston, M., & Van Rees, K. C. J. (2010). Hybrid poplar growth in bioenergy production systems: Biomass prediction with a simple process-based model (3PG). Biomass and Bioenergy, 34(5), 687-702.

8. Angers, V. A., Drapeau, P., & Bergeron, Y. (2010). Snag degradation pathways of four North American boreal tree species. Forest Ecology and Management, 259(3), 246-256.

9. Arango-Velez, A. L. (2010). Drought induced responses in hybrid and balsam poplars. (Ph.D., University of Alberta).

10. Aravanopoulos, F. A. (2010). Clonal identification based on quantitative, codominant, and dominant marker data: A comparative analysis of selected willow (Salix L.) clones. International Journal of Forestry Research, 2010, Article ID 906310.

11. Arbour, M., & Bergeron, Y. (2011). Effect of increased *Populus* cover on *Abies* regeneration in the Picea–feathermoss boreal forest. Journal of Vegetation Science, 22(6), 1132-1142.

12. Arevalo, C. B. M., Bhatti, J. S., Chang, S. X., & Sidders, D. (2009). Ecosystem carbon stocks and distribution under different land-uses in north central Alberta, Canada. Forest Ecology and Management, 257(8), 1776-1785.

13. Arevalo, C. B. M., Bhatti, J. S., Chang, S. X., & Sidders, D. (2011). Land use change effects on ecosystem carbon balance: From agricultural to hybrid poplar plantation. Agriculture, Ecosystems & Environment, 141(3), 342-349.

14. Arevalo, C., Bhatti, J., Chang, S., & Sidders, D. (2010). Distribution of recent photosynthates in saplings of two hybrid poplar clones. Communications in Soil Science and Plant Analysis, 41(8), 1004-1015.

15. Arevalo, C., Bhatti, J., Chang, S., Jassal, R., & Sidders, D. (2010). Soil respiration in four different land use systems in north central Alberta, Canada. Journal of Geophysical Research-Biogeosciences, 115(G1).

16. Azaiez, A., Boyle, B., Levée, V., & Séguin, A. (2009). Transcriptome profiling in hybrid poplar following interactions with melampsora rust fungi. Molecular Plant-Microbe Interactions : MPMI, 22(2), 190-200.

17. Bajwa, P. K., Phaenark, C., Grant, N., Xiao, Z., Paice, M., Martin, V. J. J., et al. (2011). Ethanol production from selected lignocellulosic hydrolysates by genome shuffled strains of scheffersomyces stipitis. Bioresource Technology, 102(21), 9965-9969.

18. Bambrick, A. D., Whalen, J. K., Bradley, R. L., Cogliastro, A., Gordon, A. M., Olivier, A., et al. (2010). Spatial heterogeneity of soil organic carbon in tree-based intercropping systems in Quebec and Ontario, Canada. Agroforestry Systems, 79(3), 343-353.

19. Barchet, G. L. H. (2010). Effects of drought stress on metabolite profiles of hybrid and pure lines of Populus spp. (M.Sc., University of British Columbia).

20. Beaudette, C., Bradley, R. L., Whalen, J. K., McVetty, P. B. E., Vessey, K., & Smith, D. L. (2010). Tree-based intercropping does not compromise canola (brassica napus L.) seed oil yield

and reduces soil nitrous oxide emissions. Agriculture, Ecosystems & Environment, 139(1-2), 33-39.

21. Beck, K., Salenikovich, A., Cloutier, A., & Beauregard, R. (2009). Development of a new engineered wood product for structural applications made from trembling aspen and paper birch. Forest Products Journal, 59(7-8), 31-35.

22. Benomar, L., DesRochers, A., & Larocque, G. (2011). Changes in specific leaf area and photosynthetic nitrogen-use efficiency associated with physiological acclimation of two hybrid poplar clones to intraclonal competition. Canadian Journal of Forest Research, 41(7), 1465-1476.

23. Bergeron, M., Lacombe, S., Bradley, R. L., Whalen, J., Cogliastro, A., Jutras, M. F., et al. (2011). Reduced soil nutrient leaching following the establishment of tree-based intercropping systems in eastern Canada. Agroforestry Systems, 83(3), 321-330.

24. Bilodeau-Gauthier, S., Paré, D., Messier, C., & Bélanger, N. (2011). Juvenile growth of hybrid poplars on acidic boreal soil determined by environmental effects of soil preparation, vegetation control, and fertilization. Forest Ecology and Management, 261(3), 620-629.

25. Bladon, K. D., Lieffers, V. J., Silins, U., Landhäusser, S. M., & Blenis, P. V. (2008). Elevated mortality of residual trees following structural retention harvesting in boreal mixedwoods. Forestry Chronicle, 84(1), 70-75.

26. Block, R., Knight, J., Booth, N., & Van Rees, K. (2009). Nursery stock type, nitrogen fertilization and shoot pruning effects on the growth of juvenile hybrid poplar in Saskatchewan. Canadian Journal of Plant Science, 89(2), 289-301.

27. Boivin, F., Paquette, A., Papaik, M. J., Thiffault, N., & Messier, C. (2010). Do position and species identity of neighbours matter in 8-15-year-old post harvest mesic stands in the boreal mixedwood. Forest Ecology and Management, 260(7), 1124-1131.

28. Bona, K. A., Burgess, M. S., Fyles, J. W., Camiré, C., & Dutilleul, P. (2008). Weed cover in hybrid poplar (Populus) plantations on Quebec forest soils under different lime treatments. Forest Ecology and Management, 255(7), 2761-2770.

29. Booth, N. W. H. (2008). Nitrogen fertilization of hybrid poplar plantations in Saskatchewan, Canada. (M.Sc., University of Saskatchewan).

30. Bouchard, M., & Pothier, D. (2011). Long-term influence of fire and harvesting on boreal forest age structure and forest composition in eastern Quebec. Forest Ecology and Management, 261(4), 811-820.

31. Boudreault, C., Coxson, D. S., Vincent, E., Bergeron, Y., & Marsh, J. (2008). Variation in epiphytic lichen and bryophyte composition and diversity along a gradient of productivity in Populus tremuloides stands of northeastern British Columbia, Canada. Écoscience, 15(1), 101-112.

32. Boyle, B., Levée, V., Hamel, L., Nicole, M., & Séguin, A. (2010). Molecular and histochemical characterisation of two distinct poplar *Melampsora* leaf rust pathosystems. Plant Biology (Stuttgart, Germany), 12(2), 364-376.

33. Bradford, J., & Kastendick, D. (2010). Age-related patterns of forest complexity and carbon storage in pine and aspen-birch ecosystems of northern Minnesota, USA. Canadian Journal of Forest Research, 40(3), 401-409.

34. Brassard, B. W., Chen, H. Y. H., Bergeron, Y., & Paré, D. (2011). Coarse root biomass allometric equations for *Abies balsamea*, *Picea mariana*, *Pinus banksiana*, and *Populus tremuloides* in the boreal forest of Ontario, Canada. Biomass and Bioenergy, 35(10), 4189-4196.

35. Brereton, N. J., Pitre, F. E., Ray, M. J., Karp, A., & Murphy, R. J. (2011). Investigation of tension wood formation and 2,6-dichlorbenzonitrile application in short rotation coppice willow composition and enzymatic saccharification. Biotechnology for Biofuels, 4(1), 13-13.

36. Brochu, V., Girard-Martel, M., Duval, I., Lerat, S., Grondin, G., Domingue, O., et al. (2010). Habituation to thaxtomin A in hybrid poplar cell suspensions provides enhanced and durable resistance to inhibitors of cellulose synthesis. BMC Plant Biology, 10(1), 272-272.

37. Busov, V., Yordanov, Y., Gou, J., Meilan, R., Ma, C., Regan, S., et al. (2011). Activation tagging is an effective gene tagging system in *Populus*. Tree Genetics & Genomes, 7(1), 91-101.

38. Bussières, J., Boudreau, S., & Rochefort, L. (2008). Establishing trees on cut-over peatlands in eastern Canada. Mires and Peat, 3, Article 10.

39. Cai, T., Price, D. T., Orchansky, A. L., & Thomas, B. R. (2011). Carbon, water, and energy exchanges of a hybrid poplar plantation during the first five years following planting. Ecosystems, 14(4), 658-671.

40. Campbell, J., Bradfield, G., Prescott, C., & Fredeen, A. (2010). The influence of overstorey *Populus* on epiphytic lichens in subboreal spruce forests of British Columbia. Canadian Journal of Forest Research, 40(1), 143-154.

41. Canada. Environment Canada, & Canadian Government EBook Collection. (2011). Recovery strategy for the green-scaled willow (*Salix chlorolepis*) in Canada. Ottawa: Environment Canada.

42. Canam, T., Mak, S. W. Y., & Mansfield, S. D. (2008). Spatial and temporal expression profiling of cell-wall invertase genes during early development in hybrid poplar. Tree Physiology, 28(7), 1059-1067.

43. Canam, T., Unda, F., & Mansfield, S. D. (2008). Heterologous expression and functional characterization of two hybrid poplar cell-wall invertases. Planta, 228(6), 1011-1019.

44. Carnegie, D., & Ramsay, J. A. (2009). Anaerobic ethylene glycol degradation by microorganisms in poplar and willow rhizospheres. Biodegradation, 20(4), 551-558.

45. Cavanagh, A., Gasser, M. O., & Labrecque, M. (2011). Pig slurry as fertilizer on willow plantation. Biomass and Bioenergy, 35(10), 4165-4173.

46. Cavard, X., Bergeron, Y., Chen, H. Y. H., & Paré, D. (2011). Effect of forest canopy composition on soil nutrients and dynamics of the understorey: Mixed canopies serve neither vascular nor bryophyte strata. Journal of Vegetation Science, 22(6), 1105-1119.

47. Cavard, X., Bergeron, Y., Chen, H. Y. H., Paré, D., Laganière, J., & Brassard, B. (2011). Competition and facilitation between tree species change with stand development. Oikos, 120(11), 1683-1695.

48. Chang-Yi, X., Ying, C. C., Yanchuk, A. D., & Holowachuk, D. L. (2009). Ecotypic mode of regional differentiation caused by restricted gene migration: A case in black cottonwood (*Populus trichocarpa*) along the Pacific Northwest coast. Canadian Journal of Forest Research, 39(3), 519-526.

49. Cheng, Y., Cai, Z., Zhang, J., & Chang, S. X. (2011). Gross N transformations were little affected by 4 years of simulated N and S depositions in an aspen-white spruce dominated boreal forest in Alberta, Canada. Forest Ecology and Management, 262(3), 571-578.

50. Chifflot, V., Rivest, D., Olivier, A., Cogliastro, A., & Khasa, D. (2009). Molecular analysis of arbuscular mycorrhizal community structure and spores distribution in tree-based intercropping and forest systems.131(1), 32-39.

51. Clinch, R. L., Thevathasan, N. V., Gordon, A. M., Volk, T. A., & Sidders, D. (2009). Biophysical interactions in a short rotation willow intercropping system in southern Ontario, Canada. Agriculture, Ecosystems and Environment, 131(1), 61-69.

52. Cloutier-Hurteau, B., Sauve, S., & Courchesne, F. (2011). Predicting Al, Cu, and Zn concentrations in the fine roots of trembling aspen (*Populus tremuloides*) using bulk and rhizosphere soil properties. Canadian Journal of Forest Research, 41(6), 1267-1279.

53. Coleman, H. D., Samuels, A. L., Guy, R. D., & Mansfield, S. D. (2008). Perturbed lignification impacts tree growth in hybrid poplar--A function of sink strength, vascular integrity, and photosynthetic assimilation. Plant Physiology, 148(3), 1229-1237.

54. Coll, L., Schneider, R., Berninger, F., Domenicano, S., & Messier, C. (2011). Quantifying the effect of nitrogen-induced physiological and structural changes on poplar growth using a carbon-balance model. Tree Physiology, 31(4), 381-390.

55. Comeau, P. G., Filipescu, C. N., Kabzems, R., & DeLong, C. (2009). Growth of white spruce underplanted beneath spaced and unspaced aspen stands in northeastern B.C. - 10 year results. Forest Ecology and Management, 257(3), 1087-1094.

56. Corredor, A., van Rees, K., & Vujanovic, V. (2009). Molecular profiling of fungal functional groups in the rhizosphere of short-rotation willow plantations. Canadian Journal of Plant Pathology, 31(1), 141-142.

57. Corredor, A., Van Rees, K., & Vujanovic, V. (2010). Functional groups of microfungi associated to roots of willows grown under short-rotation intensive culture. Canadian Journal of Plant Pathology, 32(3), 421-422.

58. Cortini, F., & Comeau, P. G. (2008). Evaluation of competitive effects of green alder, willow and other tall shrubs on white spruce and lodgepole pine in northern Alberta. Forest Ecology and Management, 255(1), 82-91.

59. Cortini, F., Filipescu, C. N., Groot, A., MacIsaac, D. A., & Nunifu, T. (2011). Regional models of diameter as a function of individual tree attributes, climate and site characteristics for six major tree species in Alberta, Canada. Forests, 2(4), 814-831.

60. Cumming, S., Trindade, M., Greene, D., & Macdonald, S. E. (2009). Canopy and emergent white spruce in pure broadleaf stands: Frequency, predictive models, and ecological importance. Canadian Journal of Forest Research, 39(10).

61. Dabros, A. (2009). Effects of simulated climate change on post-disturbance *Populus tremuloides - Picea mariana* ecosystems in northwestern Quebec. (Doctor of Philosophy, McGill University).

62. Dabros, A., & Fyles, J. W. (2010). Effects of open-top chambers and substrate type on biogeochemical processes at disturbed boreal forest sites in northwestern Quebec. Plant and Soil, 327(1), 465-479.

63. Dafoe, N. (2008). Identification and characterization of phloem and xylem sap proteins in *Populus trichocarpa* x *Populus deltoides*. (Ph.D, University of Victoria).

64. Dafoe, N. J., & Constabel, C. P. (2009). Proteomic analysis of hybrid poplar xylem sap. Phytochemistry, 70(7), 856-863.

65. Dafoe, N. J., Gowen, B. E., & Constabel, C. P. (2010). Thaumatin-like proteins are differentially expressed and localized in phloem tissues of hybrid poplar. BMC Plant Biology, 10(1), 191-191.

66. Deslauriers, A., Giovannelli, A., Rossi, S., Castro, G., Fragnelli, G., & Traversi, L. (2009). Intra-annual cambial activity and carbon availability in stem of poplar. Tree Physiology, 29(10), 1223-1235.

67. DesRochers, A., & Tremblay, F. (2009). The effect of root and shoot pruning on early growth of hybrid poplars. Forest Ecology and Management, 258(9), 2062-2067.

68. Di Baccio, D., Galla, G., Bracci, T., Andreucci, A., Barcaccia, G., Tognetti, R., et al. (2011). Transcriptome analyses of *Populus x euramericana* clone I-214 leaves exposed to excess zinc. Tree Physiology, 31(12), 1293-1308.

69. Domenicano, S., Coll, L., Messier, C., & Berninger, F. (2011). Nitrogen forms affect root structure and water uptake in the hybrid poplar. New Forests, 42(3), 347-362.

70. Dominy, S. W. J., Gilsenan, R., McKenney, D. W., Allen, D. J., Hatton, T., Koven, A., et al. (2010). A retrospective and lessons learned from Natural Resources Canada's forest 2020 afforestation initiative. Forestry Chronicle, 86(3), 339-347.

71. Duchemin, M., & Hogue, R. (2009). Reduction in agricultural non-point source pollution in the first year following establishment of an integrated grass/tree filter strip system in southern Quebec (Canada). Agriculture, Ecosystems & Environment, 131(1-2), 85-97.

72. Duplessis, S., Major, I., Martin, F., & Séguin, A. (2009). Poplar and pathogen interactions: Insights from Populus genome-wide analyses of resistance and defense gene families and gene expression profiling. Critical Reviews in Plant Sciences, 28(5), 309.

73. Dupuis, S., Arseneault, D., & Sirois, L. (2011). Change from pre-settlement to present-day forest composition reconstructed from early land survey records in eastern Québec, Canada. Journal of Vegetation Science, 22(3), 564-575.

74. Eftekhari, A. (2009). Chemical and biological study on constituents of *Populus tremuloides* buds (M.Sc., Université du Québec à Chicoutimi).

75. Ens, J. A., Farrell, R. E., & Bélanger, N. (2009). Rapid biomass estimation using optical stem density of willow (*Salix* spp.) grown in short rotation. Biomass and Bioenergy, 33(2), 174-179.

76. Fayed, M. A. (2011). Metabolite variation in ecologically diverse black cottonwood, *Populus trichocarpa* Torr. & A. Gray. (M.Sc., University of British Columbia).

77. Feau, N., Mottet, M., Perinet, P., Hamelin, R., & Bernier, L. (2010). Recent advances related to poplar leaf spot and canker caused by *Septoria musiva*. Canadian Journal of Plant Pathology, 32(2), 122-134.

78. Feau, N., Vialle, A., Allaire, M., Tanguay, P., Joly, D. L., Frey, P., et al. (2009). Fungal pathogen (mis-) identifications: A case study with DNA barcodes on *Melampsora* rusts of aspen and white poplar. Mycological Research, 113(6), 713-724.

79. Filipescu, C., & Comeau, P. (2011). Influence of Populus tremuloides density on air and soil temperature. Scandinavian Journal of Forest Research, 26(5), 421-428.

80. Fillion, M., Brisson, J., Guidi, W., & Labrecque, M. (2011). Increasing phosphorus removal in willow and poplar vegetation filters using arbuscular mycorrhizal fungi. Ecological Engineering, 37(2), 199-205.

81. Fleming, R., & Smith, A. (2011). Examining 40-year stand development following vegetation control: White spruce planted in a trembling aspen dominated cutover. Canadian Journal of Forest Research, 41(4), 728-739.

82. Forbes, B., Fauria, M., & Zetterberg, P. (2010). Russian arctic warming and 'greening' are closely tracked by tundra shrub willows. Global Change Biology, 16(5), 1542-1554.

83. Fortier, J., Gagnon, D., Truax, B., & Lambert, F. (2010). Biomass and volume yield after 6 years in multiclonal hybrid poplar riparian buffer strips. Biomass and Bioenergy, 34(7), 1028-1040.

84. Fortier, J., Gagnon, D., Truax, B., & Lambert, F. (2010). Nutrient accumulation and carbon sequestration in 6-year-old hybrid poplars in multiclonal agricultural riparian buffer strips. Agriculture, Ecosystems and Environment, 137(3), 276-287.

85. Fortier, J., Gagnon, D., Truax, B., & Lambert, F. (2011). Understory plant diversity and biomass in hybrid poplar riparian buffer strips in pastures. New Forests, 42(2), 241-265.

86. Fortin, S. (2008). Expansion postcoloniale du tremble (Populus tremuloides) dans le bassin de la rivière York, en Gaspésie. (Ph.D., Université du Québec à Chicoutimi).

87. Fréchette, E., Ensminger, I., Bergeron, Y., Gessler, A., Berninger, F., & Ball, M. (2011). Will changes in root-zone temperature in boreal spring affect recovery of photosynthesis in Picea mariana and Populus tremuloides in a future climate? Tree Physiology, 31(11), 1204-1216.

88. Fujimura, K. E., Egger, K. N., & Henry, G. H. (2008). The effect of experimental warming on the root-associated fungal community of *Salix arctica*. ISME Journal, 2(1), 105-114.

89. Galvez, D. A., Landhäusser, S. M., & Tyree, M. T. (2011). Root carbon reserve dynamics in aspen seedlings: Does simulated drought induce reserve limitation? Tree Physiology, 31(3), 250-257.

90. Gaudet, M., Pietrini, F., Beritognolo, I., Iori, V., Zacchini, M., Massacci, A., et al. (2011). Intraspecific variation of physiological and molecular response to cadmium stress in *Populus nigra* L. Tree Physiology, 31(12), 1309-1318.

91. Geraldes, A., Pang, J., Thiessen, N., Cezard, T., Moore, R., YongJun, Z., et al. (2011). SNP discovery in black cottonwood (*Populus trichocarpa*) by population transcriptome resequencing. Molecular Ecology Resources, 11, 81-92.

92. Germain, H., & Séguin, A. (2011). Innate immunity: Has poplar made its BED? The New Phytologist, 189(3), 678-687.

93. Gerwing, T. G. (2009). Reproductive ecology of the sitka willow (*Salix sitchensis*). (M.Sc., University of Northern British Columbia).

94. Gradowski, T., Lieffers, V. J., Landhäusser, S. M., Sidders, D., Volney, J., & Spence, J. R. (2010). Regeneration of *Populus* nine years after variable retention harvest in boreal mixedwood forests. Forest Ecology and Management, 259(3), 383-389.

95. Gray, L. K., Gylander, T., Mbogga, M. S., PeiYu, C., & Hamann, A. (2011). Assisted migration to address climate change: Recommendations for aspen reforestation in western Canada. Ecological Applications, 21(5), 1591-1603.

96. Groot, A., Man, R., & Wood, J. (2009). Spatial and temporal patterns of *Populus tremuloides* regeneration in small forest openings in northern Ontario. Forestry Chronicle, 85(4), 548-557.

97. Guidi, W., & Labrecque, M. (2010). Effects of high water supply on growth, water use, and nutrient allocation in willow and poplar grown in a 1-year pot trial. Water, Air, and Soil Pollution, 207(1), 85-101.

98. Guigou Cairus, G. (2008). Estimating genetic flow between exotic and native poplar species in Québec. (M.Sc., Université Laval).

99. Guillemette, T., & DesRochers, A. (2008). Early growth and nutrition of hybrid poplars fertilized at planting in the boreal forest of western Quebec. Forest Ecology and Management, 255(7), 2981-2989.

100. Gunderson, J. J., Knight, J. D., & Van Rees, K. C. J. (2008). Relating hybrid poplar fine root production, soil nutrients, and hydrocarbon contamination. Bioremediation Journal, 12(3), 156-167.

101. Gyug, L. W., Steeger, C., & Ohanjanian, I. (2009). Characteristics and densities of Williamson's Sapsucker nest trees in British Columbia. Canadian Journal of Forest Research, 39(12), 2319-2331.

102. Hacke, U. G., Plavcová, L., Almeida-Rodriguez, A., King-Jones, S., Zhou, W., & Cooke, J. E. K. (2010). Influence of nitrogen fertilization on xylem traits and aquaporin expression in stems of hybrid poplar. Tree Physiology, 30(8), 1016-1025.

103. Hairabedian, M. M. (2011). The short-term impacts of aspen clear-cutting on upland groundwater recharge. (M.Sc., University of Alberta).

104. Hamel, L. (2008). Caractérisation de la famille des MAPKs et des MAP2Ks chez le peuplier, *Populus trichocarpa*, et évaluation de leurs implications en défense. (Ph.D., Université de Sherbrooke).

105. Hamel, L., Benchabane, M., Nicole, M., Major, I. T., Morency, M., Pelletier, G., et al. (2011). Stress-responsive mitogen-activated protein kinases interact with the EAR motif of a poplar zinc finger protein and mediate its degradation through the 26S proteasome. Plant Physiology, 157(3), 1379-1393.

106. Hamelin, R. C., Feau, N., Tsui, C. K., Kope, H., & Zeglen, S. (2009). DNA barcoding of *Septoria* species from leaf spots and stem cankers of poplar in British Columbia, Canada to assess risk of spread. Phytopathology, 99(6, Suppl. S), S51.

107. Hangs, R. D., Van Rees, K. C. J., Schoenau, J. J., & Guo, X. (2011). A simple technique for estimating above-ground biomass in short-rotation willow plantations. Biomass and Bioenergy, 35(5), 2156-2162.

108. Hangs, R., Konecsni, S., & Van Rees, K. (2010). Development of willow clones for agroforestry and bioenergy. Saskatchewan Agriculture Development Fund.

109. Hangs, R., Schoenau, J., Van Rees, K., & Steppuhn, H. (2011). Examining the salt tolerance of willow (*Salix* spp.) bioenergy species for use on salt-affected agricultural lands. Canadian Journal of Plant Science, 91(3), 509-517.

110. Harper, G. J. (2008). Quantifying branch, crown and bole development in *Populus tremuloides* michx. from north-eastern British Columbia. Forest Ecology and Management, 255(7), 2286-2296.

111. Harper, G., O'Neill, M., Fielder, P., Newsome, T., & DeLong, C. (2009). Lodgepole pine growth as a function of competition and canopy light environment within aspen dominated mixedwoods of central interior British Columbia. Forest Ecology and Management, 257(8), 1829-1838.

112. Harrison, E. J. (2008). Activation tagging as a powerful tool for gene discovery in poplar: Diverse developmental mutants revealed in a population of activation-tagged poplar and the shriveled leaf activation-tagged poplar mutant: Discovery of a novel gene. (M.Sc., Queen's University).

113. Hart, C. L. (2009). High-resolution pollen analysis of two lakes at the boreal forest-aspen parkland ecotone in central Saskatchewan, Canada. (M.Sc, The University of Regina).

114. Heineman, J. L., Sachs, D. L., Simard, S. W., & Jean Mather, W. (2010). Climate and site characteristics affect juvenile trembling aspen development in conifer plantations across southern British Columbia. Forest Ecology and Management, 260(11), 1975-1984.

115. Heineman, J. L., Simard, S. W., Sachs, D. L., & Mather, W. J. (2009). Trembling aspen removal effects on lodgepole pine in southern interior British Columbia: Ten-year results. Western Journal of Applied Forestry, 24(1), 17-23.

116. Herschbach, C., Teuber, M., Eiblmeier, M., Ehlting, B., Ache, P., Polle, A., et al. (2010). Changes in sulphur metabolism of grey poplar (*Populus x canescens*) leaves during salt stress: A metabolic link to photorespiration. Tree Physiology, 30(9), 1161-1173.

117. Hogg, E., Brandt, J., & Michaellian, M. (2008). Impacts of a regional drought on the productivity, dieback, and biomass of western Canadian aspen forests. Canadian Journal of Forest Research, 38(6), 1373-1384.

118. Holmden, C., & Bélanger, N. (2010). Ca isotope cycling in a forested ecosystem. Geochimica Et Cosmochimica Acta, 74(3), 995-1015.

119. Hosseini-Nasabnia, Z., Van Rees, K., & Vujanovic, V. (2010). Interaction between pathogenic and beneficial fungi in willow phyllosphare. Canadian Journal of Plant Pathology, 32(3), 422-422.

120. Huang, J., Tardif, J. C., Bergeron, Y., Denneler, B., Berninger, F., & Girardin, M. A. R. T. I. N. P. (2010). Radial growth response of four dominant boreal tree species to climate along a latitudinal gradient in the eastern Canadian boreal forest. Global Change Biology, 16(2), 711-731.

121. Huang, J., Tardif, J., Denneler, B., Bergeron, Y., & Berninger, F. (2008). Tree-ring evidence extends the historic northern range limit of severe defoliation by insects in the aspen stands of western Quebec, Canada. Canadian Journal of Forest Research, 38(9), 2535-2544.

122. Huang, S., Wiens, D. P., Yang, Y., Meng, S. X., & Vanderschaaf, C. L. (2009). Assessing the impacts of species composition, top height and density on individual tree height prediction of quaking aspen in boreal mixedwoods. Forest Ecology and Management, 258(7), 1235-1247.

123. Huang, X., Yin, C., Duan, B., & Li, C. (2008). Interactions between drought and shade on growth and physiological traits in two *Populus cathayana* populations. Canadian Journal of Forest Research, 38(7), 1877-1887.

124. Ismail, M. (2010). Molecular genetic diversity among natural populations of *Populus*. (Ph.D., University of British Columbia).

125. Johnstone, W. (2008). The effects of initial spacing and rectangularity on the early growth of hybrid poplar. Western Journal of Applied Forestry, 23(4), 189-196.

126. Joly, D. L., Feau, N., Tanguay, P., & Hamelin, R. C. (2010). Comparative analysis of secreted protein evolution using expressed sequence tags from four poplar leaf rusts (*Melampsora* spp.). BMC Genomics, 11(1), 422-422.

127. Joss, B. N., Hall, R. J., Sidders, D. M., & Keddy, T. J. (2008). Fuzzy-logic modeling of land suitability for hybrid poplar across the prairie provinces of Canada. Environmental Monitoring and Assessment, 141(1-3), 79-96.

128. Jung, K., Chang, S. X., & Arshad, M. A. (2011). Effects of canopy-deposition interaction on H+ supply to soils in *Pinus banksiana* and *Populus tremuloides* ecosystems in the Athabasca oil sands region in Alberta, Canada. Environmental Pollution, 159(5, Sp. Iss. SI), 1327-1333.

129. Kabba, B. S., Knight, J. D., & Van Rees, K. C. J. (2011). Modeling nitrogen uptake for hybrid poplar with and without weed competition. Forest Ecology and Management, 262(2), 131-138.

130. Kalcsits, L., Kendall, E., Silim, S., & Tanino, K. (2009). Magnetic resonance microimaging indicates water diffusion correlates with dormancy induction in cultured hybrid poplar (*Populus* spp.) buds. Tree Physiology, 29(10), 1269-1277.

131. Kalcsits, L., Silim, S., & Tanino, K. (2009). Warm temperature accelerates short photoperiod-induced growth cessation and dormancy induction in hybrid poplar (*Populus* x spp.). Trees-Structure and Function, 23(5), 971-979.

132. Kamelchuk, D. P. (2010). Effects of fertilization on hybrid and native poplar clones. (M.Sc., University of Alberta).

133. Kanaga, M., Ryel, R., Mock, K., & Pfrender, M. (2008). Quantitative-genetic variation in morphological and physiological traits within a quaking aspen (*Populus tremuloides*) population. Canadian Journal of Forest Research, 38(6), 1690-1694.

134. Kaneda, M. (2009). Elucidation of secondary cell wall secretion mechanisms of *Arabidopsis thaliana*, Poplar (*Populus deltoides* x *P. trichocarpa*) and Pine (*Pinus contorta*). (PhD, University of British Columbia).

135. Kawchuk, L. M., Howard, R. J., Kalischuk, M. L., Northover, P. R., Desjardins, M., & Spencer, R. C. J. (2010). First report of bronze leaf disease on poplar in Alberta, Canada and sequence of *Apioplagiostoma populi*. Plant Disease, 94(3), 377-377.

136. Keyser, T. (2010). Thinning and site quality influence aboveground tree carbon stocks in yellow-poplar forests of the southern Appalachians. Canadian Journal of Forest Research, 40(4), 659-667.

137. Kocaefe, D., Shi, J.L., Yang, D.Q., & Bouazara, M. (2008). Mechanical properties, dimensional stability, and mold resistance of heat-treated jack pine and aspen. Forest Products Journal, 58(6), 88-93.

138. Konecsni, S. M. (2010). Fertilization of willow bioenergy cropping systems in Saskatchewan, Canada. (M.Sc., University of Saskatchewan).

139. Lacerte, V., Larocque, G. R., Woods, M., & Parton, W. J. (2008). Validating FVS-Ontario individual model components using independent datasets based on permanent sample plots located in Quebec. Sainte-Foy: Laurentian Forestry Centre, Canadian Forest Service.

140. Laganière, J., Angers, D. A., Paré, D., Bergeron, Y., & Chen, H. Y. H. (2011). Black spruce soils accumulate more uncomplexed organic matter than aspen soils. Soil Science Society of America Journal, 75(3), 1125-1132.

141. Laganière, J., Paré, D., & Bradley, R. L. (2009). Linking the abundance of aspen with soil faunal communities and rates of belowground processes within single stands of mixed aspen-black spruce. Applied Soil Ecology, 41(1), 19-28.

142. Laganière, J., Paré, D., & Bradley, R. L. (2010). How does a tree species influence litter decomposition? Separating the relative contribution of litter quality, litter mixing, and forest floor conditions. Canadian Journal of Forest Research, 40(3), 465-475.

143. Landhäusser, S. M. (2011). Aspen shoots are carbon autonomous during bud break. Trees, 25(3), 531-536.

144. Landhäusser, S. M., Deshaies, D., & Lieffers, V. J. (2010). Disturbance facilitates rapid range expansion of aspen into higher elevations of the Rocky Mountains under a warming climate. Journal of Biogeography, 37(1), 68-76.

145. Landhäusser, S., Wan, X., Lieffers, V., & Chow, P. (2010). Nitrate stimulates root suckering in trembling aspen (*Populus tremuloides*). Canadian Journal of Forest Research, 40(10), 1962-1969.

146. Lapointe-Garant, M., JianGuo, H., Gea-Izquierdo, G., Raulier, F., Bernier, P., & Berninger, F. (2010). Use of tree rings to study the effect of climate change on trembling aspen in Québec. Global Change Biology, 16(7), 2039-2051.

147. Laquerre, S., Harvey, B., & Leduc, A. (2011). Spatial analysis of response of trembling aspen patches to clearcutting in black spruce-dominated stands. Forestry Chronicle, 87(1), 77-85.

148. Laquerre, S., Leduc, A., & Harvey, B. D. (2009). Increase in canopy aspen in black spruce forests of north-western Quebec after clearcutting. [Augmentation du couvert en peuplier faux-tremble dans les pessieres noires du nord-ouest du Quebec apres coupe totale] Ecoscience, 16(4), 483-491.

149. LaRade, S. (2010). Long-term agronomic and environmental impact of aspen control strategies in the aspen parkland. (M.Sc., University of Alberta).

150. LaRade, S., & Bork, E. (2011). Aspen forest overstory relations to understory production. Canadian Journal of Plant Science, 91(5), 847-851.

151. Larchevêque, M., Desrochers, A., & Larocque, G. R. (2011). Comparison of manure compost and mineral fertilizer for hybrid poplar plantation establishment on boreal heavy clay soils. Annals of Forest Science, 68(4), 849-860.

152. Larchevêque, M., Larocque, G., Desrochers, A., Tremblay, F., Gaussiran, S., Boutin, R., et al. (2010). Juvenile productivity of five hybrid poplar clones and 20 genetically improved white and Norway spruces in boreal clay-belt of Quebec, Canada. Forestry Chronicle, 86(2), 225-233.

153. Larchevêque, M., Maurel, M., Desrochers, A., & Larocque, G. R. (2011). How does drought tolerance compare between two improved hybrids of balsam poplar and an unimproved native species? Tree Physiology, 31(3), 240-249.

154. Lavoie, J., Capek-Menard, E., & Chornet, E. (2010). Evaluation of the co-product pulp from Salix viminalis energy crops. Biomass and Bioenergy, 34(9), 1342-1347.

155. LeBoldus, J. M. (2010). The *Septoria musiva* -- *Populus* pathosystem: Biology and epidemiology. (Ph.D., University of Alberta).

156. LeBoldus, J. M., Blenis, P. V., Thomas, B. R., Feau, N., & Bernier, L. (2009). Susceptibility of *Populus balsamifera* to *Septoria musiva*: A field study and greenhouse experiment. Plant Disease, 93(11), 1146-1150.

157. LeBoldus, J., Blenis, P., & Thomas, B. (2008). Clone by isolate interaction in the hybrid poplar-*Septoria musiva* pathosystem. Canadian Journal of Forest Research, 38(7), 1888-1896.

158. Legay, S., Sivadon, P., Blervacq, A., Pavy, N., Baghdady, A., Tremblay, L., et al. (2010). EgMYB1, an R2R3 MYB transcription factor from eucalyptus negatively regulates secondary cell wall formation in *Arabidopsis* and poplar. New Phytologist, 188(3), 774-786.

159. Lennie, A. D. (2009). Trembling aspen regeneration response to understory protection harvesting in boreal mixedwood forests. (M.Sc., University of Alberta).

160. Lennie, A., Landhäusser, S., Lieffers, V., & Sidders, D. (2009). Regeneration of aspen following partial and strip understory protection harvest in boreal mixedwood forests. Forestry Chronicle, 85(4), 631-638.

161. Leonelli, G., Denneler, B., & Bergeron, Y. (2008). Climate sensitivity of trembling aspen radial growth along a productivity gradient in northeastern British Columbia, Canada. Canadian Journal of Forest Research, 38(5), 1211-1222.

162. Levée, V., Major, I., Levasseur, C., Tremblay, L., MacKay, J., & Séguin, A. (2009). Expression profiling and functional analysis of *Populus* WRKY23 reveals a regulatory role in defense. New Phytologist, 184(1), 48-70.

163. Li, E. (2009). Identification and characterization of regulatory genes associated with secondary wall formation in *Populus* and *Arabidopsis thaliana*. (Ph.D., University of British Columbia).

164. Li, H. (2010). Genetic adaptation of aspen populations to spring risk environments a novel remote sensing approach. (M.Sc., University of Alberta).

165. Li, H., Wang, X., & Hamann, A. (2010). Genetic adaptation of aspen (*Populus tremuloides*) populations to spring risk environments: A novel remote sensing approach. Canadian Journal of Forest Research, 40(11), 2082-2090.

166. Li, X., Zheng, X., Han, S., Zheng, J., & Li, T. (2010). Effects of nitrogen additions on nitrogen resorption and use efficiencies and foliar litterfall of six tree species in a mixed birch and poplar forest, northeastern China. Canadian Journal of Forest Research, 40(11), 2256-2261.

167. Lilles, E. B., Purdy, B. G., Chang, S. X., & Macdonald, S. E. (2010). Soil and groundwater characteristics of saline sites supporting boreal mixedwood forests in northern Alberta. Canadian Journal of Soil Science, 90(1), 1-14.

168. Lin, Y., & Wei, X. (2008). The impact of large-scale forest harvesting on hydrology in the willow watershed of central British Columbia. Journal of Hydrology (Amsterdam), 359(1), 141-149.

169. Lteif, A., Whalen, J. K., Bradley, R. L., & Camiré, C. (2010). Nitrogen transformations revealed by isotope dilution in an organically fertilized hybrid poplar plantation. Plant and Soil, 333(1), 105-116.

170. Lteif, A., Whalen, J., Bradley, R., & Camire, C. (2008). Diagnostic tools to evaluate the foliar nutrition and growth of hybrid poplars. Canadian Journal of Forest Research, 38(8), 2138-2147.

171. Macisaac, D. A., & Krygier, R. (2009). Development and long-term evaluation of harvesting patterns to reduce windthrow risk of understorey spruce in aspen-white spruce mixedwood stands in Alberta, Canada. Forestry, 82(3), 323-342.

172. Mahama, A., Hall, R., & Zalesny, R. (2011). Differential interspecific incompatibility among *Populus* hybrids in sections Aigeiros Duby and Tacamahaca Spach. Forestry Chronicle, 87(6), 790-796.

173. Major, I. T., & Constabel, C. P. (2008). Functional analysis of the Kunitz Trypsin inhibitor family in poplar reveals biochemical diversity and multiplicity in defense against herbivores. Plant Physiology, 146(3), 888-903.

174. Major, I. T., Nicole, M., Duplessis, S., & Séguin, A. (2010). Photosynthetic and respiratory changes in leaves of poplar elicited by rust infection. Photosynthesis Research, 104(1), 41-48.

175. Man, R., & Rice, J. A. (2010). Response of aspen stands to forest tent caterpillar defoliation and subsequent overstory mortality in northeastern Ontario, Canada. Forest Ecology and Management, 260(10), 1853-1860.

176. Man, R., Kayahara, G., Rice, J., & MacDonald, G. (2008). Response of trembling aspen to partial cutting and subsequent forest tent caterpillar defoliation in a boreal mixedwood stand in northeastern Ontario, Canada. Canadian Journal of Forest Research, 38(6), 1349-1356.

177. Man, R., Rice, J. A., Freeman, L., & Stuart, S. (2011). Effects of pre- and post-harvest spray with glyphosate and partial cutting on growth and quality of aspen regeneration in a boreal mixedwood forest. Forest Ecology and Management, 262(7), 1298-1304.

178. Man, R., Rice, J., & MacDonald, G. (2010). Five-year light, vegetation, and regeneration dynamics of boreal mixedwoods following silvicultural treatments to establish productive aspen-spruce mixtures in northeastern Ontario. Canadian Journal of Forest Research, 40(8), 1529-1541.

179. Manceur, A. M., Boland, G. J., Thevathasan, N. V., & Gordon, A. M. (2009). Dry matter partitions and specific leaf weight of soybean change with tree competition in an intercropping system. Agroforestry Systems, 76(2), 295-301.

180. Mansfield, S. D., KyuYoung, K., Iliadis, L., Tachos, S., & Avramidis, S. (2011). Predicting the strength of *Populus* spp. clones using artificial neural networks and ε-regression support vector machines (ε-rSVM). Holzforschung, 65(6), 855-863.

181. Marchand, P. P., & Masse, S. (2008). Issues related to the development and implementation of afforestation and agroforestry technologies for energy biomass production: Results of focus group sessions in Quebec and the Prairie provinces. Sainte-Foy: Laurentian Forestry Centre, Canadian Forest Service.

182. Marchetti, S., Worrall, J., & Eager, T. (2011). Secondary insects and diseases contribute to sudden aspen decline in southwestern Colorado, USA. Canadian Journal of Forest Research, 41(12), 2315-2325.

183. Marron, N., Ricciotti, L., Bastien, C., Beritognolo, I., Gaudet, M., Paolucci, I., et al. (2010). Plasticity of growth and biomass production of an intraspecific *Populus alba* family grown at three sites across Europe during three growing seasons. Canadian Journal of Forest Research, 40(10), 1887-1903.

184. Martin-DeMoor, J. (2009). Natural white spruce regeneration in aspen-dominated boreal mixedwoods following harvest. (M.Sc., University of Alberta).

185. Martin-DeMoor, J., Lieffers, V., & Macdonald, S. (2010). Natural regeneration of white spruce in aspen-dominated boreal mixedwoods following harvesting. Canadian Journal of Forest Research, 40(3), 585-594.

186. Martineau, L. C., Hervé, J., Muhamad, A., Saleem, A., Harris, C. S., Arnason, J. T., et al. (2010). Anti-adipogenic activities of *Alnus incana* and *Populus balsamifera* bark extracts, part I: Sites and mechanisms of action. Planta Medica, 76(13), 1439-1446.

187. Matson, A., Pennock, D., & BedardHaughn, A. (2009). Methane and nitrous oxide emissions from mature forest stands in the boreal forest, Saskatchewan, Canada. Forest Ecology and Management, 258(7), 1073-1083.

188. McCulloch, L., & Kabzems, R. (2009). Aspen complex stand establishment decision aid. BC Journal of Ecosystems and Management, 10(2), 51-58.

189. McKenney, D. W., Yemshanov, D., Fraleigh, S., Allen, D., & Preto, F. (2011). An economic assessment of the use of short-rotation coppice woody biomass to heat greenhouses in southern Canada. Biomass and Bioenergy, 35(1), 374-384.

190. Meirmans, P. G., Lamothe, M., Gros-Louis, M., Khasa, D., Périnet, P., Bousquet, J., et al. (2010). Complex patterns of hybridization between exotic and native North American poplar species. American Journal of Botany, 97(10), 1688-1697.

191. Mellway, R. D. (2009). The regulation of stress-induced proanthocyanidin metabolism in poplar. (Ph.D., University of Victoria).

192. Meng, S. X., Huang, S., Lieffers, V. J., & Yang, Y. (2008). Modelling the change in aspen species composition in boreal mixedwoods. Forestry (Oxford), 81(5), 575-586.

193. Mettanurak, T., Zink-Sharp, A., Copenheaver, C., & Zedaker, S. (2010). Effect of growth suppression and release on strength and specific gravity of yellow-poplar (none *Populus*). Canadian Journal of Forest Research, 40(8), 1661-1670.

194. Michaelian, M., Hogg, E. H., Hall, R. J., & Arsenault, E. (2011). Massive mortality of aspen following severe drought along the southern edge of the Canadian boreal forest. Global Change Biology, 17(6), 2084-2094.

195. Minor, M., & Norton, R. (2008). Effects of weed and erosion control on communities of soil mites (*Oribatida* and *Gamasina*) in short-rotation willow plantings in central New York. Canadian Journal of Forest Research, 38(5), 1061-1070.

196. Moore, K. (2008). The effect of papermaking conditions on the bulk and roughness of coated wood-free papers containing aspen high-yield pulp. (M.A.Sc., University of Toronto).

197. Mottet, M.-J., & Perinet, P. (2010). Breeding hybrid poplar in Quebec to improve their resistance to *Septoria musiva*. Phytopathology, 100(6, Suppl. S), S196.

198. Moulinier, J., Lorenzetti, F., & Bergeron, Y. (2011). Gap dynamics in aspen stands of the clay belt of northwestern Quebec following a forest tent caterpillar outbreak. Canadian Journal of Forest Research, 41(8), 1606-1617.

199. Mundell, T. L., Landhäusser, S. M., & Lieffers, V. J. (2008). Root carbohydrates and aspen regeneration in relation to season of harvest and machine traffic. Forest Ecology and Management, 255(1), 68-74.

200. Muto, E. A., Kreutzweiser, D. P., & Sibley, P. K. (2011). Over-winter decomposition and associated macroinvertebrate communities of three deciduous leaf species in forest streams on the Canadian boreal shield. Hydrobiologia, 658(1), 111-126.

201. Myers-Smith, I. H., Hik, D. S., Kennedy, C., Cooley, D., Johnstone, J. F., Kenney, A. J., et al. (2011). Expansion of canopy-forming willows over the twentieth century on Herschel Island, Yukon territory, Canada. Ambio, 40(6), 610-623.

202. Nash, R. M. (2009). Drought adaptations of hybrid poplar clones commonly grown on the Canadian prairies. (M.Sc., University of Saskatchewan).

203. Newsome, T. A., Heineman, J. L., & Nemec, A. F. L. (2008). Competitive interactions between juvenile trembling aspen and lodgepole pine: A comparison of two interior British Columbia ecosystems. Forest Ecology and Management, 255(7), 2950-2962.

204. Newsome, T. A., Heineman, J. L., & Nemec, A. F. L. (2010). A comparison of lodgepole pine responses to varying levels of trembling aspen removal in two dry south-central British Columbia ecosystems. Forest Ecology and Management, 259(6), 1170-1180.

205. Ngantcha, A. C. (2010). DNA fingerprinting and genetic relationships among willow (Salix spp.). (M.Sc, University of Saskatchewan).

206. Nunifu, T. (2009). Compatible diameter and height increment models for lodgepole pine, trembling aspen, and white spruce. Canadian Journal of Forest Research, 39(1), 180-192.

207. Nygren, P., Lu, M., & Ozier-Lafontaine, H. (2009). Effects of turnover and internal variability of tree root systems on modelling coarse root architecture: Comparing simulations for young Populus deltoides with field data. Canadian Journal of Forest Research, 39(1), 97-108.

208. O'Neill, M. K., Shock, C. C., Lombard, K. A., Heyduck, R. F., Feibert, E. B. G., Smeal, D., et al. (2010). Hybrid poplar (*Populus* ssp.) selections for arid and semi-arid intermountain regions of the western United States. Agroforestry Systems, 79(3), 409-418.

209. Oaten, D. K., & Larsen, K. W. (2008). Aspen stands as small mammal "hotspots" within dry forest ecosystems of British Columbia. Northwest Science, 82(4), 276-285.

210. Olson, M. S., Robertson, A. L., Takebayashi, N., Silim, S., Schroeder, W. R., & Tiffin, P. (2010). Nucleotide diversity and linkage disequilibrium in balsam poplar (*Populus balsamifera*). New Phytologist, 186(2), 526-536.

211. Ono, J. (2011). Transcriptome evolution in black cottonwood (*Populus trichocarpa*). (MSc, University of British Columbia).

212. Pakull, B., Groppe, K., Mecucci, F., Gaudet, M., Sabatti, M., & Fladung, M. (2011). Genetic mapping of linkage group XIX and identification of sex-linked SSR markers in a *Populus tremula* × *Populus tremuloides* cross. Canadian Journal of Forest Research, 41(2), 245-253.

213. Palmer, A. R. (2011). Natural variation and short-term impact of aspen harvesting on surface stream chemistry in the boreal plains. (M.Sc., University of Alberta).

214. Paquette, A., Messier, C., Perinet, P., & Cogliastro, A. (2008). Simulating light availability under different hybrid poplar clones in a mixed intensive plantation system. Forest Science, 54(5), 481-489.

215. Park, J., Canam, T., Kang, K., Unda, F., & Mansfield, S. D. (2009). Sucrose phosphate synthase expression influences poplar phenology. Tree Physiology, 29(7), 937-946.

216. Patterson, S. J., Chanasyk, D. S., Naeth, M. A., & Mapfumo, E. (2009). Effluent effects on the nutrient concentrations and growth of reed canarygrass (*Phalaris arundinacea* L.) and hybrid poplar (*Populus deltoides* × *P. petrowskyana* L.). Canadian Journal of Soil Science, 89(2), 223-234.

217. Pechanova, O., Hsu, C., Adams, J. P., Pechan, T., Vandervelde, L., Drnevich, J., et al. (2010). Apoplast proteome reveals that extracellular matrix contributes to multistress response in poplar. BMC Genomics, 11(1), 674-674.

218. Penner, M. (2008). Yield prediction for mixed species stands in boreal Ontario. Forestry Chronicle, 84(1), 46-52.

219. Philippe, R. N., Ralph, S. G., Külheim, C., Jancsik, S. I., & Bohlmann, J. (2009). Poplar defense against insects: Genome analysis, full-length cDNA cloning, and transcriptome and protein analysis of the poplar kunitz-type protease inhibitor family. New Phytologist, 184(4), 865-884.

220. Philippe, R. N., Ralph, S. G., Mansfield, S. D., & Bohlmann, J. (2010). Transcriptome profiles of hybrid poplar (*Populus trichocarpa* × *deltoides*) reveal rapid changes in undamaged, systemic sink leaves after simulated feeding by forest tent caterpillar (*Malacosoma disstria*). The New Phytologist, 188(3), 787-802.

221. Pinno, B. D. (2008). Site productivity of poplars in Canada: Relationships with soil properties and competition intensity. (Ph.D, University of Saskatchewan).

222. Pinno, B. D., & Bélanger, N. (2009). Competition control in juvenile hybrid poplar plantations across a range of site productivities in central Saskatchewan, Canada. New Forests, 37(2), 213-225.

223. Pinno, B. D., & Bélanger, N. (2011). Estimating trembling aspen productivity in the boreal transition ecoregion of Saskatchewan using site and soil variables. Canadian Journal of Soil Science, 91(4), 661-669.

224. Pinno, B. D., Paré, D., Guindon, L., & Bélanger, N. (2009). Predicting productivity of trembling aspen in the boreal shield ecozone of Quebec using different sources of soil and site information. Forest Ecology and Management, 257(3), 782-789.

225. Pinno, B. D., Thomas, B. R., & Bélanger, N. (2010). Predicting the productivity of a young hybrid poplar clone under intensive plantation management in northern Alberta, Canada using soil and site characteristics. New Forests, 39(1), 89-103.

226. Pinno, B. D., Wilson, S. D., Steinaker, D. F., Van Rees, K. C. J., & McDonald, S. A. (2010). Fine root dynamics of trembling aspen in boreal forest and aspen parkland in central Canada. Annals of Forest Science, 67(7), 710-710.

227. Pinto, F., Romaniuk, S., & Ferguson, M. (2008). Changes to preindustrial forest tree composition in central and northeastern Ontario, Canada. Canadian Journal of Forest Research, 38(7), 1842-1854.

228. Pitre, F. E., Lafarguette, F., Boyle, B., Pavy, N., Caron, S., Dallaire, N., et al. (2010). High nitrogen fertilization and stem leaning have overlapping effects on wood formation in poplar but invoke largely distinct molecular pathways. Tree Physiology, 30(10), 1273-1289.

229. Pitt, D., Comeau, P. G., Parker, W. C., MacIsaac, D., McPherson, S., Hoepting, M. K., et al. (Mar 2010). Early vegetation control for the regeneration of a single-cohort, intimate mixture of white spruce and trembling aspen on upland boreal sites. Canadian Journal of Forest Research, 40(3), 549.

230. Pointeau, S., Sallé, A., Lesieur, V., Bankhead-Dronnet, S., Bonnaffoux, M., & Lieutier, F. (2011). Estimating the effect of poplar resistance on the performance of the woolly poplar aphid, *Phloeomyzus passerinii*, in various experimental conditions. Canadian Journal of Forest Research, 41(6), 1233-1241.

231. Pointeau, V. M. (2008). Water-use efficiency and productivity in native Canadian populations of *Populus trichocarpa* and *Populus balsamifera*. (M.Sc., University of British Columbia).

232. Pokharel, B., & Froese, R. E. (2009). Representing site productivity in the basal area increment model for FVS-Ontario. Forest Ecology and Management, 258(5), 657-666.

233. Prevost, M., Dumais, D., & Pothier, D. (2010). Growth and mortality following partial cutting in a trembling aspen-conifer stand: Results after 10 years. Canadian Journal of Forest Research, 40(5), 894-903.

234. Quoreshi, A. M., Pichcb, Y., & Khasa, D. P. (2008). Field performance of conifer and hardwood species 5 years after nursery inoculation in the Canadian Prairie provinces. New Forests, 35(3), 235-253.

235. Raj, S. J. S. (2009). Clone history shapes the *Populus* drought transcriptome. (M.Sc., University of Toronto).

236. Ramlal, E., Yemshanov, D., Fox, G., & McKenney, D. (2009). A bioeconomic model of afforestation in southern Ontario: Integration of fibre, carbon and municipal biosolids values. Journal of Environmental Management, 90(5), 1833-1843.

237. Redburn, M. J., & Strong, W. L. (2008). Successional development of silviculturally treated and untreated high-latitude Populus tremuloides clearcuts in northern Alberta, Canada. Forest Ecology and Management, 255(7), 2937-2949.

238. Redding, T. E., & Devito, K. J. (2008). Lateral flow thresholds for aspen forested hillslopes on the western boreal plain, Alberta, Canada. Hydrological Processes, 22(21), 4287-4300.

239. Redding, T., & Devito, K. (2010). Mechanisms and pathways of lateral flow on aspen-forested, luvisolic soils, western boreal plains, Alberta, Canada. Hydrological Processes, 24(21), 2995-3010.

240. Renkema, K. N. (2009). Aspen (*Populus tremuloides*) root suckering as influenced by log storage, traffic-induced-root wounding, slash accumulation, and soil compaction. (M.Sc, University of Alberta).

241. Renkema, K., Lieffers, V., & Landhäusser, S. (2009). Aspen regeneration on log decking areas as influenced by season and duration of log storage. New Forests, 38(3), 323-335.

242. Renton, J. C. (2010). The impact of cattle grazing on aspen regeneration on crown lands in western Manitoba. (M.Sc., University of Manitoba).

243. Rivest, D., Cogliastro, A., & Olivier, A. (2009). Tree-based intercropping systems increase growth and nutrient status of hybrid poplar: A case study from two Northeastern American experiments. Journal of Environmental Management, 91(2), 432-440.

244. Rivest, D., Cogliastro, A., Bradley, R., & Olivier, A. (2010). Intercropping hybrid poplar with soybean increases soil microbial biomass, mineral N supply and tree growth. Agroforestry Systems, 80(1), 33-40.

245. Rivest, D., Cogliastro, A., Vanasse, A., & Olivier, A. (2009). Production of soybean associated with different hybrid poplar clones in a tree-based intercropping system in southwestern Québec, Canada. Agriculture, Ecosystems and Environment, 131(1), 51-60.

246. Rood, S. B., Bigelow, S. G., & Hall, A. A. (2011). Root architecture of riparian trees: River cut-banks provide natural hydraulic excavation, revealing that cottonwoods are facultative phreatophytes. Trees: Structure and Function, 25(5), 907-917.

247. Rood, S. B., Nielsen, J. L., Shenton, L., Gill, K. M., & Letts, M. G. (2010). Effects of flooding on leaf development, transpiration, and photosynthesis in narrowleaf cottonwood, a willow-like poplar. Photosynthesis Research, 104(1), 31-39.

248. Roy, V., Dubeau, D., & Auger, I. (2010). Biological control of intolerant hardwood competition: Silvicultural efficacy of *Chondrostereum purpureum* and worker productivity in conifer plantations. Forest Ecology and Management, 259(8), 1571-1579.

249. Royer-Tardif, S., & Bradley, R. L. (2009). Soil properties, understory vegetation and microbial community structure and stability in pure and mixed-wood stands of trembling aspen and jack pine from southern boreal forest in northwestern Quebec. Journal of Nematology, 41(4), 376.

250. Royer-Tardif, S., & Bradley, R. L. (2011). Evidence that soil fertility controls the mixing of jack pine with trembling aspen. Forest Ecology and Management, 262(6), 1054-1060.

251. Saint-Germain, M., & Drapeau, P. (2011). Response of saprophagous wood-boring beetles (coleoptera: Cerambycidae) to severe habitat loss due to logging in an aspen-dominated boreal landscape. Landscape Ecology, 26(4), 573-586.

252. Saurette, D. D., Chang, S. X., & Thomas, B. R. (2008). Autotrophic and heterotrophic respiration rates across a chronosequence of hybrid poplar plantations in northern Alberta. Canadian Journal of Soil Science, 88(3), 261-272.

253. Saurette, D. D., Chang, S. X., & Thomas, B. R. (2008). Land-use conversion effects on CO 2 emissions: From agricultural to hybrid poplar plantation. Ecological Research, 23(3), 623-633.

254. Savoie, P., Lavoie, F., D'Amours, L., Schroeder, W., & Kort, J. (2010). Harvesting natural willow rings with a bio-baler around Saskatchewan prairie marshes. Canadian Biosystems Engineering, 52, 2.1.

255. Schneider, R., Riopel, M., Pothier, D., & Côté, L. (2008). Predicting decay and round-wood end use volume in trembling aspen (*Populus tremuloides* Michx.) prévision du volume de bois carié et de la répartition par produits chez le peuplier faux-tremble (*Populus tremuloides* Michx.). Annals of Forest Science, 65(6), 608-608.

256. Schreiber, S. G., Hacke, U. G., Hamann, A., & Thomas, B. R. (2011). Genetic variation of hydraulic and wood anatomical traits in hybrid poplar and trembling aspen. New Phytologist, 190(1), 150-160.

257. Schroeder, W., Kort, J., Savoie, P., & Preto, F. (2009). Biomass harvest from natural willow rings around prairie wetlands. Bionenergy Research, 2(3), 99-105.

258. Shi, Z. (2010). Afforestation and stand age affected soil respiration and net ecosystem productivity in hybrid poplar plantations in central Alberta, Canada. (M.Sc., University of Alberta).

259. Siemens, J. A. (2008). Effects of nitrogen, pH, and mycorrhizal fungi on the growth, water relations, and physiology of trembling aspen (Populus tremuloides) and balsam poplar (*Populus balsamifera*). (Ph.D., University of Alberta).

260. Siemens, J. A., & Zwiazek, J. J. (2008). Root hydraulic properties and growth of balsam poplar (*Populus balsamifera*) mycorrhizal with *Hebeloma crustuliniforme* and *Wilcoxina mikolae* var. *mikolae*. Mycorrhiza, 18(8), 393-401.

261. Siemens, J. A., Calvo-Polanco, M., Zwiazek, J. J., & Näsholm, T. (2011). *Hebeloma crustuliniforme* facilitates ammonium and nitrate assimilation in trembling aspen (*Populus tremuloides*) seedlings. Tree Physiology, 31(11), 1238-1250.

262. Silim, S., Nash, R., Reynard, D., White, B., & Schroeder, W. (2009). Leaf gas exchange and water potential responses to drought in nine poplar (*Populus* spp.) clones with contrasting drought tolerance. Trees: Structure and Function, 23(5), 959-969.

263. Simpson, J. D., & Daigle, B. I. (2009). Five years' storage of seeds from three willow species. Native Plants Journal, 10(1), 63.

264. Singh, B. (2008). Nutrient uptake by hybrid poplar in competition with weed species under growth chamber and field conditions using the soil supply and nutrient demand (SSAND) model. (Ph.D., University of Saskatchewan).

265. Smirnova, E., Bussière, B., Tremblay, F., & Bergeron, Y. (2011). Vegetation succession and impacts of biointrusion on covers used to limit acid mine drainage. Journal of Environmental Quality, 40(1), 133-143.

266. Snedden, J., Landhäusser, S. M., Lieffers, V. J., & Charleson, L. R. (2010). Propagating trembling aspen from root cuttings: Impact of storage length and phenological period of root donor plants. New Forests, 39(2), 169-182.

267. Soolanayakanahally, R. (2011). Latitudinal gradients in adaptive traits of *Populus*. (PhD, University of British Columbia).

268. Stadnyk, C. N. (2010). Root dynamics and carbon accumulation of six willow clones in Saskatchewan. (M.Sc., University of Saskatchewan).

269. Stankowski, P. (2010). Ecological niche modelling: Salix in Ontario. (M.Sc.F., Lakehead University).

270. Stankowski, P. A., & Parker, W. H. (2010). Species distribution modelling: Does one size fit all? A phytogeographic analysis of Salix in Ontario. Ecological Modelling, 221(13), 1655-1664.

271. Stanton-Kennedy, T. S. (2008). Soil and vegetation change on a coal mine 15 years after reclamation in the aspen parkland of Alberta. (M.L.A., University of Guelph).

272. Startsev, N. A., Lieffers, V. J., Landhaeusser, S. M., & Velazquez-Martinez, A. (2008). N-transfer through aspen litter and feather moss layers after fertilization with ammonium nitrate and urea. Plant and Soil, 311(1-2), 51-59.

273. Stefani, F. O. P., Moncalvo, J., Séguin, A., Bérubé, J. A., & Hamelin, R. C. (2009). Impact of an 8-year-old transgenic poplar plantation on the ectomycorrhizal fungal community. Applied and Environmental Microbiology, 75(23), 7527-7536.

274. Stenvall, N., Piisila, M., & Pulkkinen, P. (2009). Seasonal fluctuation of root carbohydrates in hybrid aspen clones and its relationship to the sprouting efficiency of root cuttings. Canadian Journal of Forest Research, 39(8), 1531-1537.

275. Steppuhn, H., Kort, J., & Wall, K. (2008). First year growth response of selected hybrid poplar cuttings to root-zone salinity. Canadian Journal of Plant Science, 88(3), 473-483.

276. Strong, W. L. (2009). *Populus tremuloides* michx. postfire stand dynamics in the northern boreal-cordilleran ecoclimatic region of central Yukon territory, Canada. Forest Ecology and Management, 258(7), 1110-1120.

277. Strong, W. L. (2011). Lateral *Picea* shadow effects on *Populus tremuloides* understory vegetation in central Yukon, Canada. Forest Ecology and Management, 261(11), 1866-1875.

278. Strong, W. L. (2011). Tree canopy effects on understory species abundance in high-latitude *Populus tremuloides* stands, Yukon, Canada. Community Ecology, 12(1), 89-98.

279. Strong, W. L., & Redburn, M. J. (2009). Latitude-related variation in understory vegetation of boreal *Populus tremuloides* stands in Alberta, Canada. Community Ecology, 10(1), 35-44.

280. Sturrock, R. N., Frankel, S. J., Brown, A. V., Hennon, P. E., Kliejunas, J. T., Lewis, K. J., et al. (2011). Climate change and forest diseases. Plant Pathology, 60(1), 133-149.

281. Talbot, P., Thompson, S., Schroeder, W., & Isabel, N. (2011). An efficient single nucleotide polymorphism assay to diagnose the genomic identity of poplar species and hybrids on the Canadian prairies. Canadian Journal of Forest Research, 41(5), 1102-1111.

282. Tan, X., Chang, S. X., & Kabzems, R. (2008). Soil compaction and forest floor removal reduced microbial biomass and enzyme activities in a boreal aspen forest soil. Biology and Fertility of Soils, 44(3), 471-479.

283. Teklay, T., & Chang, S. X. (2008). Temporal changes in soil carbon and nitrogen storage in a hybrid poplar chronosequence in northern Alberta. Geoderma, 144(3-4), 613-619.

284. Teklay, T., Zheng, S., Attaeian, B., & Chang, S. X. (2010). Temperature and substrate effects on C & N mineralization and microbial community function of soils from a hybrid poplar chronosequence. Applied Soil Ecology, 46(3), 413-421.

285. Temmel, N. A. (2011). Investigation of the genomics of gender regulation in *Populus trichocarpa*. (Ph.D., University of British Columbia).

286. Teodorescu, T. I., Guidi, W., & Labrecque, M. (2011). The use of non-dormant rods as planting material: A new approach to establishing willow for environmental applications. Ecological Engineering, 37(9), 1430-1433.

287. Thompson, S. L., Lamothe, M., Meirmans, P. G., Perinet, P., & Isabel, N. (2010). Repeated unidirectional introgression towards Populus balsamifera in contact zones of exotic and native poplars. Molecular Ecology, 19(1), 132-145.

288. Tozer, D. C., Nol, E., & Burke, D. M. (2011). Quality of mature aspen and maple forests for breeding Yellow-bellied Sapsuckers (*Sphyrapicus varius*). Canadian Journal of Zoology, 89(2), 148-160.

289. Tran, L. T., & Constabel, C. P. (2011). The polyphenol oxidase gene family in poplar: Phylogeny, differential expression and identification of a novel, vacuolar isoform. Planta, 234(4), 799-813.

290. van den Driessche, R., Thomas, B. R., & Kamelchuk, D. P. (2008). Effects of N, NP, and NPKS fertilizers applied to four-year old hybrid poplar plantations. New Forests, 35(3), 221-233.

291. Veljanovski, V., Major, I. T., Patton, J. J., Bol, E., Louvet, S., Hawkins, B. J., et al. (2010). Induction of acid phosphatase transcripts, protein and enzymatic activity by simulated herbivory of hybrid poplar. Phytochemistry, 71(5), 619-626.

292. Vialle, A., Frey, P., Hambleton, S., Bernier, L., & Hamelin, R. C. (2011). Poplar rust systematics and refinement of *Melampsora* species delineation. Fungal Diversity, 50(1), 227-248.

293. Vigneault, F. (2009). Caractérisation de la famille des protéines kinases de type NIMA chez les plantes et analyse fonctionnelle de PNek1, une NEK du peuplier (*Populus tremula* X *P. alba* clone 717 I-B4). (Ph.D., Québec : Université Laval).

294. Voicu, M. C. (2009). Regulation of water flow in bur oak (*Quercus macrocarpa*) and aspen (*Populus tremuloides*) leaves. (Ph.D., University of Alberta).

295. Voicu, M. C., & Zwiazek, J. J. (2010). Inhibitor studies of leaf lamina hydraulic conductance in trembling aspen (*Populus tremuloides* Michx.) leaves. Tree Physiology, 30(2), 193-204.

296. Voicu, M. C., & Zwiazek, J. J. (2011). Diurnal and seasonal changes of leaf lamina hydraulic conductance in bur oak (*Quercus macrocarpa*) and trembling aspen (*Populus tremuloides*). Trees, 25(3), 485-495.

297. Vujanovic, V., & Labrecque, M. (2008). Potentially pathogenic and biocontrol ascomycota associated with green wall structures of basket willow (*Salix viminalis* L.) revealed by phenotypic characters and ITS phylogeny. Biocontrol, 53(2), 413-426.

298. Vyse, A., & Simard, S. W. (2009). Broadleaves in the interior of British Columbia: Their extent, use, management and prospects for investment in genetic conservation and improvement. Forestry Chronicle, 85(4), 528-537.

299. Weng, Y. H., & Parker, W. H. (2008). Adaptive variation in fall cold hardiness of aspen from northwestern Ontario. Tree Physiology, 28(1), 143-150.

300. Wildhagen, H., Dürr, J., Ehlting, B., & Rennenberg, H. (2010). Seasonal nitrogen cycling in the bark of field-grown grey poplar is correlated with meteorological factors and gene expression of bark storage proteins. Tree Physiology, 30(9), 1096-1110.

301. Wolken, J. M., Lieffers, V. J., Landhäusser, S. M., & Mulak, T. (2009). Spring frost and decay fungi are implicated in suppressing aspen re-growth following partial cleaning in juvenile stands. Annals of Forest Science, 66(8), 805p1-805p8.

302. Xiao, T., Chang, S. X., & Kabzems, R. (2008). Soil compaction and forest floor removal reduced microbial biomass and enzyme activities in a boreal aspen forest soil. Biology and Fertility of Soils, 44(3), 471-479.

303. Xie, C., Ying, C., Yanchuk, A., & Holowachuk, D. (2009). Ecotypic mode of regional differentiation caused by restricted gene migration: A case in black cottonwood (*Populus trichocarpa*) along the Pacific Northwest coast. Canadian Journal of Forest Research, 39(3), 519-526.

304. Yang, D., Wang, X., & Wan, H. (2010). Optimizing manufacturing conditions for durable composite panels with eastern white cedar and aspen strands. Forest Products Journal, 60(5), 460-464.

305. Yang, Y., Huang, S., Meng, S., Trincado, G., & VanderSchaaf, C. (2009). A multilevel individual tree basal area increment model for aspen in boreal mixedwood stands. Canadian Journal of Forest Research, 39(11), 2203-2214.

306. Ye, F., & Comeau, P. (2009). Effects of gap size and surrounding trees on light patterns and aspen branch growth in the western boreal forest. Canadian Journal of Forest Research, 39(11), 2021-2032.

307. Yemele, M., Blanchet, P., Cloutier, A., & Koubaa, A. (2008). Effects of bark content and particle geometry on the physical and mechanical properties of particleboard made from black spruce and trembling aspen bark. Forest Products Journal, 58(11), 48-56.

308. Yemele, M., Cloutier, A., Diouf, P., Koubaa, A., Blanchet, P., & Stevanovic, T. (2008). Physical and mechanical properties of particleboard made from extracted black spruce and trembling aspen bark. Forest Products Journal, 58(10), 38-46.

309. Yemshanov, D., & McKenney, D. (2008). Fast-growing poplar plantations as a bioenergy supply source for Canada. Biomass and Bioenergy, 32(3), 185-197.

310. Yevtushenko, D. P., & Misra, S. (2010). Efficient agrobacterium -mediated transformation of commercial hybrid poplar *Populus nigra* L. × *P. maximowiczii* A. Henry. Plant Cell Reports, 29(3), 211-221.

311. Yu, Q., Zhang, S. Y., Pliura, A., MacKay, J., Bousquet, J., & Perinet, P. (2008). Variation in mechanical properties of selected young poplar hybrid crosses. Forest Science, 54(3), 255-259.

312. Yuqing, Y., Shongming, H., Meng, S. X., Trincado, G., & VanderSchaaf, C. L. (2009). A multilevel individual tree basal area increment model for aspen in boreal mixedwood stands. Canadian Journal of Forest Research, 39(11), 2203-2214.

313. Zhang, Q. Y., Middleton, E. M., Margolis, H. A., Drolet, G. G., Barr, A. A., & Black, T. A. (2009). Can a satellite-derived estimate of the fraction of PAR absorbed by chlorophyll (FAPARchl) improve predictions of light-use efficiency and ecosystem photosynthesis for a boreal aspen forest? Remote Sensing of Environment, 113(4), 880-888.

314. Zhang, X., Van Rees, K., & Vujanovic, V. (2008). Fungal community structure associated with high density willow plantations. Canadian Journal of Plant Pathology, 30(2), 386-387.

315. Zhou, C., Dai, C., & Smith, G. (2010). Viscoelasticity of aspen wood strands during hot pressing: Experimentation and modeling. Holzforschung, 64(6), 713-723.

316. Zhou, C., Smith, G., & Dai, C. (2009). Characterizing hydro-thermal compression behavior of aspen wood strands. Holzforschung, 63(5), 609-617.

317. Zhou, Z., Wang, M., Hu, J., Lu, M., & Wang, J. H. (2010). Improve freezing tolerance in transgenic poplar by overexpressing a ω-3 fatty acid desaturase gene. Molecular Breeding, 25(4), 571-579.

15 Appendix I

Summary stands in ha by species and classifiers ecozone based on the 2006 National Forest Inventory area and volume estimates derived from forest stands where the dominant, or lead species are either poplars or willows:

Eco Zone	P. BAL	P. BAL	P. DEL	P. GRA	P. SPP	P. TRE	P. TRI	SALI BEB	SALI NIG	SALI SPP	Total
Atlantic Maritime	14,393			8,570	73,402	1,119,999					1,216,364
Boreal Cordillera	135,772					1,576,646					1,712,418
Boreal Plains	217,610	527,442			32,097	15,331,674				756	16,109,580
Boreal Shield	67,411			96,836	12,160,840	3,916,926		8,280		632	16,250,926
Hudson Plains					95,145	7,629					102,774
Mixedwood Plains	11,109		291	8,378	276,746	61,412			470	9,496	367,903
Montane Cordillera	128,719				1,499	1,228,438	7,298				1,365,954
Pacific Maritime	57,670					85,424	15,004				158,098
Prairies	699,638					1,774,591					2,474,229
Taiga Cordillera						10,292					10,292
Taiga Plains	102,511					4,031,030					4,133,540
Taiga Shield	28,118					1,152,018					1,180,136
Total	1,462,950	527,442	291	113,784	12,639,730	30,296,079	22,302	8,280	470	10,884	45,082,213

Source: Natural Resources Canada, Canadian Forest Service

16 Appendix II

Summary of the Questionnaires, n=7

Table 1: Total area of poplars and willows 2011 by main forest categories, forest function and area planted from 2008 to 2011 (area change over the last 4 years).

Forest category		Total Area 2011 (ha)	Total area by forest function in %				Area planted from 2008-2011 (reforestation and afforestation) (ha)
			Production				
			Industrial roundwood, (%)	Fuelwood biomass (%)	Protec-tion (%)	Other* (%)	
Indigenous	Poplars	1,207,157	40	10	50		
	Willows						
	Mix of P&W						
	Total	1,207,157					
Planted	Poplars	44,128	45	45		10	
	Willows						
	Mix of P&W						
	Total	44,128					
Agrofor./ TOF	Poplars	20,193					
	Willows	7000					
	Mix of P&W						
	Total	27,193					
Grand Total		1,278,478					

Table 2: Mean Annual Increment (MAI), rotation lengths, and wood removals 2011 by forest category, species, cultivar or clone.

Forest category and species, cultivar or clone		Avg MAI m^3/ha/yr	Average rotation length (yrs)			Wood removals 2011 in m^3		
			Production		Protection	Production		Protection
			Industr. roundwood	fuelwood, biomass		Industr. roundwood,	fuelwood, biomass	
Indigenous	**Poplars**							
	P. tremuloides +P. balsamifera	2.5	60-80			2.8 million		
	P. tremuloides	2.5-3.0	80			964		
	P. balsamifera	2.5-3.0	80			241		
	P. tremuloides	15	33		80			
	Willows							
	S.myabeana (SX67)	36		3			1520	
	S.myabeana (SX 64)	36		3			760	
Planted	**Poplars**							
	Hybrid poplar	16	18-20			0		
	P. tremuloides	2.5-3.0	80					
	P. balsamifera	2.5-3.0	80					
	TXD 53 242				15yrs			
	D TAC 7				15yrs			
	P. tremuloides	20	20			43,050		
	Willows							
	None reported							

Table 3: Main cultivars/clones in use in planted forests.

Main cultivars/clones in use	Originates from certified germplasm	Major end-use
Poplars		
1) 'Walker' hybrid poplar	No	Pulp
2) 'Okanese' Hybrid poplar	No	Pulp
3) 'Northwest' hybrid poplar	No	Pulp
4) 'P38P38' hybrid poplar	No	Pulp
5) Hybrid aspen (T x Ta)*	No	Pulp
6) NM-6	No	Pulp
7) DTAC 7	No	Pulp
8) TD 52-226	No	Pulp
9) TD 15-29	No	Pulp
10) D Tac 7	Yes	Remediation
11) TXD 53 242	Yes	Remediation
12) NM6	Yes	Remediation
13) Walker	Yes	Agro Forestry
14) Assiniboine	Yes	Agro Forestry
15) Okanese	Yes	Agro Forestry
16) Katepwa	Yes	Agro Forestry
17) CanAm	Yes	Agro Forestry
18) Populus tremuloides	No	Orientated Strand Board
19) Populus balsamifera	No	Orientated Strand Board
Willows		
1)SX 67 Salix Myabeana	Yes	Biomass
2) SX 64 Salix Myabeana	Yes	Biomass
3) Owasco/Salix viminalis x S. miyabeana	Yes	Biomass
4) SX 61 Salix Sachalinensis	Yes	Biomass
5) Tully Champion/Salix viminalis x S. miyabeana	Yes	Biomass
6) Otisco/Salix viminalis x S. miyabeana	Yes	Biomass
7) Fabius /Salix viminalis x S. miyabeana	Yes	Biomass
8) Fischcreek /Salix purpurea	Yes	Biomass
9) Sherburne /Salix sachalinensis x S. miyabeana	Yes	Biomass
10) acutifolia	Yes	Agro Forestry
11) alba sericea	Yes	Agro Forestry
12) amygdaloides	Yes	Agro Forestry

- **P. tremuloides x P. tremula*

Table 4: Tree ownership in 2011.

Forest category		Public ownership			Private corporate ownership			Private smallholder ownership			Other ownership		
		Prod	Prot	Other	Prod	Prot	Other	Prod	Prot	Other	Prod.	Prot.	Other
		%	%	%	%	%	%	%	%	%	%	%	%
Indigenous	Poplars	90	10										
	Willows												
Planted	Poplars	32.5		.5	32.5		.5	33.9		.1			
	Willows				100								
Agrofor./ TOF	Poplars				26			24	25				25
	Willows								100				

Table 5: Forest products from poplars and willows.

Forest category		Fuelwood chips	Industrial roundw. (logs, pulpw.)	Wood-pulp (mech. or chem.)	Particleboard fibreb. (MDF, (hardboard)	Veneer sheets	Plywood	Sawn-timber
			'000 m³ (r)					
Indigenous	From poplars			10,050				
	From willows							
Planted	From poplars			1,000	600,000 (OSB)			
	From willows	1.14						
Agrofor./ TOF	From poplars							
	From willows							

Table 6: Foreign trade with poplars and willows in 2011.

Imports of poplar and willow products 2011	**'000 m3 (r)**	**Countries of origin**	**Estimated share of country of origin in p&w imports of this product (%)**
Fuelwood, chips			
Industrial roundwood (logs, pulpwood)	7,000	USA	
Wood pulp (mech. or chem.)			
Particleboard, fibreboard (hardboard, MDF)			
Veneer sheets			
Plywood			
Sawn timber			
Exports of poplar and willow products 2011	**'000 m3 (r)**	**Destination countries**	**Estimated share of the destination country in p&w exports of this product (%)**
Fuelwood, chips			
Industrial roundwood (logs, pulpwood)			
Wood pulp (chem.. or chem..)		1) United States 2) Korea 3) China	1) ~38% 2) ~22% 3) ~22%
Particleboard, fibreboard (hardboard, MDF)			
Veneer sheets			
Plywood			
Sawntimber			

Table 7: Your opinion is important to us! Please reflect on the prevailing trends until 2020 in the development of poplars and willows in your country!

	increase	decrease	remain as it is	don't know
The conversion of **natural** poplar and willow forests to other land uses will...	1	1	3	2
The area of **planted to** poplar and willow forests will....	4	1	2	
The area of poplars and willows for bioenergy plantations will	5		1	2
Investments in poplar and willow tree breeding programs will	2	2	3	
Government investments in the poplar and willow sector will ...	3		2	2
Private investments in the poplar and willow sector will ...	4	1	2	
The significance of poplars and willows for **productive** purposes will	4		2	1
The significance of poplars and willows for **environmental** purposes will	6			1
The rejection by environmental groups of **planted** poplar and willow forests will	2	1	2	2
The acceptance by the general public of poplars and willows being important natural resources will........	2		5	