Activities Related to Poplar and Willow Cultivation and Utilization in Canada

Canadian Report to the 25th Session of the International Poplar Commission

BERLIN, GERMANY
PERIOD 2012–2015
MAY 2016

Photo credits: Jim Witiw, Daishowa Marubeni International Ltd. (background) / Barb Thomas (seedling, harvester, survey crew) / Louisiana Pacific Canada Ltd., Forest Resources Division (logs)

POPLARS & WILLOWS CANADA
PEUPLIERS & SAULES

Poplar and Willow Council of Canada
Conseil canadien des peupliers et des saules

ACTIVITIES RELATED TO POPLAR AND WILLOW CULTIVATION AND UTILIZATION IN CANADA

2012-2015

Canadian Report to the International Poplar Commission

25th Session, Berlin, Germany

13-16 September 2016

Prepared by: John Doornbos, Edmonton, Alberta,
Jim Richardson, Ottawa, Ontario, and
Cees van Oosten, Nanaimo, British Columbia

For: Poplar and Willow Council of Canada/
Conseil canadien des peupliers et des saules

With financial support from the Natural Resources Canada - Canadian Forest Service, / Ressources naturelles Canada - Service canadien des fôrets,

30 April 2016

FOREWORD

The International Poplar Commission (IPC) of Food and Agriculture Organisation (FAO) envisages supporting rural livelihoods, enhancing food security and contributing to sustainable land-use by promoting the genetic conservation and utilization of poplars and willows. These fast-growing crops have the potential to enhance ecosystem services including the storage of carbon, and the conservation and remediation of soil and water.

Recent research, deployment and technology transfer on poplar and willows in Canada and elsewhere have indicated a great demand for plywood and pellet production as well as biofuel conversion. As demand for poplar and willow is increasing in the global market, there is a need to carry out massive cultivation of improved cultivars involving land owners, government agencies and other stake-holders.

I am very pleases that the German Federal Ministry of Food and Agriculture is organising the 25th session of the IPC on “Poplars and Other Fast-Growing Trees - Renewable Resources for Future Green Economies”. I hope Canada’s National Report spearheaded by the Canadian Forest Service (CFS) and the Poplar and Willow Council of Canada (PWCC) provides new knowledge and is useful to practitioners worldwide.

I wish to gratefully acknowledge the support of Natural Resources Canada - Canadian Forest Service, without which production of this report would not have been possible.

I extend my good wishes for the success of this global meeting on poplar and willows.

Sincerely,

Raju Soolanayakanahally
Chair, Poplar and Willow Council of Canada

TABLE OF CONTENTS

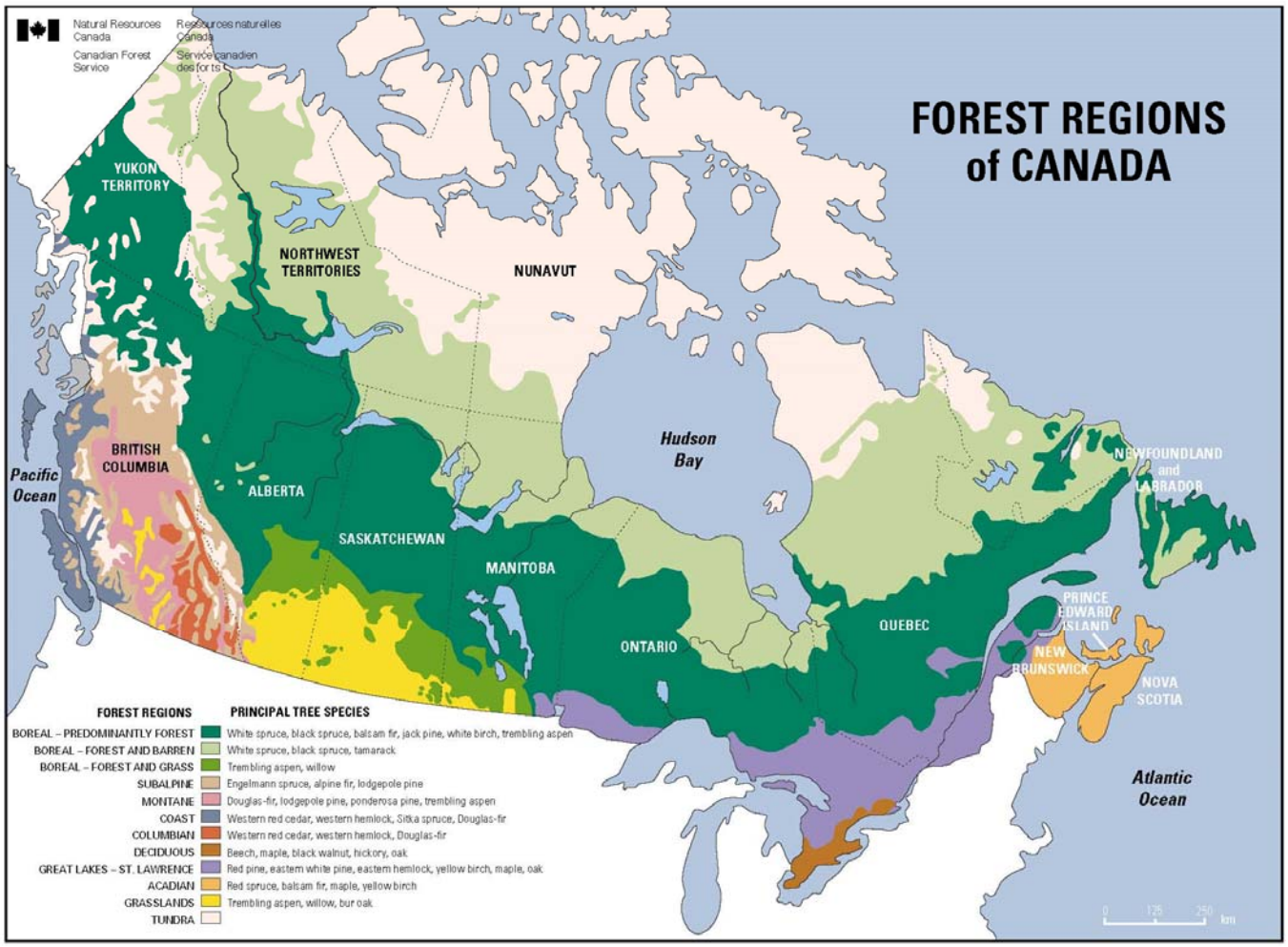
I. POLICY AND LEGAL FRAMEWORK

Canada's forestland has a unique pattern of ownership. Approximately 90% of Canada's forestland is owned by the Canadian provinces and territories, 6% is privately-owned and 4% is owned by the federal government[1]. Provinces in Canada have exclusive jurisdiction over forest management and agriculture regulations, and associated property taxation; jurisdiction in the Territories is in the process of being devolved. Although only 6% of forestland in Canada is privately-owned, it produces 10% of harvested timber. Privately-owned forestland usually contains the most productive forestland, where the most intensive silviculture regimes are practised. Federally-owned forestland includes lands held on behalf of Canada's aboriginal communities, National Defence, Natural Resources Canada and Parks Canada.

Forestland ownership varies in Canada from almost 95% provincially-owned forestland in British Columbia to 48% in New Brunswick. Governments hold publicly-owned forestland (either provincially- or federally-owned); these lands are referred to as Crown Lands. Provincial policies and legislation on property valuation and taxation for land used to grow tree crops vary widely across Canada. Although Federal income tax rules apply nationwide and are administered by the Canada Revenue Agency (CRA), there are no specific policies or federal tax incentives pertaining to *Populus* or *Salix*.

The vast majority of forests in Canada's boreal forest zone (see map on page 5) support natural components and even pure stands of trembling aspen (*Populus tremuloides*), often with a minor component of balsam poplar (*Populus balsamifera*). Where these stands are harvested, predominant forest regeneration is with naturally occurring trembling aspen, which will predominantly regenerate from existing root systems through coppicing. The vast majority of boreal forests are managed by or through the respective provincial forest services, and in several cases provincial regulations deal with reforestation using various poplar species. Willow is not recognized as a forest tree species in Canada and thus no regulations exist for its regeneration in forests; however, provincial and/or regional regulations may exist when willow is used for rehabilitation or reclamation in riparian areas and on various provincially-owned lands following major disturbances, e.g. mining, oil sands development, oil & gas reclamation, etc.

[1] http://www.nrcan.gc.ca/forests/canada/ownership/17495



It is important here to explain the concept of 'short-rotation-intensive-culture' (SRIC) of poplar or willow crops[1] as it is understood in Canada. SRIC refers to the establishment and management of poplar and/or willow crops on farmland, using an intensive agronomic approach including soil preparation, systematic crop layout, mechanical and/or chemical weed control, insect and disease control, protection from various other biotic factors (e.g. deer browse), followed by harvesting. In some cases these crops are grown in coppice culture using very short harvest cycles[2] (e.g. one to five years) on a root system that can produce several harvest cycles. In other cases only one crop is harvested from the same root system before it is replaced. Such crops could include pulpwood, sawlogs and veneer logs. In the

[1] SRIC crops in Canada are considered Trees Outside Forests, using the International Poplar Commission (IPC) categories for National Reports.

[2] 'Harvest cycle' refers to the number of years the above-ground biomass is allowed to grow before it is harvested. In coppice culture of poplar or willow, crops can be harvested from the same root system for several cycles. The number of years the same root system is used before being replaced is referred to as the 'rotation'.

latter two cases, periodic pruning of branches can be carried out to produce higher value logs.

1. British Columbia (BC)

a. Trees Outside Forests on Private Land

Currently, short-rotation-intensive-culture (SRIC) using poplar or willow is recognized as a farm practice on agricultural lands in British Columbia (BC) and therefore qualifies as 'primary agricultural production'. The Classification of Land as a Farm Regulation, B.C. Reg. 411/95, made under the BC Assessment Act, provides that, upon application, the following land may qualify for 'farm class':

- land used for a qualifying agricultural use;
- land used for purposes that contribute to a qualifying agricultural use, e.g. irrigation, access to farm outbuildings, shelterbelts.

Depending on the parcel size, the income derived from these and other farm activities allows producers to maintain 'Farm Class' status with the associated assessed land values and property taxes for a particular municipality or regional district[1].

It may be up to 12 years before a producer harvests a SRIC hybrid poplar or willow crop. This is the maximum length of a crop cycle ('rotation')[2] allowed by the BC Assessment Authority to maintain 'Farm Class' status for income derived from the land.

There no longer are any industrial companies actively growing or processing SRIC hybrid poplar crops (plantations) in BC due to a lack of viable markets. As a result, the existing stands are becoming over-mature. SRIC willow crops are grown by a few smaller companies, primarily for environmental and bioenergy purposes.

---

[1] https://www.bcassessment.ca/services-and-products/_layouts/15/WopiFrame.aspx?sourcedoc=/services-and-products/Shared%20Documents/BCAL15102%20BCA_farm_brochure_digital.pdf&action=default

[2] It is unclear how coppice crops are viewed under the Act, since a rotation (a root system supporting one or more above-ground biomass harvests) can accommodate several harvest cycles that, combined, exceed the 12 year maximum rotation.

b. Agroforestry on Private Lands or Provincial Crown lands

The BC Ministry of Agriculture maintains an Agroforestry Unit[1] in the Sector Development Branch. As defined in BC, agroforestry is a land management approach that purposefully integrates the growing of trees with crops or livestock. Integration can involve deliberately retaining or adding trees or shrubs into agriculture production systems or deliberately adding or enhancing crops or livestock in forest production systems.

To date, the agroforestry program has been focused on silvopasture systems on both private lands and provincially-owned Crown lands. On privately-held farmland a number of individual projects were started under the Agroforestry Industry Development Initiative of the Ministry of Agriculture; however, no records of these are maintained by the Ministry, which is primarily focused on the integration of provincially-owned Crown range lands with silvopastoral management systems.

In BC, management of SRIC poplar or willow crops on agricultural land is not considered agroforestry, unless it is integrated with other practices on the same land unit.

c. Planted Forests on Provincially-Owned Crown lands

BC makes provision for the registration, selection and use of poplar, including hybrid poplar, on provincially-owned Crown lands. Conditions apply if vegetative plant material is collected from a single parent tree. A limit of 10 hectares applies when vegetative material collected from a single hybrid poplar tree is used to establish a hybrid poplar forest stand[1]. Willow is not recognized as a tree species and is not covered by this regulation.

2. Alberta (AB)

The Province of Alberta is divided into two main administrative areas in regard to land use, the White Area and the Green Area:

- the White Area is generally settled or suitable for settlement and is usually associated with more intensive uses such as agriculture, urban centres and well-developed infrastructure;

[1] http://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/agricultural-land-and-environment/agroforestry/agroforestry-resources

- the Green Area, is largely permanent forest and is mostly associated with less intensive uses such as timber harvesting, wild-land recreation and grazing.

Much of the privately-held forestland, woodlots and agricultural land suitable for afforestation to poplar (trembling aspen and poplar, including hybrid poplar) are located in the White Area. Both areas are managed in a multiple use context.

a. Trees Outside Forests on Private Land ('White Area')

There are no specific policies or tax measures promoting the management of poplar or willow species in Alberta on private land located in the 'White Area'.

b. Planted Forests on Provincially-Owned Crown lands ('Green Area')

Most planting on provincially-owned Crown land is on recently harvested natural timberlands (or indigenous forestlands) located in the 'Green Area', and primarily involves reforestation with various conifer species. Where a large component of trembling aspen was present before harvesting, the expectation is that it will regenerate naturally from root suckering.

Hybrid poplars (and any other non-native species) are not permitted to be planted within the 'Green Area'. Under current rules of the Alberta Forest Genetic Resource Management and Conservation Standards[1] (FGRMS), locally collected cuttings of naturally occurring poplar species, mostly balsam poplar, can be deployed in the Green Area (up to a maximum of 5,000 plants from a single clone within the seed zone of collection). All tree seedlings and cuttings are currently required to be from local sources (seed zones defined by FGRMS).

An updated set of standards is planned for release in 2016 which does not change the exclusion of non-native species including hybrid poplar. Under the updated FGRMS:

- genetic diversity of clonally deployed material must be at the same minimum level as that for seed deployment;

[1] http://aep.alberta.ca/lands-forests/forestry/documents/FGRMS-GeneticConservationStandards-2009.pdf

- clonal deployment can be enabled under three categories: rehabilitation, extensive management and intensive management; and
- each deployment category has limitations to the extent of area on which clones can be deployed, minimum effective population size and proportion of male/female clones.

3. Saskatchewan (SK)

a. Trees Outside Forests on Private Land

There are no specific policies or tax measures promoting the management of poplar or willow species on private land in Saskatchewan.

b. Planted Forests on Provincially-Owned Crown lands

Saskatchewan regulates which tree species may be planted in the provincially-owned forests through the Saskatchewan Environmental Code Forest Regeneration Assessment Chapter and Standard[1]. Trembling aspen and balsam poplar are acceptable in all Saskatchewan ecoregions. Plains cottonwood (*Populus deltoides* ssp. *monilifera*) is acceptable for planting in the Cypress Upland Ecoregion in south-western Saskatchewan.

Exceptions to the species above have and can be made for research purposes such as provenance trials of hybrid poplar within the Crown provincial forest.

4. Manitoba (MB)

Manitoba has no policies or regulations regarding the establishment or management of poplar or willow species.

5. Ontario (ON)

As in the Prairie Provinces of Alberta, Saskatchewan and Manitoba, the Province of Ontario does not have specific tax measures promoting the management of poplar or willow species.

The Ministry of Natural Resources and Forestry (MNRF) does recognize trembling aspen), bigtooth aspen (*Populus grandidentata*) and balsam poplar as forest

[1] http://environment.gov.sk.ca/adx/aspx/adxGetMedia.aspx?DocID=1ccf5bc7-0f91-4765-a819-a20c58e72b27 – Table 3 in Appendix 1 of the Standard outlines acceptable species that can be used for reforestation by Ecoregion - http://environment.gov.sk.ca/adx/aspx/adxGetMedia.aspx?DocID=fb4ed9dc-4ec8-4ab7-b939-3cb1f491adf1

species. The MNRF recently revised its silviculture guide[1]where it addresses the management of the aforementioned poplar species. The guide makes no mention of naturally occurring eastern cottonwood (*Populus deltoides*) or the presence of *Populus ×jackii* – spontaneous hybrids between *P. deltoides* (♀) and *P. balsamifera* (♂); several *P. ×jackii* hybrids entered commercial use in Ontario and Quebec in the 1970's and 1980's.

6. Quebec (QC)

a. Trees Outside Forests on Private Land

In 2009 the *Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec* (MAPAQ – Quebec Ministry of Agriculture, Fisheries and Food) recognized SRIC willow biomass crops as agricultural production. This was followed in 2010 by the recognition also of SRIC poplar biomass crops as legitimate agricultural production. This recognition of SRIC poplar and willow does not extend to the production of solid wood products, such as logs for oriented strandboard (OSB), pulpwood and saw log production, which require longer rotations.

b. Planted Forests on Publicly-Owned and Private Lands

In 2013, the *Loi sur l'aménagement durable du territoire forestier* (Sustainable Forest Development Act)[2] replaced the then-current Forest Act, introducing major changes to the way forests are managed. However, there were no major changes to the legislative provisions governing private forest land; many of the elements introduced over the previous 15 year period remain in place, in particular the regionalization of the decision-making process through regional agencies that affect private forest development. Under the Act many of the previous financial support programs remain in place for private forests. Although private forest ownership is only 8% of the total forestland area[3], it accounts for 16% of the timber produced. Private forests are among the most accessible and productive forests in Quebec. Small landowners have to obtain authorization prior to planting any trees.

---

[1] OMNRF. 2015. Forest management guide to silviculture in the Great Lakes-St. Lawrence and boreal forests of Ontario. Toronto: Queens Printer for Ontario. 394 pp. – download at https://www.ontario.ca/document/forest-management-guide-silviculture-great-lakes-st-lawrence-and-boreal-forests-ontario-0

[2] http://mffp.gouv.qc.ca/le-ministere/lois-reglements-forets/ - also: http://mffp.gouv.qc.ca/the-forests/understanding-the-forest/?lang=en

[3] South of 52° north latitude.

Once they are eligible, they can apply for grants with the various Regional Agencies.

The *Ministère des Forêts, de la Faune et des Parcs* (MFFP) created a silvicultural intensity gradient for forests, covering Extensive, Basic, Intensive and Elite silvicultural management regimes[1]. For the latter two categories more intensive management is justified through their respective financial returns and it is under these two regimes that much of the hybrid poplar would be planted on the best forestlands.

7. New Brunswick (NB), Nova Scotia (NS), Prince Edward Island (PEI) and Newfoundland and Labrador (NL)

The Provinces of New Brunswick, Nova Scotia, Prince Edward Island and Newfoundland and Labrador have not reported specific policies or tax measures promoting the management of poplar or willow species.

New Brunswick does not allow planting of poplar or willow on provincially-owned Crown forestland.

[1] http://mffp.gouv.qc.ca/english/publications/forest/sustainable-forest-management-strategy.pdf

I. TECHNICAL INFORMATION

1. Identification, registration and varietal control

Canada has no federal regulations for the identification, registration or control of poplar or willow clones. Although Canada has a 1990 Plant Breeders Rights Act[1], it applies only to certain species prescribed by its regulations. Neither poplar nor willow is covered. Poplar and willow clones are widely propagated vegetatively for various purposes, without any legal protection of intellectual property rights for the breeder unless specific contractual arrangements for that purpose are in place. There is also no mechanism to certify the origin and clonal identity of poplar or willow clones (except for poplar clones in Quebec). In the 1990s the Poplar and Willow Council of Canada attempted to introduce a voluntary Certification Service, under which commercial nurseries could register certified clones. The Certification Service did not find support from the nursery industry and the initiative was subsequently abandoned. Despite that setback, the Genetics and Breeding Working Group of the Poplar and Willow Council of Canada (PWCC) has been actively developing and managing a directory of Canadian improved populations of poplar and willow. This 'clone directory' is an electronic, searchable database of poplar, willow, and their clones in Canada. It incorporates the related databases from several public and private organizations involved in poplar and willow breeding programs in Canada, and includes information, as available, on source, collection or breeding history, parentage and testing of clones and hybrids[2].

Notwithstanding the absence of registered poplar clones under the 1990 Plant Breeders Rights Act, Agriculture and Agri-Food Canada (AAFC) did obtain registered trademarks for two hybrid poplar clones - 'Okanese' and 'AC SundancerTM' – that were produced at its now closed Shelterbelt Centre[3] (formerly operated by the Prairie Farm Rehabilitation Administration (PFRA) of AAFC). These clones, both male, were bred from the same female parent 'Walker'[4].

---

[1] http://laws-lois.justice.gc.ca/eng/acts/P-14.6/

[2] Currently the directory is unavailable pending updating and restructuring, but will become available to the Poplar and Willow Council of Canada members at http://www.poplar.ca/.

[3] The Shelterbelt Centre at Indian Head, Saskatchewan closed down in 2013, after having been in operation since 1901.

[4] 'Walker', a female clone, has been in long-term use as a major shelterbelt tree on the Canadian Prairies and the US Midwest Plains region; it was an early hybrid used in SRIC poplar farming in Alberta and Saskatchewan. 'Walker' is an open-pollinated seedling cross of *Populus deltoides* × *P.*

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. The problem is easily solvable using DNA technology, which has become much more affordable.

Several provinces in Canada have regulations pertaining to deployment of exotic species, including hybrid poplar, on provincially-owned Crown land, as discussed in Chapter I of this report.

British Columbia makes provision for the registration, selection and use of poplar, including hybrid poplar, on provincially-owned Crown lands. Despite this policy provision, there are currently no registered poplar or vegetative lots, nor recent records of seed use stored in the provincial Seed Planning and Registry system (SPAR). Willow is not covered.

In the Province of Quebec the *Ministère des Forêts, de la Faune et des Parcs* (MFFP) 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 MFFP provides hybrid poplar planting stock without charge to companies that operate on provincial public lands and 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 in the province. Although the hybrid poplars are available for deployment in Quebec only, MFFP has always shared genetic material, such as parental male and female flowers and various clones for testing and other purposes with poplar breeders elsewhere.

MFFP obtained a replicate of the Agriculture Canada Balsam Poplar (AgCanBaP) collection from AAFC and established a common garden test in Quebec in 2013. This new test completes the existing network of balsam poplar experimental plantations established across Canada. The AgCanBaP collection (see page 31) continues to be managed and maintained by AAFC at Indian Head, Saskatchewan.

MFFP is very active in germplasm conservation activities in Quebec. Selected parental trees of *P. deltoides*, *P. maximowiczii* and *P. trichocarpa* were propagated with success and cuttings were made available for material exchange

---

×*petrowskyana* (itself a *P. laurifolia* × *P. nigra* cross). It was selected in 1944 at Indian Head, Saskatchewan and has been widely distributed for shelterbelt use since 1963.

and breeding. A broader population of *P. trichocarpa* (IUFRO collection from Oregon, Washington, and BC) was shipped from Quebec in 2012 to Indian Head and Edmonton, Alberta. Pollen from *P. trichocarpa*, *P. maximowiczii* and *P. deltoides* was stored for long-term conservation and for plant material exchange. Pollen from *P. maximowiczii* was provided to GreenWood Resources (Oregon, USA) in 2014 and 2015 for breeding purposes.

Other provinces and territories do not have poplar or willow breeding or selection programs and have not reported provisions or policies for the identification, registration and varietal control of poplar or willow.

2. Production Systems and Cultivation

a. Nursery

Poplar, including hybrid poplar

During the period 2012 to 2015 Kruger Products LP in British Columbia and Alberta Alberta-Pacific Forest Industries Inc. in Alberta discontinued the establishment of SRIC hybrid poplar crops on private agricultural land; Kruger Products LP also discontinued planting poplar, including hybrid poplar, on provincially-owned Crown lands managed under licence from the Province of British Columbia. As a result, large-scale nursery production of hybrid poplar in western Canada for the establishment of poplar stands has rapidly declined.

At present small quantities of poplar are being produced by independent nurseries that market this material for fill-planting[1] (with hybrid poplars) of existing SRIC hybrid poplar crops, reforestation, reclamation of access roads, reclamation of areas disturbed by mining and the oil & gas industry, shelterbelts and limited planting on existing tree farms owned by various land owners. One large nursery in Alberta reports producing hybrid poplar clones for use by private landowners in shelterbelt plantings in Alberta's 'White Zone', a practice also used in the other Prairie Provinces, even though there is a trend to eliminate existing shelterbelts. Shelterbelt use on farms growing annual crops in the Prairie Provinces of Canada is declining. Two key reasons are (1) that agricultural commodity prices have been rising rapidly, especially for pulse crops, making cropland too valuable for tree

[1] Fill-planting is a technique of filling in small areas of plantation failures to ensure at least 90% coverage of a plantation area with a viable crop. Fill-planting usually takes place at the start of the second growing season.

cover, and (2) that the use of minimal-till and zero-till soil preparation practices has greatly decreased topsoil losses due to wind erosion. Many of the hybrid poplars planted in farm shelterbelts originate from the selection and breeding work at Indian Head. Use of native poplar on provincially-owned lands reflects policies and intentions to control or ban the use of non-native poplar on such land, as in Alberta.

Although there is nursery production of aspen in Canada, difficulty in vegetative propagation of this species limits its commercial production and use; one nursery in Alberta reported producing aspen planting stock from seed.

In Quebec the *Ministère des Forêts, de la Faune et des Parcs* (MFFP) controls hybrid poplar nursery production and distribution through its provincially-owned nurseries. Since the vast majority of planting in Quebec takes place on forestland and there is a 'no-herbicide' policy in place, large planting stock is required to ensure survival. For that reason the majority of poplar stock is grown as bareroot stecklings[1]. Small unrooted cuttings are planted in bareroot nursery beds and grown for one year. In the fall the stock is lifted, processed and cold-stored for outplanting the following spring.

The MFFP uses approximately 40 different hybrid poplar clones which are propagated in provincially-owned nurseries. Quebec recently expanded its clonal list by adding 13 clones of different hybrid combinations: *P. maximowiczii* × *P. nigra* (MN), *P. deltoides* × *P. maximowiczii* (DM), *P. maximowiczii* × *P. trichocarpa* (MT), *P. maximowiczii* × *P. balsamifera* (MB) and a complex four-way cross ((*P. deltoides* × *P. nigra*) × *P. balsamifera*) × *P. maximowiczii* ((DNxB)xM). The stock is distributed to landowners for outplanting on both private and public lands.

The MFFP has been experimenting with and developing the use of unrooted poplar whips, which are attractive due to lower costs of production, handling, storage, transport and planting. Domtar Corporation[2] in Windsor, Quebec, has been planting unrooted whips in Quebec in combination with soil mounding as a form of intensive site preparation. This is a technique

[1] Steckling or set is the name given in Quebec to a rooted whip. The size is usually between 1.5 and 2.0 m and is sufficient to dominate existing competing vegetation and avoid browsing by deer.
[2] Domtar Corporation is a large pulp & paper company. See also http://mirador.domtar.com/document/PGAF_english.pdf

that was pioneered and developed successfully by Kruger Products LP[1] in British Columbia.

There are no nursery production reports for poplar from the Provinces of Ontario, New Brunswick, Nova Scotia, Prince Edward Island or Newfoundland and Labrador.

Willow, including hybrid willow

The production of willow planting stock has generally increased over the last several years. Use of willow species has been increasing for environmental applications, such as reclamation, phytoremediation and potential use for bioenergy.

Bionera Resources Inc.[2] in British Columbia established 24 ha of willow stoolbed nurseries at three sites in Canada - Prince George and Campbell River in British Columbia and Prince Albert in Saskatchewan, and one site in the USA at Woodburn, Oregon. The company produces mostly hybrid willow varieties under licence from the State University of New York (SUNY)[3] at Syracuse, NY and Lantmännen[4] in Sweden, as well several varieties in the public domain from Cornell University[5], Ithaca, NY. Currently these stoolbeds produce unrooted cuttings for bioenergy projects. A minor amount of hybrid poplar is also grown for the same purpose.

The stoolbed nursery at Prince George, BC, is owned by PRT Growing Services Ltd.'s Red Rock Nursery[6], and produces unrooted willow stock under contract to Bionera. It produced 30,000 willow cuttings in 2015 for training purposes, and hopes to increase production in 2016. The intent is to develop a self-propelled whip cutter and bundler which will allow easier transport of the material to a processing building where it can be sorted, sized and packaged. Bionera is transitioning from using a cutting planter to a whip planter. An important aspect of this shift is the strict requirement for

[1] Kruger Products LP in British Columbia ended its poplar growing business in 2012 after a long and successful program.
[2] Bionera is a wholly owned subsidiary of PRT Growing Services Ltd. - http://www.bionera.com/. PRT Growing Services Ltd. is the owner of the stoolbeds, which grow willow and poplar stock under contract to Bionera.
[3] http://www.esf.edu/willow/
[4] http://lantmannen.se/en/start/press-och-media/news-and-press-releases/lantmannen-in-strategic-partnerhip-for-plant-breeding/
[5] http://willow.cals.cornell.edu/
[6] http://www.prt.com/

certain growth attributes, such as straight stems and a uniform distribution of stem diameters. These attributes influence the selection of desirable willow varieties for future use, based on such strict growth attributes as well as yield potential.

Agro Énergie[1], a Canadian farm enterprise in Quebec, has been in business since 2006 to develop short-rotation willow coppice as a 'stable and efficient biomass crop' for the bioenergy and bio-refining industry. Besides producing willow biomass feedstock, the company also produces willow cuttings for sale in Ontario, Quebec and the Maritime Provinces of New Brunswick, Nova Scotia and Prince Edward Island.

b. Planted Forests

'Planted Forests' are taken here to include forest ecosystems which have been converted from natural or indigenous forests to plantations dominated by poplar - hybrid poplar, eastern cottonwood, balsam poplar or black cottonwood. Typically these plantations are extensively managed, but may have received substantial mechanical site preparation to aid in planting and in controlling competing vegetation. For the purpose of this report, forest areas with *P.* ×*jackii* – the spontaneous hybrid between *P. deltoides* (♀) and *P. balsamifera* (♂) found in Ontario and Quebec – are not considered as 'planted forests'. Nor are plantings of native or hybrid poplar species carried out to reclaim roads, landings used in forest harvesting, etc.; these account for only a small percentage of the entire forest area.

Before Kruger Products LP ceased management of poplar on its private and provincially-owned Crown forestland[2] in BC in 2012, the company harvested forest stands with a high component of native black cottonwood on Crown forestland and converted these lands into poplar stands, primarily with hybrid poplar. The company often used a small hydraulic excavator to prepare planting spots by mounding the soil to ease establishment of unrooted poplar whips. Such planting spot preparation not only facilitated a more systematic plantation layout, it also prevented encroaching competing vegetation from overtopping and thus competing for light with the newly planted poplars. An added benefit was that mounding increased the soil temperature, stimulating root initiation and development. This proved to be

[1] http://agroenergie.ca/en

[2] Kruger Products LP operated the only deciduous Tree Farm Licence in the Province of British Columbia. The company did not plant beyond the spring of 2012.

a very successful strategy and was considered an 'extensive' management regime (vs. the SRIC systems used on farmland). Fill-planting, when necessary, was often opportunistic, using locally harvested whips of black cottonwood. The isolation of these forest stands on alluvial floodplains in several BC coastal inlets did not justify the cost of shipping in new planting stock from the nursery. Although these new forest stands were dominated by vigorously growing hybrid poplar, they often had a substantial component of black cottonwood, either from fill-planting a year later or from spontaneous vegetative reproduction of buried black cottonwood branches after the harvesting process. With the cessation of the company's poplar operations, planting hybrid poplar on provincially-owned Crown land has stopped.

The only other province where reforestation of forestlands with hybrid poplar takes place is Quebec, where it occurs on both provincially-owned forestland and private forestland. *Réseau Ligniculture Québec*[1] reports that in the period 2012-2015, approximately 3,100 ha of new hybrid poplar plantations were planted by the forest industry in several regions of Quebec, a slight decrease from historic levels.

Quebec 2012-2015	Area of poplar planted (ha)		
	Private	Provincial	**Total**
Domtar[2]	1,600	-	1,600
Norampac[3]	218	-	218
Other companies	-	1,282	1,282
Total area planted	1,818	1,282	**3,100**

This brings the total area of hybrid poplar plantations managed by the forest industry in Quebec to an estimated 12,000 ha, of which Domtar manages approximately 5,000 ha on their privately-owned forestlands.

Chemical fertilizers are not generally used in plantation management in Quebec due to the high expense and the relatively long period required to amortize the investment. Norampac obtains provincial approval to apply

[1] http://www.rlq.uqam.ca/
[2] Domtar Corporation is a large pulp & paper company
[3] Norampac, a packaging company, is a division of Cascades Canada ULC. It is unclear what proportion of Norampac's 218 ha of planting was on company-owned farmland and could have been classified as SRIC crops of hybrid poplar.

industrial ash and biosolids[1] on its farmland as a soil amendment. Domtar also uses soil amendments, including lime, industrial ash, municipal and mill biosolids, to improve its forest sites.

Hybrid poplar clones used in Quebec are provided by the *Ministère des Forêts, de la Faune et des Parcs* (MFFP) for the different regions on the basis of clonal trials conducted by the Ministry. The majority of these plantations have been established with stand densities from 800 to 1,111 stems per ha on forest sites that were previously harvested by clearcutting. The expected yields are 200-250 m^3 over a 15-25 year rotation (harvest cycle). Poplar wood from plantations will be used to augment traditional fibre supplies for pulp and paper mills and OSB mills.

Small private forestland owners in Quebec planted nearly 320 ha of hybrid poplar plantations during the period 2012-2015, bringing the total on small forestland holdings to 1,400 ha.

c. Indigenous Forests[2]

Poplar occurs in indigenous forests in Canada primarily in forest ecosystems in the boreal forest region (see map on page 6) dominated by natural trembling aspen, in which there are often minor components of balsam poplar and, in British Columbia, black cottonwood[3]. The latter two species are found on better forest conditions such as riparian sites.

Throughout British Columbia, indigenous forests, whether boreal or not, may contain minor components of black cottonwood. In the more southern regions of Manitoba, Ontario, Quebec, New Brunswick and Nova Scotia, components of bigtooth aspen (*P. grandidentata*) are found in a number of different forest ecotypes.

Indigenous aspen forests in the boreal forest zone usually have a significant component of coniferous species. Without human intervention in these boreal aspen-dominated forests, naturally occurring forest fires result in a

[1] Biosolids or sludge (in this case '*boues d'usines*' – industrial biosolids). Biosolids result from the treatment of wastewater (often municipal) which removes the solids (sludge) from the liquid effluent.
[2] See also footnote to table on page 51 in regard to definition of 'indigenous forests'.
[3] Black cottonwood (*P. trichocarpa*) occurs naturally throughout the forest regions of British Columbia, including the northeastern boreal region of the province and the adjoining northwestern boreal region of Alberta. Black cottonwood and balsam poplar (*P. balsamifera*) interbreed freely where they occur together.

continuous cycle of forest renewal, often enabling the aspen to regenerate in overwhelming numbers of stems thus dominating the boreal landscape. However, where fire has been absent for many years, whether by chance or as a result of fire control, these indigenous forests slowly develop into a climax forest dominated by coniferous species.

Natural regeneration of trembling aspen is usually prolific from existing root systems and requires little extra planting effort, except in the rehabilitation of abandoned forest access roads, landings used in forest harvesting and areas disturbed by oil and gas exploration. Rehabilitation planting takes place with rooted cuttings of aspen or with unrooted cuttings or whips of balsam poplar, and in some instances black cottonwood.

Much of these aspen-dominated forests is included in commercially important harvest licences. In some cases these licences authorize more than one company to utilize the timber: one is licensed to harvest the coniferous component, while the other harvests the aspen.

d. Agroforestry

In the context of poplar and willow in Canada, agroforestry generally involves plantations of poplar or willow established outside of forests, where the woody species are managed to benefit primary agricultural production. Examples of agroforestry with poplar and willow in Canada include production of beef cattle with the trees providing shade and shelter, row cropping with the trees providing protection from wind, and planting poplar or willow to provide shade to enhance crops such as mushrooms and certain berry crops which require shade.

In Alberta, the Agroforestry and Woodlot Extension Society[1] (AWES) provides information annually to more then 500 livestock producers throughout Alberta on proper design of shelterbelts to reduce stress on livestock during winter and summer months, to protect dugouts, providing water for cattle, from aerial contaminants and to keep substantial snow drifts off haying areas in winter. The shelterbelts have a critical component of hybrid poplar in the outside rows, which protects the slower-growing white spruce (*Picea glauca*) in the centre row from wind stress. AWES in Alberta wants to investigate the influence of single-row poplar shelterbelts on crop productivity. The Society

[1] http://www.awes-ab.ca/home.html

has identified a lack of research applicable to current cropping methods used and is seeking funding to carry out this research.

In 2000, Quebec researchers at the *Fiducie de recherche sur la forêt des Cantons-de-l'Est* (FRFCE)[1] initiated afforestation trials with several hybrid poplar clones on different parcels of abandoned farmland in southern Quebec. The purpose was to measure the effect of clones and sites on the development of an understory of non-timber forest products, specifically medicinal plants. Results will be published.

e. Trees Outside Forests – SRIC Systems for Wood Production

For the purpose of this report, 'Trees Outside Forests' refers to 'short-rotation-intensive-culture (SRIC)' crops[2] of poplar or willow managed on an agronomic basis and typically located on farmland. SRIC crops may involve intensive soil preparation, systematic crop layout and intensive mechanical and/or chemical weed control throughout the crop rotation, with one rotation potentially including several harvest cycles in the case of coppicing.

SRIC systems are primarily managed for the production of wood for end uses such as feedstock for bioenergy (using a coppice system), chemicals, mechanical and chemical pulp manufacture, engineered wood products (including OSB, plywood and parallel strand lumber), veneer and lumber products. SRIC crops are also managed to provide environmental services, such as the disposal of municipal or industrial biosolids and effluent, with the beneficial side effects to the crop of an organic fertilizer.

Willow for fibre production

In British Columbia, PRT Growing Services Ltd. has established 30 ha of various willow varieties (and a few hybrid poplar clones) on its private land near Prince George. The operation began as a viability trial but is transitioning into harvesting of cuttings and whips[3], and in some cases chipping for biofuel. The plantation is located on land that a decade earlier produced conifer bareroot planting stock for the forest industry. The company switched over to greenhouse production of containerized conifer

[1] http://www.frfce.qc.ca/ - the forest research trust of the Eastern Townships.
[2] In the USA, equivalent systems are referred to as short rotation woody crops (SRWC). Besides poplar and willow, SRWC includes other woody species, such as *Eucalyptus* spp. and *Platanus occidentalis* (American sycamore).
[3] Cuttings and whips are sold to the company's wholly-owned subsidiary Bionera Resources Inc.

stock and decided to use the land to grow willow biofuel feedstock to heat its greenhouses; the willow biomass produced for heating will displace the use of natural gas. A wood chip furnace was installed, which is currently running on 95% mill waste chips and 5% willow, harvested from its SRIC cropland. Over the next five years the company hopes to increase the willow proportion to about 50% of its annual feedstock requirements, approximately 300 tonnes of chips per year.

The company is evaluating the performance of its SRIC willow varieties and has identified 5 ha with desirable willow varieties that will eventually be scaled up to provide the required feedstock, as well as cuttings and whips for its client; this area receives enhanced treatment with fertilizer and improved pest and weed control. The remaining 25 ha will eventually be harvested and converted to the better willow varieties. The production of cuttings and whips, and the associated land management, fits in well with the greenhouse side of the operation and provides additional employment opportunities for its seasonal workforce.

PRT Growing Services Ltd. is also working on an agreement with the city of Prince George to receive and utilize municipal biosolids as a soil amendment for the very sandy soils in the company's stoolbed area and SRIC willow bioenergy plantation. Several years ago biosolids were applied in a large-scale trial, which had a very positive impact on the site's productivity and the soil's moisture-holding capacity. The willow crop experienced a very significant boost in productivity; however, one observed side effect was an 'exploding' weed problem[1], which led to the development of a more effective weed control strategy.

Bionera Resources Inc. is PRT Growing Services Ltd's wholly-owned subsidiary. The company established approximately 160 ha of SRIC willow crops in 2014 and 190 ha in 2015 on marginal agricultural land in Alberta, and is projected to establish another 200 ha in 2016. These multi-purpose SRIC willow crops will utilize municipal biosolids to produce biomass for composting and to improve soil productivity. Bionera is transitioning from using a cutting planter to a whip planter, which has favourably impacted the productivity of the stoolbed operations at PRT Growing Services Ltd, as well as in its own planting operations.

[1] Personal observation Cees van Oosten

Research on willow has been on-going in Quebec for many years, laying the groundwork for potential commercial uses of willow for various purposes. Agro Énergie in Quebec[1] has specialized in the production of SRIC willow coppice and has established over 300 hectares of SRIC willow crops, using more than 30 native and hybrid willows.

Studies[2] were initiated in 2011 to determine which combinations of soil, climatic conditions and cultivars are conducive to greater growth in eastern Canada. The performance of five willow cultivars was followed over three growing seasons on eight sites representing a large hydro-climatic gradient. The results indicate that, at the landscape level, climate variables largely explain the yield of the selected willow varieties. Nonetheless, soil pH, extractible P and clay content likely also play an important role in crop yield.

In another Quebec study[3], silt content, pH, exchangeable soil Ca and Mg, and organic C were all significantly and linearly related to aboveground yields. Annual yields were generally negatively correlated with drought within and across sites, supporting the earlier finding that climate variables largely explain the yield of the selected willow varieties.

Poplar for fibre production

In Alberta one major forest corporation, Alberta-Pacific Forest Industries Inc. (AlPac) manages approximately 10,000 ha of SRIC hybrid poplar crops on leased farmland. These crops are located close to the mill and will augment traditional trembling aspen fibre supply from provincially-owned Crown forestland in the 'Green Area', which the company manages under a Forest Management Agreement (FMA) with the province. AlPac ceased all new hybrid poplar planting activities in 2012 for economic reasons; a planned increase in mill capacity was put on hold and the company decided to add softwood fibre to its feedstock for the Kraft mill. Plans are to start harvesting the SRIC hybrid poplar on their poplar farm once trees start to reach merchantable size; the first harvests are expected within the next five year period.

---

[1] http://www.agroenergie.ca

[2] Personal communication Michel Labrecque, *Institut de recherche en biologie végétale*, *Université de Montréal*.

[3] Personal communication Michel Labrecque, *Institut de recherche en biologie végétale*, *Université de Montréal*.

Even though AlPac decided not to continue planting, the company is still managing the 10,000 ha poplar farm. The company's website[1] reports it is still involved in poplar farm research and is testing thousands of hybrid poplar genotypes.

In Quebec, Norampac has planted 218 ha of hybrid poplar on company-owned farm- and forestland; it is unclear what proportion of this was planted on the farmland. The company has been planting privately-owned fallow farmland since 1996 using the same techniques throughout this period. Industrial ash and biosolids are spread and ploughed under, followed by harrowing to break up and smooth out the soil surface to get the site ready for mechanical planting of the poplar crop. The company plants 700 stems per ha and for the first three years, an offset disk harrow is used between the planted rows to control weeds (no herbicides are used). The purpose of these SRIC hybrid poplar crops is to produce sawlogs, with a by-product of wood chips that can be used in the production of corrugated cardboard for packaging.

f. Trees Outside Forests – SRIC Systems for Environmental Uses

In this category, SRIC systems are managed primarily to provide environmental services, but production of wood fibre is often a secondary consideration.

Passive Remediation Systems Ltd.[2] in British Columbia uses hybrid poplar clones adapted to the dry Interior of British Columbia on small phytoremediation projects. Currently two projects use irrigated leachates from active landfills. In one project in Salmon Arm a hybrid poplar plantation growing on a capped and decommissioned municipal landfill intercepts leachate from reaching the groundwater. An interesting aspect of this landfill is that leachate is also pumped back under the cap into the landfill, where it stimulates the production of methane gas that is subsequently collected, treated and then injected into an adjacent natural gas pipeline. The pumped-back leachate is again collected at the bottom of the landfill and is re-circulated through a settling pond before being used again for irrigation. Carbon credits have been sold, which will offset the cost of the project.

[1] https://alpac.ca/forest-sustainability/research-and-monitoring/intensive-management
[2] www.psri.ca

The company is also experimenting with small-scale production of biochar from non-contaminated poplar wood, bark and foliage in anticipation of future demand for this highly effective form of soil amendment.

Researchers at the *Fiducie de recherche sur la forêt des Cantons-de*-l'Est (FRFCE) in southern Quebec recently reported[1] on the impact of narrow buffers planted with hybrid poplar in riparian zones bordering small streams in watersheds with contrasting agricultural land use. Prior to planting tree buffers, the riparian areas were covered by herbaceous plants. The main benefits of treed buffers are accumulation of carbon, and uptake of nitrogen and phosphorus that would otherwise have entered the streams. In addition to these beneficial environmental attributes, the buffers also present an opportunity to harvest stem biomass for fuelwood to heat local farm buildings, displacing fossil fuels.

3. Genetics, Conservation and Improvement

a. Salix

One of the challenges being faced by researchers and end-users is the lack of willow clones appropriate for biomass production, that are adapted to the climatic conditions of Canada's Prairie Provinces and the adjacent central and northern Interior of British Columbia. In the absence of a willow breeding program in western Canada, Bionera and researchers with Natural Resources Canada - Canadian Forest Service (CFS) have imported superior willow clonal material from breeding programs in the United States, Sweden and the United Kingdom.

Most of the European material was imported into Canada after quarantine at the State University of New York in Syracuse, NY and at Cornell University in Ithaca, NY. Ten Swedish clones from Lantmännen, four clones from SUNY and 14 clones from Rothamsted Research Ltd. in the UK were established by the CFS in small plantings in Alberta and are monitored for winter shoot die-back and root kill. Of the 14 Rothamsted clones, established in 2013 and 2014, seven were imported directly from the UK as micro-propagated plantlets in sterile growth media; these are still in quarantine at the CFS lab in Edmonton (AB). Bionera has tested over 14 SUNY and Lantmännen clones in Alberta and the central Interior of British Columbia. Early results show that many of these clones are suitable for deployment in west central to southern

[1] Forests 2016, 7, 37; doi:10.3390/f7020037 - www.mdpi.com/journal/forests

Alberta, but some shoot dieback does occur depending on the year and the clone. No root system mortality has been observed to date.

The *Institut de recherche en biologie végétale*, *Université de Montréal* in Quebec conducted research[1] to establish the phylogenetic structure of the genus *Salix* using molecular data on 122 native and introduced willow species of North America[2]. The work provided strong support for a division of the genus into two subgenera, *Salix* and *Vetrix*. The genus *Salix* clearly has two clades[3] which have distinct biogeographic patterns.

Agriculture and Agri-Food Canada (AAFC) in Saskatoon, Saskatchewan, established and manages one of the largest *in situ* collections of *Salix* (AgCanSalix) genetic resources at Indian Head, Saskatchewan[4]. This genetic resource is presently being managed mainly for purposes of bioenergy feedstock development and environmental applications. In order to develop feedstock with improved yields for the Canadian climate, AAFC's priority has been to assemble genetically diverse base populations, from which parents can be selected for controlled pollination. Currently, AgCanSalix encompasses native wild collections of various willow species to ensure vast genetic diversity. Work is in progress to develop genomic and phenotypic resources for the AgCanSalix collection, while a reference genome is being assembled at AAFC in Saskatoon, SK.

In 2013, AAFC at Indian Head carried out willow breeding and continues to manage and maintain the material at the site of the former Shelterbelt Centre.

The Atlantic Forestry Centre[5] of the CFS in Fredericton, New Brunswick, is field testing eight promising North American willows to identify clones with superior growth performance (biomass production) and adaptability to the highly disturbed, infertile sites associated with mining operations in eastern and central Canada. The goal is to use willows to revegetate areas associated

[1] Personal communication Michel Labrecque, *Institut de recherche en biologie végétale*, *Université de Montréal*.
[2] Phylogeny is the evolution of a genetically related group of organisms as distinguished from the development of the individual organism.
[3] A 'clade' is a group of biological taxa that includes all descendants of one common ancestor.
[4] Personal communication Raju Soolanayakanahally. See also http://www.biofuelnet.ca/wp-content/uploads/2015/08/Raju-Advanced-Biofuel-Symposium-2015.pdf.
[5] Personal communication Alexander Mosseler, Research Scientist, Atlantic Forestry Centre, Natural Resources Canada - Canadian Forest Service.

with wetlands and riparian zones in order to begin the successional processes required for natural (or artificial) forest restoration. The CFS recently listed 10 selected clones of *Salix eriocephala* and *S. discolor* in the Poplar and Willow Clone Directory, maintained by the Poplar and Willow Council of Canada (PWCC).

b. Populus

The genus *Populus* is represented in Canada by six naturally occurring species (and one subspecies):

Species	Section	Common name(s)	Distribution
Populus deltoides	Aigeiros	Eastern cottonwood	Southern Ontario and Quebec
P. deltoides (subsp. *monilifera*)		Plains cottonwood	South-western Alberta and southern Saskatchewan
P. balsamifera	Tacamahaca	Balsam poplar	All provinces and territories; mainly in the boreal zone
P. trichocarpa		Black cottonwood	British Columbia and south-western Alberta
P. angustifolia		Narrowleaf cottonwood	South-eastern British Columbia and south-western Alberta
P. tremuloides	Populus	Trembling aspen Quaking aspen	All provinces and territories
P. grandidentata		Bigtooth aspen	Southern Manitoba, Ontario, Quebec, New Brunswick and Nova Scotia

Three species are commercially significant: in order of decreasing commercial importance, *P. tremuloides* (trembling aspen), *P. balsamifera* (balsam poplar) and *P. trichocarpa* (black cottonwood). *P. balsamifera* and *P. trichocarpa* hybridize spontaneously where their ranges overlap in northwestern BC. *P. balsamifera* and *P. deltoides* (eastern cottonwood) are also known to hybridize spontaneously where their ranges overlap in southern Ontario and Quebec; the offspring are known as *P.* ×*jackii* .

POPCAN Project on poplar genomics

Researchers at the University of British Columbia, University of Victoria, University of Alberta, University of Toronto, and Agriculture and Agri-Food Canada (AAFC) collaborated from 2011 to 2015 on the POPCAN[1] project

[1] http://www.genomebc.ca/index.php?cID=952, or http://www.genomecanada.ca/en/popcan-genetic-improvement-poplar-trees-canadian-bioenergy-feedstock-0

funded by Genome Canada and Genome BC. The overall goal of the project was to employ genomic information and tools towards the improvement of *Populus* genotypes to enable the establishment of sustainable, renewable lignocellulosic raw material from managed plantations. One specific goal of the project was to thoroughly understand the genetic underpinnings of tree growth (biomass accumulation) and biofuel trait variation (cell wall biosynthesis) in two poplar species, *Populus trichocarpa* and *P. balsamifera*, suitable for deployment as pure species or hybrids on the Canadian landscape and to use this information to accelerate *Populus* breeding and selection for economically viable poplar plantations for bioenergy or traditional uses in Canada. Other goals were to understand the genetic basis of adaptation to environment by different North American poplar species, and to shed light on the role played by gene expression variation and epigenetics on trait variation in *Populus*. An integrated social sciences research component - 'GE3LS'[1] - was intended to provide a framework for land use change, and make recommendations on economic and public policy to guide the development and establishment of poplar plantations in Canada.

The POPCAN project[2] sequenced 1,194 *Populus* genomes, which were aligned to the *P. trichocarpa* reference genome, including genomes of 435 unique *P. trichocarpa* genotypes grown in a common garden at UBC (Totem Field collection) and 478 *P. balsamifera* genotypes grown in common gardens at AAFC's facilities in Indian Head and Prince Albert, Saskatchewan. A significant and novel finding was that *P. trichocarpa* populations in northern and interior BC are significantly admixed with *P. balsamifera* alleles in specific genomic regions, and that this introgression contributes to adaptation.

POPCAN phenotyped 435 unique accessions in the *P. trichocarpa* Totem Field collection for 85 phenology, biomass/growth, gas exchange/nutrient acquisition, foliar, and health/disease (susceptibility to *Melampsora* spp. and *Septoria* spp.) traits, and for 25 wood- and bioenergy-related traits (solid wood traits, lignin, cell wall carbohydrates, alpha cellulose, and cellulose crystallinity). Phenotyping was completed for the same wood- and bioenergy-related traits in two of the replicate *P. balsamifera* trials and in addition, phenotyping of 477 accessions was completed at Indian Head for phenology, biomass, and carbon isotope (water use efficiency) traits. These phenotypic

[1] http://taigaforesthealth.com/ResearchActivities/GE3Ls.aspx#dynamics

[2] Personal communication POPCAN project leaders Carl Douglas, Department of Botany, University of British Columbia and Shawn Mansfield, Canada Research Chair in Wood and Fibre Quality, Department of Wood Science, University of British Columbia.

data are the most extensive for tree species to date, and provide unprecedented information on trait variation relevant to bioenergy and biomass for association and genomic selection applications for population improvement.

POPCAN research used *P. trichocarpa* data on genetic polymorphism (SNP[1]) and phenotypic variation in the 110 traits, with the goal of identifying SNPs significantly associated with phenotypic variation in any of the 110 traits, and initiated genomic selection as a tool for poplar feedstock improvement. Results included:

- identification of candidate SNPs, associated with key bioenergy and wood quality traits, that offer the possibility of marker assisted breeding;
- identification of the sex determination in poplar, where highly accurate markers were developed to predict gender, using vegetative tissue from trees at any stage of development before flowering, which was not previously possible; and
- identification of 40 SNPs within 26 unique *P. trichocarpa* genes significantly associated with *Melampsora* rust severity measured in the field over 3 years; two SNPs were repeated in all three years suggesting non-race specificity and three additional SNPs were differentially expressed in other poplar rust interactions; the five SNPs have orthologs[2] in *Arabidopsis*; these findings are of significance for speeding the genetic improvement of this long-lived, economically important organism.

Other tree genomics research

Other current research[3] at the University of British Columbia includes:

- an evaluation of the genotypic and phenotypic plasticity of willow accession for cell wall and biofuels traits;
- an investigation of the molecular underpinnings of salt tolerance for trees, with the aim of planting genotypes for land reclamation on natural gas sites;
- a project investigating the ability of poplar and willow genotypes to compartmentalize luxury phosphorus; this work is being used to supply appropriate genotypes to act as biofilters for excess phosphorus uptake;

[1] SNP - single-nucleotide polymorphism.
[2] Orthologs - genes in different species that evolved by speciation from a common ancestral gene.
[3] Personal communication Shawn Mansfield, Canada Research Chair in Wood and Fibre Quality, Department of Wood Science, University of British Columbia.

the project will also investigate the molecular response and use reverse genetic tools to test candidate genes;

- several projects that use transgenic technologies to re-wire the lignin biosynthetic pathway in poplar with an attempt to alter the cell wall chemistry;
- several projects investigating the fate of sucrose in poplar, using several techniques to alter carbon partitioning to alter the allocation of carbon towards carbohydrate biosynthesis; and
- a planned project to investigate the ability of *P. balsamifera*, *P. tremuloides* and *Alnus rubra* (red alder) to tolerate heavy metals generated by mining activities (currently under application and under review with Genome Canada).

Research at the University of Alberta[1] is being carried out to explore the underpinnings of hybrid vigour in a pure species, *P. balsamifera*. This research is taking advantage of a breeding project and associated field trials conducted by Alberta-Pacific Forest Industries Inc. (AlPac) and the Quebec *Direction de la recherche forestière*, *Ministère des Forêts, de la Faune et des Parcs*. Breeding was conducted within local populations as well as between provincial populations. Three field trials are being measured for growth and phenology and a greenhouse trial conducted with selected progeny (based on a range of field performance) and parents to assess hormone levels, growth responses and DNA sequencing information to determine any apparent hybrid vigour.

Agriculture and Agri-Food Canada (AAFC) in Saskatoon, Saskatchewan, also established and manages a large *in situ* collection of *P. balsamifera* (AgCanBaP) genetic resources at the former Shelterbelt Centre at Indian Head, Saskatchewan[2]. This is presently being managed mainly for purposes of bioenergy feedstock development and environmental applications. In order to develop feedstock with improved yields for the Canadian climate, the priority has been to assemble genetically diverse base populations, from which parents can be chosen for controlled pollinations. Currently, AgCanBaP encompasses native wild collections sourced across Canada to ensure vast genetic diversity among genotypes/populations in growth phenology,

[1] Personal Communication Barbara Thomas, Industrial Research Chair in Tree Improvement, Department of Renewable Resources, University of Alberta.

[2] Personal communication Raju Soolanayakanahally, AAFC, Saskatoon, SK. See also https://www.yumpu.com/en/document/view/4770451/fifth-international-poplar-symposium-poplars-and-willows-from-/53.

physiology and molecular genetic variants (N = 1000; 65 populations). Researchers at the University of British Columbia used a subset of 500 native *P. balsamifera* to sequence the entire genome, in addition to generating extensive phenotypic data. Multi-year breeding efforts at AAFC have generated both intra- and inter-specific hybrids.

Researchers at Concordia University[1] in Montreal (QC) have been reconstructing the phylogeny of poplars using genomic sequence data. The resulting information will allow detailed examination of evolutionary trends in the genus *Populus* and testing of numerous hypotheses related to evolution of forest trees. The comparative analyses of genome sequence data allow development of species-specific molecular markers for studying natural hybridization, genetic architecture and dynamics of hybrid zones and assessing the parentage in poplar breeding programs. One of the stated objectives is to provide training of students in poplar genetics work.

Poplar breeding and improvement research

In cooperation with the *Direction de la recherche forestière* of the Quebec *Ministère des Forêts, de la Faune et des Parcs* (MFFP) and the *Réseau Ligniculture Québec*, the Poplar and Willow Council of Canada hosted a Genetics Workshop in August 2012 in Québec City. The workshop focused mostly on the long-term conservation of poplar and willow genetic resources, the development of a national genetics and breeding strategy, and the promotion of the Canadian poplar and willow species collections and cultivars originating from several public and private organizations.

The MFFP has been involved in a hybrid poplar breeding and improvement program since 1969. The program has produced superior hybrid poplar clones for deployment on both provincially-owned and private lands. Selected clones are suited to the highly varied growing conditions in Quebec. The following selection criteria are used: growth, cold tolerance, tree form, disease and insect resistance, and site adaptability. Five poplar species are used for hybridization: *P. deltoides*, *P. balsamifera*, *P. maximowiczii* (Japanese poplar), *P. trichocarpa* and *P. nigra* (black poplar). The MFFP has more than 10,000 clones under evaluation and the program has more than 40 operational hybrid poplar clones (Aigeiros-Tacamahaca hybrids) available for

[1] Personal communication Selvadurai Dayanandan, Concordia University, Montreal, QC. See also: http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0103645.

deployment. To maintain genetic diversity, the MFFP strives for 10-15 clones per planting region. For southern Quebec the presence of *Septoria musiva*[1] stem canker drives the breeding and selection of new clones. New fast-growing MN (*P. maximowiczii* × *P. nigra*), MB (*P. maximowiczii* × *P. balsamifera*), and DM (*P. deltoides* × *P. maximowiczii*) clones, resistant to *Septoria musiva*, or clones with a high tolerance to cold damage, were recently selected and added to the list of hybrid poplars available for deployment in the province.

The MFFP selected parental trees of *P. trichocarpa* and *P. maximowiczii* that were crossed in 2012 to produce MT (*P. maximowiczii* × *P. trichocarpa*) and TM (*P. trichocarpa* × *P. maximowiczii*) progenies for mass selection of fast-growing hybrid clones for biomass, and TT (*P. trichocarpa* × *P. trichocarpa*) to obtain a new intraspecific generation of *P. trichocarpa*.

Research carried out by the *Université du Québec en Abitibi-Témiscamingue* (UQAT)[2] on clonal diversity in natural stands of *P. tremuloides* and *P. balsamifera* has shown that, after fire or harvest, genetic diversity is preserved in the root systems due to extensive root grafting between trees and the maintenance of live parental root structures. Roots of dead trees are kept alive by other trees and will resprout after severe site disturbance. These root connections between trees also help trees to cope with stress caused by, for instance, forest tent caterpillar (*Malacosoma disstria*) outbreaks and summer drought episodes.

4. Forest Protection

a. Biotic factors

Septoria musiva *on poplar*

The genus *Populus* is susceptible to a range of pathogens, of which *Septoria musiva* stem canker is the most devastating in hybrid poplar plantations in North America. In British Columbia the pathogenic fungus *Septoria musiva* was confirmed present in 2006[3] in a hybrid poplar stoolbed in the Fraser Valley, approximately 120 km east of Vancouver[4]. This was the first

[1] Although the scientifically-correct name for this ascomycete fungus is *Sphaerulina musiva* (teleomorph: *Mycosphaerella populorum*), most practitioners still refer to it as *Septoria musiva*.
[2] Personal communication Annie DesRochers, Université-du-Québec-en-Abitibi-Témiscamingue.
[3] https://www.pnwfungi.org/index.php/pnwfungi/article/viewFile/1035/675.
[4] Personal communication Harry Kope, Provincial Forest Pathologist, Ministry of Forests, Lands & Natural Resource Operations, BC.

confirmed occurrence of the disease west of the Rocky Mountains in North America. *Septoria* was subsequently found also in numerous hybrid poplar plantations in the Fraser Valley. The fungus can cause serious stem cankers on hybrid poplar, leading to stem breakage and in some cases to complete mortality of the trees. Many hybrid poplar plantations planted on private land in the Fraser Valley proved to be affected, with the level of damage varying substantially from clone to clone. Subsequent to this discovery, the British Columbia Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) conducted surveys, which confirmed the fungus had successfully transferred to the native black cottonwood (*Populus trichocarpa*) at several locations in the Fraser Valley[1]. Black cottonwood is an important riparian and floodplain species found throughout the province.

Since then the fungus has also been detected on southern Vancouver Island and in 2015 in the Okanagan Valley in the BC Interior. The spread outside the Fraser Valley is almost certainly associated with inadvertently moving infected planting material from infected nursery sources. The MFLNRO has proposed control measures that would include mandatory treatment of stoolbeds, bareroot beds and cuttings prior to movement to new sites and restricting the use of known susceptible hybrids.

This pathogen and its close relative *Septoria populicola* have been the subject of recent research at the University of British Columbia (UBC). A research team at the Faculty of Forestry at UBC worked on the TAIGA[2] project to develop a 'portable' on-site diagnostic tool and a high-throughput forest pathogen identification (DNA analysis) service to identify the presence of a pathogen, by developing and translating genomics resources into applications. This is particularly important in the case of new and/or inadvertently introduced forest pathogens, such as *Septoria musiva* in British Columbia, where it was not known to be present before 2006. The ultimate goal of this research is not only to identify the pathogen, but also predict the risk it poses to the forest ecosystem. The high-throughput forest pathogen identification was used extensively in BC to identify *Septoria musiva* in hybrid poplar plantations and in natural *P. trichocarpa* stands, and to distinguish it from its close relative *S. populicola*, which is a naturally occurring pathogen in BC and does not cause stem cankers.

[1] Personal communication Harry Kope, Provincial Forest Pathologist, Ministry of Forests, Lands & Natural Resource Operations.
[2] TAIGA - Tree Aggressors Identification using Genomic Approaches - http://taigaforesthealth.com/

Septoria musiva causes necrotic lesions on the leaves and cankers on highly susceptible poplar clones, leading to stem deformation that is often lethal and predisposes the tree to colonization by secondary organisms; this deformation often leads to stem breakage. The related species *S. populicola* causes only an endemic leaf spot on native poplars and susceptible hybrids. To assess the genetic determinants of wood colonization leading to canker formation, the UBC researchers[1] sequenced and compared the genomes of these two species.
They identified a cluster of 11 genes that produce a toxin unique to *S. musiva* and are co-activated when the canker pathogen is grown on artificial media enriched with host-derived carbon sources such as poplar leaf-extract and poplar wood chips. Strong discordance between the cluster and the species phylogenies suggested that it was acquired in *S. musiva* through a horizontal transfer from ascomycete fungi associated with wood decay[2]. In addition, genes involved in the degradation of hemi-cellulose were more abundant in the genome of *S. musiva* and highly expressed when the pathogen was grown on artificial media enriched with poplar wood chips. Two of these genes have been acquired horizontally from bacteria donors.

The research concluded that the acquisition, maintenance and expression of such a gene arsenal is necessary for growth in woody tissues and seems to be at the origin of the adaptation of *S. musiva* to infect and colonize poplar woody stems.

In a follow up to TAIGA, funding for which ended in 2015, the UBC researchers[3] have proposed to sequence and characterize the genomes of the most important fungal pathogens of poplar and pines that constitute their 'Pathobiome'[4]. Early detection, monitoring and surveillance, as discussed for TAIGA, are important aspects in preventing outbreaks but are hampered by a lack of genomic resources. Essentially, the ability to predict pathogenic potential and evaluate the risk that a micro-organism can cause a severe outbreak is lacking. Comparison of the genome of pathogens that infect the same host or the same host tissues, together with the identification of their unique genomic features, could mitigate this issue. The plan is to

[1] Personal communication Nicolas Feau, Department of Forest and Conservation Sciences, University of British Columbia.
[2] http://www.pnas.org/content/112/11/3451
[3] Personal communication Nicolas Feau.
[4] http://jgi.doe.gov/a-pathobiome-database-for-bioenergy-trees/

compare their genomes and to identify the core genome, i.e. common features, among pathogens that share the ability to attack and defeat the defence systems of the same host, while differing in their biology, colonization strategy and symptomatology. In addition, the UBC researchers will identify unique features within lineages and assess the importance of horizontal gene transfers in generating novel host-pathogen interactions. These data will form a basis for translating genomic resources into detection and monitoring tools.

In collaboration with the Joint Genome Institute, US Department of Energy[1], the plan is to sequence the genome of 18 pathogens, including several poplar pathogens such as the Ascomycetes *Venturia populina*, Entole*uca mammata*, *Taphrina populi-salicis*, *Cytospora chrysosperma*, *Cryptodiaporthe populea*, *Septoria populi*, and the Basidiomycete rusts *Melampsora* spp. This sequencing effort will complete the initial collection of 21 fungal genomes obtained in the previous Genome Canada TAIGA project. This genome sequencing will be completed by gene expression analyses on a subset of eight of these fungi that will help complete the gene predictions and annotations of these genomes. Preliminary analyses based on a subset of these data indicated that pathogens attacking angiosperms had more distinct gene content for plant-cell-wall-degradation-enzymes (PCWDE) than those attacking gymnosperms. One of the most discriminant PCWDE families was pectate lyase[2], responsible for the cleavage of pectin. Pectin is a major component of primary cell walls of many angiosperms and pathogens on angiosperm plants have a higher content in gene encoding for pectate lyase. Once the sequencing of the 18 additional genomes is completed, a much clearer picture of the signature genomic profiles of pathogens attacking poplars and pines will be obtained. This will allow researchers to establish whether such patterns in genomic profiles can be generalized, used for prediction of host or tissue specialization and translated into detection and monitoring tools.

Passive Remediation Systems Ltd. in the Okanagan Valley is a commercial user of hybrid poplar plant material in phytoremediation and carbon sequestration projects. The company detected and subsequently reported a suspected occurrence of *Septoria musiva* in its poplar stoolbeds and has since been cooperating with the MFLNRO and the UBC Faculty of Forestry in testing

[1] http://jgi.doe.gov/
[2] An enzyme involved in the maceration and soft rotting of plant tissue.

a fungicidal dip treatment for dormant cuttings; results are pending. The company also initiated an intensive preventative fungicide spray program in its crops to prevent further infection; spraying is followed by harvesting of all dropped foliage to avoid re-infection. The success of these measures still has to be determined, but they form the basis for a meaningful preventative treatment protocol that could be used by all poplar nursery and stoolbed operations in the province, and could ideally also be used by all operations outside the province which export poplar material to British Columbia.

In Quebec research is being conducted to determine interactions among the poplar host, the *Septoria musiva* pathogen and endophytic fungal flora in poplar. Results are pending.

Ungulate damage

A report from Alberta identified moose (*Alces alces*) as stripping the bark off the lower stems of planted hybrid poplar. Damage is serious and frequently results in the girdled trees dying and breaking off. It was observed that the moose had clonal preferences. A similar problem was observed several years ago on Vancouver Island, where Roosevelt elk (*Cervus canadensis roosevelti*) stripped bark off lower stems of certain hybrid poplar clones, and in another case where horses had been allowed to graze in a plantation on Vancouver Island. Bark stripping can be a very serious problem where poplar is grown for higher value sawlogs and veneer logs, especially when the trees have been pruned.

Elsewhere, browsing by deer presents a serious problem. In some cases plantations have had to be fenced, although the cost of such protection measures can seldom be justified. The prevalence of deer browsing in British Columbia and Quebec has led to the use of large stock – large rooted or unrooted whips have proved a good solution. However, these stock types are not as effective in preventing moose or elk browsing.

Besides browsing, male deer, elk and moose tend to prefer small trees to rub their developing antlers and remove the velvet. In some cases trees break off or are completely girdled in the process.

Rodent damage

Beavers (*Castor canadensis*) are a constant threat and can destroy large areas of planted trees overnight; poplar and willow are preferred food sources. On

northern Vancouver Island, BC, beavers have been found to display a preference for specific poplar clones.

Insects

In Alberta's Peace River region (northwest Alberta) insect defoliation problems were identified in willow in 2014 and 2015; however, the insect species was not identified.

In Quebec salvage operations were undertaken to harvest native stands of trembling aspen that were seriously affected by the forest tent caterpillar (*Malacosoma disstria*). Research is being conducted in Quebec[1] to investigate the genetic diversity and phylogeography[2] of forest tent caterpillar in Canada in order to gain insights into genetic structure, phenotypic diversity and pest outbreak dynamics.

b. Abiotic factors

The main abiotic factor affecting both poplar and willow is the occurrence of drought during the growing season. This was an issue reported for the Okanagan Valley in the Interior of British Columbia and in Alberta. One of the solutions identified for an Alberta planting project was to switch from unrooted to rooted stock. As a measure to prevent drought-related losses forest companies in Alberta, and to a lesser extent in Saskatchewan, for many years used exclusively containerized rooted poplar cuttings for plantation establishment.

Lack of winter snowpack has also been reported in industrial SRIC hybrid poplar crops in Alberta as a cause of top dieback. It is very likely that winter dieback is correlated with drought stress during the growing season.

5. Harvesting and Utilization

a. Harvesting of poplars and willows

Domtar Corporation is reported to have harvested its first hybrid poplar plantation, which had been established 15 years previously on its own private forestlands near its pulp and paper mill in Windsor, Quebec. This is the first

[1] Personal communication with Selvadurai Dayanandan, Concordia University, Montreal, QC.
[2] Phylogeography is the study and understanding of the relationships found among living things and their location on Earth.

such harvest of hybrid poplar pulpwood in the province. There were no other reports specific to harvesting of poplars or willows in Canada.

b. Utilization of poplars and willows for various wood products

Norampac in Quebec manages hybrid poplar on its private and provincially-owned forestland for use in the production of corrugated cardboard for packaging. On its privately-owned farmland the objective is to produce saw timber, with a by-product of wood chips to be used in the production of corrugated cardboard.

Several corporations in Canada harvest trembling aspen from extensive natural forests in the boreal forest zone to manufacture oriented strandboard (OSB). One corporation in Alberta uses aspen to manufacture Kraft pulp for the open market.

c. Utilization of poplars and willows as a renewable source of energy ('bioenergy')

PRT Growing Services Ltd. in British Columbia uses a wood chip furnace to produce heat for its greenhouses. As reported earlier, up to 5% of its chip requirement comes from its 30 ha of various willow varieties and a few hybrid poplar clones on its private land near Prince George, BC. The company hopes to increase that proportion over the next several years in preparation for expected increases in prices for outsourced chips.

PRT's wholly-owned subsidiary Bionera hopes to conduct its first large-scale harvest of SRIC willow crops in the fall of 2016. The company is still working to obtain the best harvesting equipment.

At the *Institut de recherche en biologie végétale* of the *Université de Montréal* and Montreal Botanical Garden in Quebec, studies[1] are being conducted to determine how wood composition and anatomical traits of willow varied in contrasting environments. Wood anatomy differed between sites in a cultivar producing high and low density wood, suggesting a probable response to an abiotic stress. Furthermore, twice as many cellulose-rich G-fibres, comprising over 50 % of secondary xylem, were found in the high

[1] These projects were initiated in 2012 and are financially supported by BioFuelNet Canada (BFN), part of Canada's Networks of Centres of Excellence (NCE) - http://www.biofuelnet.ca/

density wood, a finding with potential to bring higher value to the lignocellulosic bioethanol industry.

6. Environmental Applications[1]

a. Site and landscape improvement

In British Columbia the Environmental Farm Plan and associated Beneficial Management Practices (BMP) programs consider poplar and willow species as viable plant choices for vegetative buffer, shelterbelt and riparian management plans that are required prior to the approval of any associated cost-shared BMP applications[2]. Shelterbelts are still an integral part of the agricultural landscape in the Peace Region of north-eastern British Columbia. However, with the closing of the Shelterbelt Centre, formerly operated by the Prairie Farm Rehabilitation Administration (PFRA) of Agriculture and Agri-Food Canada (AAFC), and increasing grain commodity prices, the implementation or maintenance of shelterbelts in the Canadian prairies is decreasing annually.

The Agroforestry and Woodlot Extension Society in Alberta reports working with a land trust in Alberta to 'seal off' a valley with a well-adapted hybrid poplar[3] in order to facilitate revegetation. The valley is adjacent to a saline lake, which provides a substantial fetch for wind which can cause great stress to plants growing in the valley. The concept is for the poplar shelterbelt to provide a snow fence, allowing less stress-tolerant species to grow into the areas thus sheltered. In Alberta, balsam poplar is tested and screened for salinity tolerance, so that tolerant poplars can be planted along shores of lakes created during the mining of oil sands.

In Saskatchewan poplars and willows are typically included in the list of acceptable species for reclamation projects, such as roads, mines, water crossings, and oil and gas development. The University of Saskatchewan is completing a large program on shelterbelts and their role in mitigating greenhouse gases (GHGs)[4]. The program has shown that shelterbelts

---

[1] See also Section 2.f Trees Outside Forests – SRIC Systems for Environmental uses.
[2] http://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/programs/growing-forward-2/environmental-farm-plan
[3] 'Okanese', a hybrid of *Populus* 'Walker' and *P.* ×*petrowskyana*, originating from the Shelterbelt Centre at Indian Head, Saskatchewan; it is male, very cold-tolerant and very disease-resistant.
[4] Personal communication Ken Van Rees, University of Saskatchewan, Saskatoon, SK.

sequester significant amounts of carbon, produce fewer GHG emissions than agricultural fields and increase soil carbon beneath the shelterbelt.

In New Brunswick field tests are being conducted to review performance of eight native North American willow species[1]. These tests are aimed at revegetating highly disturbed sites for purposes of land reclamation and forest restoration. Researchers have begun to apply results to general land reclamation on former mine sites in eastern Canada.

b. Phytoremediation

Phytoremediation[2] is the direct use of living green plants for *in situ* removal, degradation, or containment of contaminants in soils, biosolids, sediments, surface water and groundwater. It is a low cost cleanup technique driven by solar energy.

There are a few phytoremediation projects in the southern Interior of British Columbia which use or are experimenting with hybrid poplar. One such project in which hybrid poplar trees are grown on a capped decommissioned landfill to intercept leachate from reaching the groundwater is described in Section 2.f.

Natural Resources Canada - Canadian Forest Service is investigating the use of willow clones in the restoration of salt-impacted sites[3] such as shorelines of so-called 'end pit lakes'[4], peatlands, and seepage sites in the Alberta oil sands. With industry support, over 80 native and non-native willow clones were screened in a greenhouse for tolerance to oil-sands-process-affected-water (OSPW), which is high in sodium. Fifteen of the most tolerant native Alberta clones from the screening were planted in the spring of 2014 in various slope positions along the edge of the end pit lake containing OSPW to determine if these were tolerant under field conditions.

---

[1] Personal communication Alex Mosseler, Research Scientist, Atlantic Forestry Centre, Natural Resources Canada - Canadian Forest Service.
[2] United Nations Environment Programme, Division of Technology, Industry and Economics - Newsletter and Technical Publications Freshwater Management Series No. 2 - http://www.unep.or.jp/Ietc/Publications/Freshwater/FMS2/1.asp
[3] Personal communication Richard Krygier, Natural Resources Canada - Canadian Wood Fibre Centre.
[4] Open pit mines turned into lakes which contain tailings consisting of a mixture of salts, suspended solids and other dissolvable chemical compounds such as acids, benzene, hydrocarbons, residual bitumen and fine silts; the top layer is fresh water.

Based on the results to date, OSPW in the rooting zone, as represented by slope position in this trial, did not impact seedling survival, which was greater than 95%. Stem length increment in the first and second growing seasons varied depending on the clone. Final results are pending.

In Quebec, the *Institut de recherche en biologie végétale* of the *Université de Montréal* reports on-going studies testing the efficiency of willow in the uptake of nutrients from municipal wastewater and biosolids[1]. The studies also investigate aboveground biomass yield and root development of the willow.

Since 2005, many studies and applied projects using willow to address issues of contaminated soils have been conducted in partnership with Quebec municipalities, governmental agencies and private companies. Studies focused on selection of the best-performing willow cultivars on polluted soils, physiological and molecular approaches to improving willow as a phytoremediation agent, and the function of bacterial and fungal communities recruited by willow in contaminated soils. These projects are still underway.

Agriculture and Agri-Food Canada (AAFC) conducted a series of trials with willow from 2006 through 2012 in the eastern province of Prince Edward Island[2]. Willow planted in parallel single rows at high densities (up to 5,300 stems per ha) along riparian zones of potato-producing farm fields, showed the ability to absorb and utilize large amounts of nutrients[3] that would otherwise have entered surface water. The effectiveness of the willow as a bio-filter was greatly enhanced by coppicing after the first growing season in order to stimulate above-ground biomass, and then maintaining the crop on three- to four-year coppice harvest cycles. Initial establishment was with unrooted cuttings planted through plastic mulch to keep out the in-row weeds during the establishment period; weeds between the plant rows were mowed. The recommendation is to mechanically harvest the willow biomass one year after potato production. Although there appears to be no viable

[1] Personal communication Michel Labrecque, Institut de recherche en biologie végétale, Université de Montréal.
[2] Personal communication Raju Soolanayakanahally, AAFC, Saskatoon, SK.
[3] Over three years, a one-ha willow buffer intercepted 300 kg N and 45 kg P – 'Willow Riparian Buffers' published by Agriculture and Agri-Food Canada, electronic version available at www.publications.gc.ca, AAFC No. 12433E.

market yet for willow biomass, it could be used as bioenergy feedstock to replace carbon-based fossil fuels or composted for soil amendments.

Natural Resources Canada - Canadian Forest Service is undertaking research under a federal Genomics R&D Initiative project entitled 'Innovative land reclamation approaches following oil sands mining: a phytoremediation approach based on tree-soil microbiome interactions'[1]. This project is using genomic tools on an industrial-scale field site on oil sands exploited by Canadian Natural Resources Limited[2] near Fort McMurray, Alberta. The objective is to speed up site reclamation by evaluating the taxonomic and functional diversities of the soil microbiome of the site, specifically free-living microbes and microbes associated with aspen roots. The soil microbiome is being assessed by analysing soil samples throughout the growing season from specific reclamation treatments and natural stands before and after disturbances. Using genomic approaches, this project should improve the land reclamation process by providing operational science-based guidelines for governments and corporations to accelerate the return of disturbed sites to a resilient and functioning ecosystem.

[1] http://ccps2015.uqat.ca/abstract/view_abstract.asp?id=63
[2] http://www.cnrl.com/

III. GENERAL INFORMATION

1. Administration and Operation of the National Poplar Commission

The Poplar and Willow Council of Canada/Conseil canadien des peupliers et des saules (PWCC) functions as the National Poplar Commission of Canada. PWCC is recognized as representing the country nationally and internationally in all matters dealing with growth, production and utilization of poplars and willows. PWCC is an incorporated not-for-profit organization established in 1978. In 2014 the Council received approval from Corporations Canada to formally change its name, which was previously the Poplar Council of Canada/Conseil du peuplier du Canada (PCC), to recognize the increasing importance of willows, particularly in environmental applications. PWCC is committed to the wise use, conservation and sustainable management of Canada's poplar and willow resources.

In March 2016, PWCC had 31 individual members and 10 corporate members. Membership continues to decline, reflecting general economic trends and the ongoing economic difficulties and consolidation in the Canadian forest industry sector. In recent years, the decline in membership has been partially mitigated by the addition of a number of members from outside Canada, particularly from the United States.

Contact information for PWCC is as follows:

Address:	Poplar and Willow Council of Canada 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

In July 2014, the membership of the Council formally adopted 'Articles of Continuance' and a new 'Bylaw Number 1' in compliance with the terms of the Canada Not-for-profit Corporations Act of 2009. These were submitted to Corporations Canada which approved them and issued a Certificate of

Continuance of the Council as a federally incorporated not-for-profit organization. The new bylaw covers matters of governance and management of the organization generally and comprehensively in language that should reduce the need for future changes.

PWCC is governed by an elected Board of Directors. As of March 2016, the members of the Board of Directors and Executive Committee were:

Raju Soolanayakanahally	Director, Chair	Agriculture and Agri-Food Canada	Saskatoon, SK	Executive Committee
Barb Thomas	Director, Past Chair	University of Alberta	Edmonton, AB	Executive Committee
Cees van Oosten	Director, Vice-Chair West	SilviConsult Woody Crops Technology Inc.	Nanaimo, BC	Executive Committee
Annie DesRochers	Director, Vice-Chair East	Université du Québec en Abitibi-Témiscamingue	Rouyn-Noranda, QC	Executive Committee
John Doornbos	Director, Treasurer	Canadian Forest Service	Edmonton, AB	Executive Committee
Deb Brenton	Executive Assistant	Poplar Council of Canada	Edmonton, AB	Executive Committee
Jim Richardson	Technical Director	J. Richardson Consulting	Ottawa, ON	Executive Committee
Pierre Périnet	Director; Chair, Genetics and Breeding Working Group	Direction de la recherche forestière, Ministère des Forêts, de la Faune, et des Parcs	Sainte-Foy, QC	
Richard Krygier	Director; Chair, Pesticide Working Group	Canadian Forest Service	Edmonton, AB	
Marc Poirier	Director; Chair, Environmental Services and Bioenergy Working Group	Bionera Resources Inc.	Victoria, BC	
Carl Douglas	Director	University of British Columbia	Vancouver, BC	
Nathalie Isabel	Director	Canadian Forest Service	Sainte-Foy, QC	
Ken Van Rees	Director	University of Saskatchewan	Saskatoon, SK	

Day-to-day operations are managed by an Executive Committee and supported by two part-time staff members: an Executive Assistant and a Technical Director. Much of the activity of the Council dealing with specific issues of poplar and willow management is undertaken by Working Groups of which there were three in 2016: the Genetics and Breeding Working Group, the Pesticide Working Group, and the Environmental Services and Bioenergy Working Group.

2. Activities of the Poplar and Willow Council of Canada

The activities of PWCC are carried out through the Executive Committee and Working Groups and include the organization of technical meetings and field visits, communication of information through newsletters and a website, and involvement in international poplar and willow activities.

The Genetics and Breeding Working Group helps to coordinate poplar genetics and breeding work across the country. As such, it maintains the Council's poplar and willow clone directory, an electronic, searchable database of poplars, willows, and poplar and willow clones in Canada incorporating the related databases from several public and private organizations involved in poplar and willow breeding programs in Canada, and includes information, as available, on source, collection or breeding history, parentage and testing of clones and hybrids. The directory has recently been updated and, following restructuring, will be made available on the PWCC website.

The Pesticide Working Group strives to expand the number of approved agricultural pesticides for use in 'short-rotation-intensive-culture' (SRIC) poplar and willow crops and acts as sponsor of these requests. It looks at the range of pesticides currently available that are appropriate for use on poplars and willows, but not currently registered for this use, and works to get the appropriate pesticides registered for use in SRIC poplar and willow crops.

The Environmental Services and Bioenergy Working Group came into being as a result of a strategic planning workshop in May 2010. It aims to improve acceptance of the use of poplars and willows for environmental services, in order to make such services an accredited and proven technology seen by regulators and engineers as a reliable alternative to business as usual. It produced a factsheet on poplars and willows for environmental services in 2012. Recognizing the increasing interest in and use of biomass for energy, and the potential of poplars and willows for bioenergy in addition to or in

conjunction with other environmental services, the mandate of the group was expanded in 2015 to include bioenergy.

PWCC organizes an Annual General Meeting which includes informative technical and field sessions, often in conjunction with other related meetings or conferences. Efforts are made to meet in a different location each year so members can see what is happening with poplar and willow across Canada. A record of each meeting is published on the website, as well as a photo library of field sites visited, and technical papers presented at the meeting may also be published on the website.

- In 2012, the Annual Meeting was held in conjunction with a one-day workshop in Ste-Foy, Quebec and two-day field tour in the Chicoutimi and Rimouski areas of Quebec; the event was organized by the Genetics and Breeding Working Group.

- In 2013, the PWCC met in Prince Edward Island as part of the 13th Biennial North American Agroforestry Conference; the meeting included field visits in Prince Edward Island, and a pre-conference tour in New Brunswick.

- In 2014, PWCC supported and collaborated in the organization of the Sixth International Poplar Symposium (IPSVI) held at the University of British Columbia in Vancouver; following the shut-down of the Symposium website, the PWCC website has been the place where all the IPSVI presentations can be accessed. As a result of the positive financial outcome of IPSVI, PWCC in conjunction with the University of British Columbia has been able to offer annual student travel awards to enable university students to present their poplar and willow papers at the annual meeting of PWCC; the first two such awards were made in 2015.

- In 2015, the Université du Québec en Abitibi-Témiscamingue in collaboration with PWCC organized a technical meeting and two-day field tour at a field station in the boreal region of Quebec, with a focus on poplar and willow management in natural settings and site reclamation using poplars and willows.

The Council publishes a newsletter once or twice a year. It typically provides information and reports on past PWCC events and announcements of future events, as well as information on Working Group accomplishments, special

research notes and other news. Delivery is via the website and E-flashes sent to members. The primary means of communication for PWCC is its website – www.poplar.ca – which was completely redesigned in 2012 to improve the appearance, navigation, search capacity and content. The site provides information for and about members, news about past events and announcements about upcoming events. Visitors can also access an extensive photo gallery, special publications and annual reports, as well as current and past issues of the newsletter.

At the international level, members of PWCC are actively involved in the activities of the International Poplar Commission (IPC). Five members participated in the 24th Session of IPC in Dehradun, India in 2012. At that Session, Barb Thomas, who was then Chair of the Council, was elected to the Executive Committee of IPC, and Jim Richardson, PWCC Technical Director, was co-opted to the Committee. With a US colleague, Jim co-edited the major work 'Poplars and Willows: Trees for Society and the Environment' which was co-published by FAO and CABI in 2014 and a year later made freely available on the FAO-IPC website. As a result of recent moves toward the disbandment of the Poplar Council of the United States (PCUS), discussions have taken place between PWCC and PCUS about possible amalgamation of the two organizations. As noted earlier, PWCC membership currently includes one US-based corporate member and several individual members.

3. Difficulties Encountered and Lessons Learned

As a mostly volunteer, non-profit organization with minimal staff, declining financial resources and Board members busy with their own work, PWCC faces a constant struggle to deliver a level of services sufficient to maintain membership interest and participation. The great geographic size of the country is also a problem shared by all national organizations in Canada. Electronic media, such as E-mail, tele-conferencing and the PWCC website are clearly the most cost-effective means of communication. The Council's newsletter, formerly published in hard copy twice a year, is now made available only on the website. E-newsflashes sent by E-mail are used to alert members to website updates.

The PWCC has always had a close relationship with US poplar and willow colleagues to share information and experience. In fact, both PWCC and PCUS originally evolved from what was a North American Poplar Council. Currently, Americans regularly participate in meetings and workshops organized by PWCC

and there is reciprocal Canadian participation in meetings of the US-based Short Rotation Woody Crops Operations Working Group, particularly when the event is in the more northern states. With a view to encouraging new younger members, PWCC offers student membership at a minimal fee. In conjunction with the University of British Columbia, it has also started to offer student travel awards to students working on poplars or willows at Canadian universities to enable them to participate in PWCC annual meetings with the presentation of technical papers.

With the help of electronic communication and cooperation with other related organizations, PWCC will continue to pursue its commitment to the wise use, conservation, and sustainable management of Canada's private and public poplar and willow resources.

ACKNOWLEDGEMENTS

The authors of this report gratefully acknowledge the contributions of technical information by the following individuals and organizations.

Organization	Name	City
Agriculture and Agrifood Canada, Environment Branch	Raju Soolanayakanahally	Saskatoon, SK
Agroforestry and Woodlot Extension Society	Jeff Renton	Edmonton, AB
Alberta Agriculture and Forestry	Erin Fraser	Edmonton, AB
Alberta-Pacific Forest Industries Inc.	Dave Kamelchuk	Boyle, AB
Bionera Resources Inc.	Marc Poirier	Victoria, BC
Bonnyville Forest Nursery Inc.	Dan McCurdy	Bonnyville, AB
British Columbia Agriculture	Leslie McAuley	Victoria, BC
British Columbia Agriculture	Dave Trotter	Victoria, BC
British Columbia Forests, Lands & Natural Resource Ops.	Harry Kope	Victoria, BC
British Columbia Forests, Lands & Natural Resource Ops.	Chang-Yi Xie	Victoria, BC
Coast to Coast Reforestation Inc.	Mike Ardiel	Edmonton, AB
Concordia University	Selvadurai Dayanandan	Montreal, QC
Domtar Corporation - Windsor	Patrick Cartier	Windsor QU
Fiducie de recherche sur la forêt des Cantons-de-l'Est	Benoit Truax	Saint-Benoît-du-Lac, QC
Genstat Consulting	Barbara Thomas	Edmonton, AB
Manitoba Conservation and Water Stewardship	Phil Keenan	Winnipeg, MB
Ministère des Forêts, de la Faune et des Parcs	Pierre Périnet	Sainte Foy, QC
Montreal Botanical Garden	Michel Labrecque	Montreal, QC
Natural Resources Canada - Canadian Forest Service	Richard Krygier	Edmonton, AB
Natural Resources Canada - Canadian Forest Service	Dawn McVittie	Edmonton, AB
Natural Resources Canada - Canadian Forest Service	Alex Mosseler	Fredericton, NB
Natural Resources Canada - Canadian Forest Service	Paul Boudewyn	Victoria, BC
Natural Resources Canada - Canadian Forest Service	Armand Séguin	Sainte Foy, QC
Natural Resources Canada - Canadian Forest Service	Suzy Domenicano	Ottawa, BC
New Brunswick Natural Resources	Anthony Bourgoin	Fredericton, NB
Norampac - Cabano	Clarence Dubé	Cabano, QC
Norbord Industries Inc.	Felix Guay	La Salle, QC
Ontario Ministry of Natural Resources and Forestry	Stephanie Parzie	Sault Ste Marie, ON
Passive Remediation Systems Ltd.	Dave Derbowka	Armstrong, BC
PRT Growing Services Ltd.	Glenn Goodwill	Beaverlodge, AB
PRT Growing Services Ltd.	Blaine McFadden	Prince George, BC
Réseau Ligniculture Québec	Pierre Gagné	Quebec, QC
Saskatchewan Environment	David Stevenson	Prince Albert, SK
Université du Québec en Abitibi-Témiscamingue	Annie DesRochers	Amos, QC
University of British Columbia, Department of Botany	Carl Douglas	Vancouver, BC
University of British Columbia, Dept. of Wood Science	Shawn Mansfield	Vancouver, BC

University of British Columbia, Faculty of Forestry	Nicolas Feau	Vancouver, BC
University of British Columbia, Faculty of Forestry	Richard Hamelin	Vancouver, BC
University of Saskatchewan, College of Agriculture and Bioresources	Ken Van Rees	Saskatoon, SK

APPENDIX 1. QUESTIONNAIRE ON POPLARS AND WILLOWS 2012-2015

- Total area of poplars and willows 2014 and Area planted from 2011 to 2014 (area change over the last 4 years)
- Wood removals 2014 in ('000 $m^{3)}$
- Forest products from poplars and willows 2014 ('000 $m^{3)}$
- Opinion Summary

Total area of poplars and willows 2014 and Area planted from 2011 to 2014 (area change over the last 4 years)						
		Total area by forest function in %				Area planted from
Forest category	Total Area 2014 (ha)	Production		Protection (%)	Other (%)	2011-2014 (reforestation + afforestation) (ha)
		Industrial roundwood (%)	Fuelwood biomass (%)			
Primary (Indigenous)						
Poplars	17,256,727	0.5	-	15.8	83.7	
Willows	42,980	-	-	17.0	83.0	
Mix of P&W	-	-	-	-	-	
Total	17,299,707					
Planted						
Poplars	21,801,081	16.1	-	3.2	80.6	
Willows	16,301	-	-	-	100.0	
Mix of P&W	-	-	-	-	-	
Total	21,817,382					
Agrofor/TOF						
Poplars	5,601,186	-	-	0.9	99.1	
Willows	28,384	-	-	-	100.0	
Mix of P&W		-	-	-	-	
Total	5,629,570					
Grand Total	44,746,659					4,574

Reported figures for Total Area (2014) are from the National Forest Inventory and include only poplars and willows. Reported figures for Area Planted (2011-2014) are from the National Forest Database (NFD) and are aggregated into Mixed Hardwood (including poplars, willows and other hardwood species).

Forest category:

- Primary: Primary (Indigenous) forests[1]. Includes all forest land that is defined as primary forest (FRA2015 definition).
- Planted: Planted forest. Includes all forest land that is not defined as primary forest. Planted, seeded and other naturally regenerated forests are included.
- Agrofor/TOF: Agroforestry, trees outside forests. Includes all non-forest land (FRA2015 definition) with poplars and willows.

Forest function:

- Production: Production forest. All forest land that is privately owned and that is either not protected, or has an IUCN protection code VI.
- Protection: Protected land. All land with IUCN protection codes IA, IB, II, III, IV, V.
- Other: Other function. All land not included in the protection or production groups. Generally described as multiple-use forests and treed areas.

[1] The documents '*Guidelines for Country Reports*' and '*Questionnaire on Poplars and Willows 2015*' provide differing definitions for 'Indigenous Forests'. For the purposes of this report, Appendix 1 tables use 'Primary forest' in place of 'Indigenous forest'.

Wood removals 2014 in ('000 m$^{3)}$						
Forest category and species, cultivar or clone		Total removals	for industrial roundwood			for fuelwood, wood chips
Primary (Indigenous)	Poplars		Veneer/ plywood	Pulpwood	Sawnwood	
Primary (Indigenous)	Willows					
Planted	Poplars					
Planted	Willows					
Grand Total		28,262	10,848	12,411	1,779	3,208

Reported figures for Wood Removals (2014) are from the National Forest Database (NFD) and are aggregated into Mixed Hardwood (including poplars, willows and other hardwood species).

The figures reported to the NFD are "roundwood" and include logs and bolts, pulpwood and other industrial.

Forest products from poplars and willows 2014 ('000 m$^{3)}$									
Forest category		Fuel wood	Chips	Industrial round wood (logs, pulpwood)	Wood-pulp (mech. or chem.)	Particle board, fibreboard (MDF, (hardboard)	Veneer sheets	Ply wood	Sawn-wood
Primary (Indigenous)	From poplars								
	From willows								
Planted	From poplars								
	From willows								
Agrofor/TOF	From poplars								
	From willows								
Total		3,209	27,015	25,039	61,012	9,518	50	235	1,460

Reported figures for Forest Products (2014) are from the National Forest Database (NFD) and are aggregated as follows:

- Mixed Hardwood (including poplars, willows and other hardwood species): Fuelwood, Chips, Industrial Roundwood, Veneer Sheets, Plywood and Sawn-wood.
- Combined Softwood and Hardwood: Wood-pulp and Particleboard/fibreboard.

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

APPENDIX 2. LIST OF POPLAR AND WILLOW PUBLICATIONS 2012-2015

Anonymous. 2012. The influence of stand and landscape characteristics on forest tent caterpillar (*Malacosoma disstria*) defoliation dynamics: The case of the 1999-2002 outbreak in northwestern Quebec. 2012. *Canadian Journal of Forest Research* 42 (10): 1827-36.

Agro, E., and Zheng YouBin. 2014. Controlled-release fertilizer application rates for container nursery crop production in southwestern Ontario, Canada. *Hortscience* 49 (11): 1414-23.

Allen, D., D. W. McKenney, D. Yemshanov, and S. Fraleigh. 2013. The economic attractiveness of short rotation coppice biomass plantations for bioenergy in northern Ontario. *Forestry Chronicle* 89 (1): 66-78.

Amichev, B. Y., M. J. Bentham, D. Cerkowniak, J. Kort, Suren Kulshreshtha, C. P. Laroque, J. Piwowar, and K. C. J. Rees. 2013. Mapping shelterbelts in Saskatchewan: A living legacy of the agriculture and agri-food Canada PFRA shelterbelt centre. In Poppy, L., Kort, J., Schroeder, B., Pollock, T. and Soolanayakanahally, R. (Eds.) Proceedings of the 13th North American Agroforestry Conference, June 19-21, 2013, Charlottetown, Prince Edward Island, Canada: 16. Available from University of Missouri Digital Library http://dl.mospace.umsystem.edu/mu/islandora/object/mu%3A90378#page/1/mode/2up.

Amichev, B. Y., R. D. Hangs, N. Bélanger, T. A. Volk, V. Vujanovic, J. J. Schoenau, and K. C. J. Rees. 2015. First-rotation yields of 30 short-rotation willow cultivars in central Saskatchewan, Canada. *BioEnergy Research* 8 (1): 292-306.

Amichev, B. Y., R. D. Hangs, S. M. Konecsni, C. N. Stadnyk, T. A. Volk, N. Bélanger, V. Vujanovic, J. J. Schoenau, J. Moukoumi, and K. C. J. Rees. 2014. Willow short-rotation production systems in Canada and northern United States: A review. *Soil Science Society of America Journal* 78: S168-82.

Amichev, B. Y., W. A. Kurz, C. Smyth, and van Rees, K. C. J. 2012. The carbon implications of large-scale afforestation of agriculturally marginal land with short-rotation willow in Saskatchewan. *GCB Bioenergy* 4 (1): 70-87.

Amichev, Beyhan, Murray Bentham, Darrel Cerkowniak, John Kort, Suren Kulshreshtha, Colin Laroque, Joseph Piwowar, and Ken Rees. 2015. Mapping and quantification of planted tree and shrub shelterbelts in Saskatchewan, Canada. *Agroforestry Systems* 89 (1): 49-65.

Anderson, Jay A., Glen W. Armstrong, Martin K. Luckert, And Wiktor L. Adamowicz. 2012. Optimal zoning of forested land considering the contribution of exotic plantations. *Mathematical & Computational Forestry & Natural Resource Sciences* 4 (2): 92-104.

Anderson, Jay A., Amanda Long, and M. K. (M Luckert. 2015. A financial analysis of establishing poplar plantations for carbon offsets using Alberta and British Columbia's afforestation protocols1. *Canadian Journal of Forest Research* 45 (2): 207-16.

Angers, V. A., Y. Bergeron, and P. Drapeau. 2012. Morphological attributes and snag classification of four North American boreal tree species: Relationships with time since death and wood density. *Forest Ecology and Management* 263: 138-47.

Angers, V. A., P. Drapeau, and Y. Bergeron. 2012. Mineralization rates and factors influencing snag decay in four North American boreal tree species. *Canadian Journal of Forest Research* 42 (1): 157-66.

Anyomi, K. A., F. Lorenzetti, Y. Bergeron, and A. Leduc. 2015. Stand dynamics, humus type and water balance explain aspen long term productivity across Canada. *Forests* 6 (2): 416-32.

Anyomi, K. A., F. Raulier, Y. Bergeron, D. Mailly, and M. P. Girardin. 2014. Spatial and temporal heterogeneity of forest site productivity drivers: A case study within the eastern boreal forests of Canada. *Landscape Ecology* 29 (5): 905-18.

Anyomi, Kenneth A., Frédéric Raulier, Yves Bergeron, and Daniel Mailly. 2013. The predominance of stand composition and structure over direct climatic and site effects in explaining aspen (*Populus tremuloides* Michaux) site index within boreal and temperate forests of western Quebec, Canada. *Forest Ecology & Management* 302: 390.

Anyomi, Kenneth A., Frédéric Raulier, Daniel Mailly, Martin P. Girardin, and Yves Bergeron. 2012. Using height growth to model local and regional response of trembling aspen (*Populus tremuloides* Michx.) to climate within the boreal forest of western Québec. *Ecological Modelling* 243: 123-32.

Apps, C. D., B. N. McLellan, T. A. Kinley, R. Serrouya, D. R. Seip, and H. U. Wittmer. 2013. Spatial factors related to mortality and population decline of endangered mountain caribou. *Journal of Wildlife Management* 77 (7): 1409-19.

Araujo, F., J. F. Hart, and S. D. Mansfield. 2015. Variation in trembling aspen and white spruce wood quality grown in mixed and single species stands in the boreal mixedwood forest. *Forests* 6 (5): 1628-48.

Arevalo, C. B. M., S. X. Chang, J. S. Bhatti, and D. Sidders. 2012. Mineralization potential and temperature sensitivity of soil organic carbon under different land uses in the parkland region of Alberta, Canada. *Soil Science Society of America Journal* 76 (1): 241-51.

Ashraf, M. I., C. P. A. Bourque, D. A. MacLean, T. Erdle, and Meng FanRui. 2015. Estimation of potential impacts of climate change on growth and yield of temperate tree species. *Mitigation and Adaptation Strategies for Global Change* 20 (1): 159-78.

Baah-Acheamfour, M., S. X. Chang, E. W. Bork, and C. N. Carlyle. 2013. Comparison of soil carbon pools under three agroforestry systems and their adjacent agricultural analogs

throughout central Alberta. In Poppy, L., Kort, J., Schroeder, B., Pollock, T. and Soolanayakanahally, R. (Eds.) Proceedings of the 13th North American Agroforestry Conference, June 19-21, 2013, Charlottetown, Prince Edward Island, Canada: 24. Available from University of Missouri Digital Library http://dl.mospace.umsystem.edu/mu/islandora/object/mu%3A90378#page/1/mode/2up.

Baah-Acheamfour, Mark, Scott X. Chang, Cameron N. Carlyle, and Edward W. Bork. 2015. Carbon pool size and stability are affected by trees and grassland cover types within agroforestry systems of western Canada. *Agriculture, Ecosystems & Environment* 213: 105-13.

Barbuta, C., P. Blanchet, A. Cloutier, V. Yadama, and E. Lowell. 2012. OSB as substrate for engineered wood flooring. *European Journal of Wood and Wood Products* 70 (1): 37-43.

Barr, A. G., G. Kamp, T. A. Black, J. H. McCaughey, and Z. Nesic. 2012. Energy balance closure at the BERMS flux towers in relation to the water balance of the white gull creek watershed 1999-2009. *Agricultural and Forest Meteorology* 153: 3-13.

Begley, A. J. P., B. T. Gray, and C. A. Paszkowski. 2012. Comparison of restored and natural wetlands as habitat for birds in the prairie pothole region of Saskatchewan, Canada. *Raffles Bulletin of Zoology* 60: 173-87.

Bell, T. H., S. E. Hassan, A. Lauron-Moreau, F. Al-Otaibi, M. Hijri, E. Yergeau, and M. St-Arnaud. 2014. Linkage between bacterial and fungal rhizosphere communities in hydrocarbon-contaminated soils is related to plant phylogeny. *ISME Journal* 8 (2): 331-43.

Benomar, Lahcen, Annie DesRochers, and Guy Larocque. 2012. The effects of spacing on growth, morphology and biomass production and allocation in two hybrid poplar clones growing in the boreal region of Canada. *Trees: Structure & Function* 26: 939-49.

Benomar, Lahcen, Annie DesRochers, and Guy R. Larocque. 2013. Comparing growth and fine root distribution in monocultures and mixed plantations of hybrid poplar and spruce. *Journal of Forestry Research* 24 (2): 247-54.

Bergeron, J. A. C., F. G. Blanchet, John R. Spence, and W. J. Volney. 2012. Ecosystem classification and inventory maps as surrogates for ground beetle assemblages in boreal forest. *Journal of Plant Ecology* 5 (1): 97-108.

Berthod, N., N. J. B. Brereton, F. E. Pitre, and M. Labrecque. 2015. Five willow varieties cultivated across diverse field environments reveal stem density variation associated with high tension wood abundance. *Frontiers in Plant Science* 6 : 948.

Bilodeau-Gauthier S, Paré D, Messier C, Bélanger N. 2013. Root production of hybrid poplars and nitrogen mineralization improve following mounding of boreal podzols. *Canadian Journal of Forest Research* 43 (12):1092-103.

Blanc, L. A., and K. Martin. 2012. Identifying suitable woodpecker nest trees using decay selection profiles in trembling aspen (*Populus tremuloides*). *Forest Ecology and Management* 286: 192-202.

Boan, J. J., B. E. McLaren, and J. R. Malcolm. 2013. Predicting non-inventoried forest elements using forest inventory data: The case of winter forage for woodland caribou. *Écoscience* 20 (2): 101-11.

Boisvert-Marsh, L., C. Périé, and S. Blois. 2014. Shifting with climate? Evidence for recent changes in tree species distribution at high latitudes. *Ecosphere* 5 (7): article 83.

Bokalo, M., K. J. Stadt, P. G. Comeau, and S. J. Titus. 2013. The validation of the mixedwood growth model (MGM) for use in forest management decision making. *Forests* 4 (1): 1-27.

Boothroyd-Roberts K, Gagnon D, Truax B. 2013. Hybrid poplar plantations are suitable habitat for reintroduced forest herbs with conservation status. *Springerplus* 2(1):1-13.

Boothroyd-Roberts, K., D. Gagnon, and B. Truax. 2013. Can hybrid poplar plantations accelerate the restoration of forest understory attributes on abandoned fields? *Forest Ecology and Management* 287: 77-89.

Boothroyd-Roberts, K., D. Gagnon, and B. Truax. 2013. Hybrid poplar plantations are suitable habitat for reintroduced forest herbs with conservation status. *Springerplus* 2 (507).

Borden, K. A., M. E. Isaac, N. V. Thevathasan, A. M. Gordon, and S. C. Thomas. 2014. Estimating coarse root biomass with ground penetrating radar in a tree-based intercropping system. *Agroforestry Systems* 88 (4): 657-69.

Borden, K. A., M. E. Isaac, and S. C. Thomas. 2013. Evaluating tree root distribution in a tree-based intercropping system with use of ground penetrating radar. In Poppy, L., Kort, J., Schroeder, B., Pollock, T. and Soolanayakanahally, R. (Eds.) Proceedings of the 13th North American Agroforestry Conference, June 19-21, 2013, Charlottetown, Prince Edward Island, Canada: 17-20. Available from University of Missouri Digital Library http://dl.mospace.umsystem.edu/mu/islandora/object/mu%3A90378#page/1/mode/2up.

Bork, Edward, Cameron Carlyle, James Cahill, Rae Haddow, and Robert Hudson. 2013. Disentangling herbivore impacts on *Populus tremuloides*: A comparison of native ungulates and cattle in Canada's aspen parkland. *Oecologia* 173 (3): 895-904.

Bose, A. K., B. D. Harvey, and S. Brais. 2014. Sapling recruitment and mortality dynamics following partial harvesting in aspen-dominated mixedwoods in eastern Canada. *Forest Ecology and Management* 329: 37-48.

Bose, A. K., B. D. Harvey, K. D. Coates, S. Brais, and Y. Bergeron. 2015. Modelling stand development after partial harvesting in boreal mixedwoods of eastern Canada. *Ecological Modelling* 300: 123-36.

Boucher, D., S. Gauthier, J. Noël, D. F. Greene, and Y. Bergeron. 2014. Salvage logging affects early post-fire tree composition in Canadian boreal forest. *Forest Ecology and Management* 325: 118-27.

Boulanger-Lapointe, N., E. Lévesque, S. Boudreau, G. H. R. Henry, and N. M. Schmidt. 2014. Population structure and dynamics of arctic willow (*Salix arctica*) in the high arctic. *Journal of Biogeography* 41 (10): 1967-78.

Bousquet, Yves, Patrice Bouchard, Anthony E. Davies, and Derek S. Sikes. 2013. Checklist of beetles (Coleoptera) of Canada and Alaska. second edition. *Zookeys* 360: 1-44.

Boutigny, A. -L, C. Guinet, A. Vialle, R. Hamelin, P. Frey, and R. Ioos. 2013. A sensitive real-time PCR assay for the detection of the two *Melampsora medusae* formae speciales on infected poplar leaves. *European Journal of Plant Pathology* 136 (3): 433-41.

Boutigny, A. -L, C. Guinet, A. Vialle, R. C. Hamelin, A. Andrieux, P. Frey, C. Husson, and R. Ioos. 2013. Optimization of a real-time PCR assay for the detection of the quarantine pathogen *Melampsora medusae* f. sp. *deltoidae*. *Fungal Biology* 117 (6): 389.

Bouttier, L., A. Paquette, C. Messier, and A. Cogliastro. 2013. Fine roots distribution, light conditions and yield in a tree-based intercrop system in southern Quebec, Canada. In Poppy, L., Kort, J., Schroeder, B., Pollock, T. and Soolanayakanahally, R. (Eds.) Proceedings of the 13th North American Agroforestry Conference, June 19-21, 2013, Charlottetown, Prince Edward Island, Canada: 11-13. Available from University of Missouri Digital Library http://dl.mospace.umsystem.edu/mu/islandora/object/mu%3A90378#page/1/mode/2up.

Bouttier, Lé, Alain Paquette, Christian Messier, David Rivest, Alain Olivier, and Alain Cogliastro. 2014. Vertical root separation and light interception in a temperate tree-based intercropping system of eastern Canada. *Agroforestry Systems* 88 (4): 693-706.

Brais, S., and P. Drouin. 2012. Interactions between deadwood and soil characteristics in a natural boreal trembling aspen - jack pine stand. *Canadian Journal of Forest Research* 42 (8): 1456-66.

Brais, Suzanne, Timothy T. Work, Émilie Robert, Christopher D. O'Connor, Manuella Strukelj, Arun Bose, Danielle Celentano, and Brian D. Harvey. 2013. Ecosystem responses to partial harvesting in eastern boreal mixedwood stands. *Forests* 4 (2): 364-85.

Breen, A. L. 2014. Balsam poplar (*Populus balsamifera* L.) communities on the arctic slope of Alaska. *Phytocoenologia* 44 (1): 1-24.

Brown, S. M., R. M. Petrone, L. Chasmer, C. Mendoza, M. S. Lazerjan, S. M. Landhäusser, U. Silins, J. Leach, and K. J. Devito. 2014. Atmospheric and soil moisture controls on evapotranspiration from above and within a western boreal plain aspen forest. *Hydrological Processes* 28 (15): 4449-62.

Calvert, K., and W. Mabee. 2015. More solar farms or more bioenergy crops? Mapping and assessing potential land-use conflicts among renewable energy technologies in eastern Ontario, Canada. *Applied Geography* 56: 209-21.

Campbell, J., P. Bengtson, A. L. Fredeen, D. S. Coxson, and C. E. Prescott. 2013. Does exogenous carbon extend the realized niche of canopy lichens? Evidence from sub-boreal forests in British Columbia. *Ecology* 94 (5): 1186-95.

Cardinael, Rémi, Naresh Thevathasan, Andrew Gordon, Rachelle Clinch, Idris Mohammed, and Derek Sidders. 2012. Growing woody biomass for bioenergy in a tree-based intercropping system in southern Ontario, Canada. *Agroforestry Systems* 86 (2): 279-86.

Caron, V., M. Norgate, F. J. Ede, T. Nyman, and P. Sunnucks. 2013. Novel microsatellite DNA markers indicate strict parthenogenesis and few genotypes in the invasive willow sawfly *Nematus oligospilus*. *Bulletin of Entomological Research* 103 (1): 74-88.

Carrera-Hernández, J. J., C. A. Mendgza, K. J. Devito, R. M. Petrone, and B. D. Smerdon. 2012. Reclamation for aspen revegetation in the Athabasca oil sands: Understanding soil water dynamics through unsaturated flow modelling. *Canadian Journal of Soil Science* 92 (1): 103-16.

Chang, Kuo-Hsien, David T. Price, Jing M. Chen, Werner A. Kurz, Cé Boisvenue, Edward H. Hogg, T. A. Black, Alemu Gonsamo, Chaoyang Wu, and Robbie A. Hember. 2014. Simulating impacts of water stress on woody biomass in the southern boreal region of western Canada using a dynamic vegetation model. *Agricultural & Forest Meteorology* 198 (11): 142-54.

ChangYi, Xie, M. R. Carlson, and C. C. Ying. 2012. Ecotypic mode of regional differentiation of black cottonwood (*Populus trichocarpa*) due to restricted gene migration: Further evidence from a field test on the northern coast of British Columbia. *Canadian Journal of Forest Research* 42 (2): 400-5.

Charbonneau, D., F. Lorenzetti, F. Doyon, and Y. Mauffette. 2012. The influence of stand and landscape characteristics on forest tent caterpillar (*Malacosoma disstria*) defoliation dynamics: The case of the 1999-2002 outbreak in northwestern Quebec. *Canadian Journal of Forest Research* 42 (10): 1827-36.

Chen, H. Y. H., and A. R. Taylor. 2012. A test of ecological succession hypotheses using 55-year time-series data for 361 boreal forest stands. *Global Ecology and Biogeography* 21 (4): 441-54.

Chomel M, DesRochers A, Baldy V, Larchevêque M, Gauquelin T. 2014. Non-additive effects of mixing hybrid poplar and white spruce on aboveground and soil carbon storage in boreal plantations. *Forest Ecology and Management* 328: 292-9.

Chomel M, Guittonny-Larchevêque M, DesRochers A, Baldy V. 2015. Home field advantage of litter decomposition in pure and mixed plantations under boreal climate. *Ecosystems* 18 (6): 1014-28.

Cohen-Fernandez, A., and M. A. Naeth. 2013. Increasing woody species diversity for sustainable limestone quarry reclamation in Canada. *Sustainability* 5 (3): 1340-55.

Coleman, R., R. Heck, N. Thevathasan, A. Gordon, M. Oelbermann, and R. P. Voroney. 2013. Seasonal fluctuations of microbial biomass carbon in tbi systems in southwestern Ontario. In Poppy, L., Kort, J., Schroeder, B., Pollock, T. and Soolanayakanahally, R. (Eds.) Proceedings of the 13th North American Agroforestry Conference, June 19-21, 2013, Charlottetown, Prince Edward Island, Canada: 23. Available from University of Missouri Digital Library http://dl.mospace.umsystem.edu/mu/islandora/object/mu%3A90378#page/1/mode/2up.

Conway, A. J., and R. K. Danby. 2014. Recent advance of forest-grassland ecotones in southwestern Yukon. *Canadian Journal of Forest Research* 44 (5): 509-20.

Cooke, Barry J., Chris J. K. MacQuarrie, and François Lorenzetti. 2012. The dynamics of forest tent caterpillar outbreaks across east-central Canada. *Ecography* 35 (5): 422-35.

Cooke, H. A., and S. J. Hannon. 2012. Nest-site selection by old boreal forest cavity excavators as a basis for structural retention guidelines in spatially-aggregated harvests. *Forest Ecology and Management* 269: 37-51.

Cormier, R. L., T. Gardali, and J. K. Wood. 2013. Assessing migratory stopover site quality for birds during fall migration along two California rivers. *Western North American Naturalist* 73 (1): 72-9.

Corredor, A. H., K. Rees, and V. Vujanovic. 2014. Host genotype and health status influence on the composition of the arbuscular mycorrhizal fungi in *Salix* bioenergy plantations. *Forest Ecology and Management* 314: 112-9.

Cortini, F., P. G. Comeau, and M. Bokalo. 2012. Trembling aspen competition and climate effects on white spruce growth in boreal mixtures of western Canada. *Forest Ecology and Management* 277 (08): 67.

Coursolle, C., H. A. Margolis, M. -A Giasson, P. -Y Bernier, B. D. Amiro, M. A. Arain, A. G. Barr, *et al*. 2012. Influence of stand age on the magnitude and seasonality of carbon fluxes in Canadian forests. *Agricultural & Forest Meteorology* 165 (11/15): 136-48.

Coxson, D., C. Björk, and M. D. Bourassa. 2014. The influence of regional gradients in climate and air pollution on epiphytes in riparian forest galleries of the upper Fraser river watershed. *Botany* 92 (1): 23-45.

Croft, H., J. M. Chen, Y. Zhang, and A. Simic. 2013. Modelling leaf chlorophyll content in broadleaf and needle leaf canopies from ground, CASI, Landsat TM 5 and MERIS reflectance data. *Remote Sensing of Environment* 133: 128-40.

Curzon, M. T., A. W. D'Amato, and B. J. Palik. 2014. Harvest residue removal and soil compaction impact forest productivity and recovery: Potential implications for bioenergy harvests. *Forest Ecology and Management* 329: 99-107.

Dagenais, D., J. Froment, Y. Roberge, and I. Koudachkina. 2012. Aesthetic and planting design criteria to improve acceptance of a new type of acoustic barrier for narrow rights-of-way. In: J. M. Evans, J. W. Goodrich-Mahoney, D. Mutrie and J. Reinemann (eds.). 9th International Symposium: Environmental concerns in rights-of-way management, Portland, Oregon, USA, 27-30 September, 2009. International Society of Arboriculture, Champaign, USA. pp. 25-40.

Das Gupta, S., M. D. MacKenzie, and S. A. Quideau. 2015. Using spatial ecology to examine above and belowground interactions on a reclaimed aspen stand in northern Alberta. *Geoderma* 259/260 (12): 12-22.

Daust, K. 2013. Impact of the rust *Puccinia linkii* on highbush cranberry, *Viburnum edule*, near Smithers, British Columbia. *Canadian Field-Naturalist* 127 (3): 270-3.

Davis, E. L., C. P. Laroque, and K. Rees. 2013. Evaluating the suitability of nine shelterbelt species for dendrochronological purposes in the Canadian prairies. *Agroforestry Systems* 87 (3): 713-27.

Derbyshire, Stephen J., Ardath Francis, Gerald A. Mulligan, and Gavin L. Graham. 2014. The biology of Canadian weeds. 153. *Stachys palustris* L. *Canadian Journal of Plant Science* 94 (4): 709-22.

DesRochers, A., A. Koubaa, and S. Morissette. 2013. Effects of pruning on growth and stem quality of three hybrid poplar clones. In Poppy, L., Kort, J., Schroeder, B., Pollock, T. and Soolanayakanahally, R. (Eds.) Proceedings of the 13th North American Agroforestry Conference, June 19-21, 2013, Charlottetown, Prince Edward Island, Canada. p. 55. Available from University of Missouri Digital Library http://dl.mospace.umsystem.edu/mu/islandora/object/mu%3A90378#page/1/mode/2up.

Desrochers A, Sigouin M. 2014. Effect of soil mounding and mechanical weed control on hybrid poplar early growth and vole damage. *Écoscience* 21(3):278-85.

Devappa, R. K., S. K. Rakshit, and R. F. H. Dekker. 2015. Potential of poplar bark phytochemicals as value-added co-products from the wood and cellulosic bioethanol industry. *BioEnergy Research* 8 (3): 1235-51.

Dhillon, B., N Feau, A.L. Aerts, S. Beauseigle, L. Bernier, A. Copeland, A. Foster, G. Navdeep, B. Henrissat, P. Herath, K.M. LaButti, A. Levasseur, E.A. Lindquist, E. Majoor, R.A. Ohm, J.S. Pangilinan, A. Pribowo, J.N. Saddler, M.L. Sakalidis, R.P. de Vries, I.V. Grigoriev, S.B. Goodwin, P. Tanguay, R.C. Hamelin. 2015. Horizontal gene transfer and gene dosage drives adaptation to wood colonization in a tree pathogen. Proc. Natl. Acad. Sci. USA 112:3451-3456.

Dhital, Narayan, F. Raulier, P. Y. Bernier, M. Lapointe-Garant, F. Berninger, and Y. Bergeron. 2015. Adaptation potential of ecosystem-based management to climate change in the eastern Canadian boreal forest. *Journal of Environmental Planning and Management* 58 (12): 2228-49.

Díaz-Aguilar, I., S. A. Quideau, H. C. Proctor, B. E. Kishchuk, and J. R. Spence. 2013. Influence of stand composition on predatory mite (*Mesostigmata*) assemblages from the forest floor in western Canadian boreal mixedwood forests. *Forest Ecology and Management* 309: 105-14.

Dickinson, M. B., E. A. Johnson, and R. Artiaga. 2013. Fire spread probabilities for experimental beds composed of mixedwood boreal forest fuels. *Canadian Journal of Forest Research* 43 (4): 321-30.

Doblas-Miranda, E., A. Paquette, T. T. Work, and A. Olivier. 2013. The effect of intercropping hybrid poplars and red oaks on soil oribatid diversity distribution [conference poster]. In Poppy, L., Kort, J., Schroeder, B., Pollock, T. and Soolanayakanahally, R. (Eds.) Proceedings of the 13th North American Agroforestry Conference, June 19-21, 2013, Charlottetown, Prince Edward Island, Canada. p. 167. Available from University of Missouri Digital Library http://dl.mospace.umsystem.edu/mu/islandora/object/mu%3A90378#page/1/mode/2up.

Domenicano, S., A. Paquette, and C. Messier. 2013. Will climate change drive temperate agroforestry systems towards increased competition or complementarity? A modelling approach. In Poppy, L., Kort, J., Schroeder, B., Pollock, T. and Soolanayakanahally, R. (Eds.) Proceedings of the 13th North American Agroforestry Conference, June 19-21, 2013, Charlottetown, Prince Edward Island, Canada. p. 32-3. Available from University of Missouri Digital Library http://dl.mospace.umsystem.edu/mu/islandora/object/mu%3A90378#page/1/mode/2up.

Drobyshev, Igor, Sylvie Gewehr, Frank Berninger, Yves Bergeron, and Matt McGlone. 2013. Species specific growth responses of black spruce and trembling aspen may enhance resilience of boreal forest to climate change. *Journal of Ecology* 101 (1): 231-42.

Duval, I., D. Lachance, I. Giguère, C. Bomal, M.-J Morency, G. Pelletier, B. Boyle, J.J. MacKay, A.J. Séguin. 2014. Large-scale screening of transcription factor–promoter interactions in spruce reveals a transcriptional network involved in vascular development. Exp. Bot. 65:2319-2333.

Edworthy, A. B., K. L. Wiebe, and K. Martin. 2012. Survival analysis of a critical resource for cavity-nesting communities: Patterns of tree cavity longevity. *Ecological Applications* 22 (6): 1733-42.

Edworthy, Amanda B., and Kathy Martin. 2013. Persistence of tree cavities used by cavity-nesting vertebrates declines in harvested forests. *Journal of Wildlife Management* 77 (4): 770-6.

Elferjani, R., A. DesRochers, and F. Tremblay. 2013. DRIS-based fertilization efficiency of young hybrid poplar plantations in the boreal region of Canada. *New Forests* 44 (4): 487-508.

Elferjani, Raed, Annie DesRochers, and Francine Tremblay. 2014. Effects of mixing clones on hybrid poplar productivity, photosynthesis and root development in northeastern Canadian plantations. *Forest Ecology & Management* 327 (09): 157.

Elsholkami, M., S. Shankar, M. Walawalkar, M. Mehta, A. Merchant, A. Elkamel, and I. Alhajri. 2014. Development of optimal energy infrastructures for the oil sands industry with

effective steam management. *Proceedings of the International Conference on Industrial Engineering & Operations Management* (01): 1135.

Ens, Joel, Richard E. Farrell, and Nicolas Bélanger. 2013. Effects of edaphic conditions on site quality for *Salix purpurea* 'Hotel' plantations across a large climatic gradient in Canada. *New Forests* 44 (6): 899-918.

Ens, Joels, Richard E. Farrell, and Nicolas Bélanger. 2013. Early effects of afforestation with willow (*Salix purpurea*, "Hotel") on soil carbon and nutrient availability. *Forests* 4 (1): 137-54.

Ferrera-Rodríguez, O., C. W. Greer, D. Juck, L. L. Consaul, E. Martínez-Romero, and L. G. Whyte. 2013. Hydrocarbon-degrading potential of microbial communities from arctic plants. *Journal of Applied Microbiology* 114 (1): 71-83.

Ficko, S., B. Smith, and B. Zeeb. 2015. Assisted revegetation following contaminated site remediation in the arctic: Four-year case study of a former radar site. *American Journal of Plant Sciences* 6 (8): 1301-12.

Fortier, J., B. Truax, D. Gagnon, and F. Lambert. 2015. Plastic allometry in coarse root biomass of mature hybrid poplar plantations. *BioEnergy Research* 8 (4): 1691-704.

Fortier, J., B. Truax, D. Gagnon, and F. Lambert. 2013. Mature hybrid poplar riparian buffers along farm streams produce high yields in response to soil fertility assessed using three methods. *Sustainability* 5 (5): 1893-916.

Fortier, J., B. Truax, D. Gagnon, and F. Lambert. 2013. Root biomass and soil carbon distribution in hybrid poplar riparian buffers, herbaceous riparian buffers and natural riparian woodlots on farmland. *Springerplus* 2 (539): 17 October 2013.

Fortier, J., B. Truax, D. Gagnon, and F. Lambert. 2012. Hybrid poplar yields in Québec: Implications for a sustainable forest zoning management system. *Forestry Chronicle* 88 (4): 391-407.

Fortin, J. P., M. R. Nemati, and M. Marchand-Roy. 2013. Rehabilitation trials in a bog peatland in Quebec. *Acta Horticulturae* (1013): 381-7.

Foster, A. J., M. J. Morency, A. Séguin, and P. Tanguay. 2014. *Agrobacterium tumefaciens*-mediated transformation for targeted disruption and over expression of genes in the poplar pathogen *Sphaerulina musiva*. *Forest Pathology* 44 (3): 233-41.

Foster A.J., G. Pelletier, P. Tanguay, and A. Séguin. 2015. Transcriptome analysis of poplar during leaf spot infection with *Sphaerulina* spp. *PLoS One* 10(9): E0138162.

Fournel, S., J. H. Palacios, R. Morissette, J. Villeneuve, S. Godbout, M. Heitz, and P. Savoie. 2015. Particulate concentrations during on-farm combustion of energy crops of different shapes and harvest seasons. *Atmospheric Environment* 104: 50-8.

Franceschini, Tony, and Robert Schneider. 2014. Influence of shade tolerance and development stage on the allometry of ten temperate tree species. *Oecologia* 176 (3): 739-49.

Fujii, K., K. Morioka, R. Hangs, S. Funakawa, T. Kosaki, and D. W. Anderson. 2013. Importance of climate and parent material on soil formation in Saskatchewan, Canada as revealed by soil solution studies. *Pedologist* 57 (1): 27-44.

Fujimura, K. E., and K. N. Egger. 2012. Host plant and environment influence community assembly of high arctic root-associated fungal communities. *Fungal Ecology* 5 (4): 409-18.

Gamon, J. A., O. Kovalchuck, C. Y. S. Wonga, A. Harris, and S. R. Garrity. 2015. Monitoring seasonal and diurnal changes in photosynthetic pigments with automated PRI and NDVI sensors. *Biogeosciences* 12 (13): 4149-59.

García, O. 2014. Can plasticity make spatial structure irrelevant in individual-tree models? *Forest Ecosystems* 1 (16): 12 August 2014.

García, Oscar. 2013. Building a dynamic growth model for trembling aspen in western Canada without age data. *Canadian Journal of Forest Research* 43 (3) (03): 256-65.

Gärtner, S. M., M. Bokalo, S. E. Macdonald, and K. Stadt. 2014. Variation in post-wildfire regeneration of boreal mixedwood forests: Underlying factors and implications for natural disturbance-based management. *New Forests* 45 (2): 215-34.

Gauslaa, Y., and T. Goward. 2012. Relative growth rates of two epiphytic lichens, *Lobaria pulmonaria* and *Hypogymnia occidentalis*, transplanted within and outside of *Populus* dripzones. *Botany* 90 (10): 954-65.

Gendreau-Berthiaume, B., D. D. Kneeshaw, and B. D. Harvey. 2012. Effects of partial cutting and partial disturbance by wind and insects on stand composition, structure and growth in boreal mixedwoods. *Forestry* 85 (4): 551-65.

Geraldes A, DiFazio SP, Slavov GT, Ranjan P, Muchero W, Hannemann J, Gunter LE, Wymore AM, Grassa CJ, Farzaneh N, *et al*. 2013. A 34K SNP genotyping array for *Populus trichocarpa*: Design, application to the study of natural populations and transferability to other *Populus* species. *Molecular Ecology Resources* 13(2):306-23.

Geraldes, A., N. Farzaneh, C. J. Grassa, A. D. McKown, R. D. Guy, S. D. Mansfield, C. J. Douglas, and Q. C. B. Cronk. 2014. Landscape genomics of *Populus trichocarpa*: The role of hybridization, limited gene flow, and natural selection in shaping patterns of population structure. *Evolution : International Journal of Organic Evolution* 68 (11): 3260-80.

Geraldes, A., S. P. DiFazio, G. T. Slavov, P. Ranjan, W. Muchero, J. Hannemann, L. E. Gunter, *et al*. 2013. A 34K SNP genotyping array for populus trichocarpa: Design, application to the study of natural populations and transferability to other *Populus* species. *Molecular Ecology Resources* 13 (2): 306-23

Geraldes A, Hefer CA, Capron A, Kolosova N, Martinez-Nuñez F, Soolanayakanahally RY, Stanton B, Guy RD, Mansfield SD, Douglas CJ, *et al*. 2015. Recent y chromosome divergence despite ancient origin of dioecy in poplars (*Populus*). *Molecular Ecology* 24 (13):3243-56.

Gerwing, T. G., A. M. A. Gerwing, E. Rapaport, and C. Alström-Rapaport. 2012. Sexual and asexual reproduction of *Salix sitchensis* and the influence of beaver (*Castor canadensis*) herbivory on reproductive success. *ISRN Ecology* 2012: Article ID 285748.

Gewehr, S., I. Drobyshev, F. Berninger, and Y. Bergeron. 2014. Soil characteristics mediate the distribution and response of boreal trees to climatic variability. *Canadian Journal of Forest Research* 44 (5): 487-98.

Göehing, J., E. Macdonald, E. Bork, and B. Thomas. 2013. What does it take to make plantation forestry successful? A comparison of alternative establishment systems on hybrid poplar performance. In Poppy, L., Kort, J., Schroeder, B., Pollock, T. and Soolanayakanahally, R. (Eds.) Proceedings of the 13th North American Agroforestry Conference, June 19-21, 2013, Charlottetown, Prince Edward Island, Canada. p. 42. Available from University of Missouri Digital Library http://dl.mospace.umsystem.edu/mu/islandora/object/mu%3A90378#page/1/mode/2up.

Grainger, Tess, and Roy Turkington. 2013. Long-term nutrient enrichment differentially affects investment in sexual reproduction in four boreal forest understory species. *Plant Ecology* 214 (8): 1017-26.

Graungaard, K., A. M. Gordon, and K. Dunfield. 2013. Microbial communities associated with nitrogen cycling in a tree based intercropping system [conference poster]. In Poppy, L., Kort, J., Schroeder, B., Pollock, T. and Soolanayakanahally, R. (Eds.) Proceedings of the 13th North American Agroforestry Conference, June 19-21, 2013, Charlottetown, Prince Edward Island, Canada. p. 177. Available from University of Missouri Digital Library http://dl.mospace.umsystem.edu/mu/islandora/object/mu%3A90378#page/1/mode/2up.

Grondin, P., S. Gauthier, D. Borcard, Y. Bergeron, and J. Noël. 2014. A new approach to ecological land classification for the Canadian boreal forest that integrates disturbances. *Landscape Ecology* 29 (1): 1-16.

Grover, B. E., M. Bokalo, and K. J. Greenway. 2014. White spruce understory protection: From planning to growth and yield. *Forestry Chronicle* 90 (1): 35-43.

Guay-Picard, A., D. Auty, A. D. Munson, and A. Achim. 2015. Partial harvesting in boreal mixedwoods: A case for planned heterogeneity in industrial silvicultural prescriptions. *Forest Ecology and Management* 358: 291-302.

Guedo, D. D., and E. G. Lamb. 2013. Prescribed burning has limited long-term effectiveness in controlling trembling aspen (*Populus tremuloides*) encroachment into fescue grassland in Prince Albert National Park. *Canadian Field-Naturalist* 127 (1): 50-6.

Guedo, D. D., and E. G. Lamb. 2013. Temporal changes in abundance-occupancy relationships within and between communities after disturbance. *Journal of Vegetation Science* 24 (4): 607-15.

Guidi Nissim, Werther, Frederic E. Pitre, Traian Ion Teodorescu, and Michel Labrecque. 2013. Long-term biomass productivity of willow bioenergy plantations maintained in southern Quebec, Canada. *Biomass & Bioenergy* 56 (09): 361-9.

Guidi, Werther, Hafssa Kadri, and Michel Labrecque. 2012. Establishment techniques to using willow for phytoremediation on a former oil refinery in southern Quebec: Achievements and constraints. *Chemistry & Ecology* 28 (1): 49-64.

Gupta, S. D., M. D. MacKenzie, and S. A. Quideau. 2015. Using spatial ecology to examine above and belowground interactions on a reclaimed aspen stand in northern Alberta. *Geoderma* 259/260: 12-22.

Gylander, T., A. Hamann, J. S. Brouard, and B. R. Thomas. 2012. The potential of aspen clonal forestry in Alberta: Breeding regions and estimates of genetic gain from selection. *Plos One* 7 (8): e44303.

Hacquard, S., D. L. Joly, Y. -C Lin, E. Tisserant, N. Feau, C. Delaruelle, V. Legué, et al. 2012. A comprehensive analysis of genes encoding small secreted proteins identifies candidate effectors in *Melampsora larici-populina* (poplar leaf rust). *Molecular Plant-Microbe Interactions* 25 (3): 279-93.

Hangs, R., J. Schoenau, K. Rees, N. Bélanger, T. Volk, and T. Jensen. 2014. First rotation biomass production and nutrient cycling within short-rotation coppice willow plantations in Saskatchewan, Canada. *BioEnergy Research* 7 (4): 1091.

Hangs, R. D., J. J. Schoenau, K. C. J. Rees, N. Bélanger, and T. Volk. 2014. Leaf litter decomposition and nutrient-release characteristics of several willow varieties within short-rotation coppice plantations in Saskatchewan, Canada. *BioEnergy Research* 7 (4): 1074-90.

Hangs, R. D., J. J. Schoenau, Van Rees, K. C. J., and J. D. Knight. 2012. The effect of irrigation on nitrogen uptake and use efficiency of two willow (*Salix* spp.) biomass energy varieties. *Canadian Journal of Plant Science* 92 (3): 563-75.

Hangs, R. D., F. C. Stevenson, J. J. Schoenau, and K. C. J. Rees. 2013. Measuring harvestable biomass in short-rotation willow bioenergy plantations using light attenuation. *BioEnergy Research* 6 (1): 83-90.

Hans, G., D. Redman, B. Leblon, J. Nader, and A. Rocque. 2015. Determination of log moisture content using ground penetrating radar (GPR). part 1. partial least squares (PLS) method. *Holzforschung* 69 (9): 1117-23.

Hans, G., D. Redman, B. Leblon, J. Nader, and A. Rocque 2015. Determination of log moisture content using ground penetrating radar (GPR). part 2. propagation velocity (PV) method. *Holzforschung* 69 (9): 1125-32.

Harbilas, D., D. Vallerand, A. Brault, A. Saleem, J. T. Arnason, L. Musallam, and P. S. Haddad. 2013. *Populus balsamifera* extract and its active component salicortin reduce obesity and attenuate insulin resistance in a diet-induced obese mouse model. *Evidence-Based Complementary and Alternative Medicine* 2013: Article ID 172537.

Harbilas, Despina, Antoine Brault, Diane Vallerand, Louis C. Martineau, Ammar Saleem, John T. Arnason, Lina Musallam, and Pierre S. Haddad. 2012. *Populus balsamifera* L. (Salicaceae) mitigates the development of obesity and improves insulin sensitivity in a diet-induced obese mouse model. *Journal of Ethnopharmacology* 141 (3): 1012-20.

Harper, G., and J. Roach. 2014. The role of broadleaf trees: Impacts of managing boreal and sub-boreal mixedwood forests in British Columbia. British Columbia Ministry of Forests and Range, Extension Note 110.

Hart, J. F., F. Araujo, B. R. Thomas, and S. D. Mansfield. 2013. Wood quality and growth characterization across intra- and inter-specific hybrid aspen clones. *Forests* 4 (4): 786-807.

Hassan, Q. K., and K. M. Rahman. 2013. Applicability of remote sensing-based surface temperature regimes in determining deciduous phenology over boreal forest. *Journal of Plant Ecology* 6 (1): 84-91.

Hayova, V. P., and D. W. Minter. 2012. *Leucostoma translucens*. [descriptions of fungi and bacteria]. *IMI Descriptions of Fungi and Bacteria* 193: Sheet 1923.

Herbison, B., M. L. Polzin, and S. B. Rood. 2015. Hydration as a possible colonization cue: Rain may promote seed release from black cottonwood trees. *Forest Ecology and Management* 350: 22-9.

Herbison, B., and S. B. Rood. 2015. Compound influences of river damming and beavers on riparian cottonwoods: A comparative study along the Lardeau and Duncan rivers, British Columbia, Canada. *Wetlands* 35 (5): 945-54.

Hewins, D. B., F. Fatemi, B. Adams, C. N. Carlyle, S. X. Chang, and E. W. Bork. 2015. Grazing, regional climate and soil biophysical impacts on microbial enzyme activity in grassland soil of western Canada. *Pedobiologia* 58 (5): 201-9.

Hogg, E. H., A. G. Barr, and T. A. Black. 2013. A simple soil moisture index for representing multi-year drought impacts on aspen productivity in the western Canadian interior. *Agricultural and Forest Meteorology* 178/179: 173-82.

Hogg, E. H., and M. Michaelian. 2015. Factors affecting fall down rates of dead aspen (*Populus tremuloides*) biomass following severe drought in west-central Canada. *Global Change Biology* 21 (5): 1968-79.

Hua, Zhang, G. H. Huang, Wang DunLing, X. D. Zhang, Li GongChen, An ChunJiang, Cui Zheng, Liao RenFei, and Nie XiangHui. 2012. An integrated multi-level watershed-reservoir modeling system for examining hydrological and biogeochemical processes in small prairie watersheds. *Water Research* 46 (4): 1207-24.

Huang, Jian-Guo, Kenneth J. Stadt, Andria Dawson, and Philip G. Comeau. 2013. Modelling growth-competition relationships in trembling aspen and white spruce mixed boreal forests of western Canada. *Plos One* 8 (10): 1-14.

Huda, A. S. M. A., A. Koubaa, A. Cloutier, R. E. Hernández, and Y. Fortin. 2014. Variation of the physical and mechanical properties of hybrid poplar clones. *Bioresources* 9 (1): 1456-71.

Huda, A. S. M. A., A. Koubaa, A. Cloutier, R. E. Hernández, and P. Périnet. 2012. Anatomical properties of selected hybrid poplar clones grown in southern Quebec. *Bioresources* 7 (3): 3779-99.

Huggard, D. J., B. E. Grover, E. Dzus, M. Smith, and J. Schieck. 2015. Effectiveness monitoring for biodiversity: Comparing 15 year old structural retention harvest areas to fires in boreal aspen. *Canadian Journal of Forest Research* 45 (2): 153-61.

Isabel, N., M. Lamothe, and S. L. Thompson. 2013. A second-generation diagnostic single nucleotide polymorphism (SNP)-based assay, optimized to distinguish among eight poplar (*Populus* L.) species and their early hybrids. *Tree Genetics and Genomes* 9 (2): 621-6.

Jassal, Rachhpal S., T. A. Black, Carmela Arevalo, Hughie Jones, Jagtar S. Bhatti, and Derek Sidders. 2013. Carbon sequestration and water use of a young hybrid poplar plantation in north-central Alberta. *Biomass & Bioenergy* 56 (09): 323-33.

Jefferies, D., R. J. Heck, and N. V. Thevathasan. 2013. X-ray computed micro tomography measured pore characteristics of soils in an agroforestry intercropping system. In Poppy, L., Kort, J., Schroeder, B., Pollock, T. and Soolanayakanahally, R. (Eds.) Proceedings of the 13th North American Agroforestry Conference, June 19-21, 2013, Charlottetown, Prince Edward Island, Canada. p. 22. Available from University of Missouri Digital Library

http://dl.mospace.umsystem.edu/mu/islandora/object/mu%3A90378#page/1/mode/2up.

Jefferies, D. A., R. J. Heck, N. V. Thevathasan, and A. M. Gordon. 2014. Characterizing soil surface structure in a temperate tree-based intercropping system using X-ray computed tomography. *Agroforestry Systems* 88 (4): 645-56.

JianGuo, Huang, Y. Bergeron, F. Berninger, Zhai LiHong, J. C. Tardif, and B. Denneler. 2013. Impact of future climate on radial growth of four major boreal tree species in the eastern Canadian boreal forest. *Plos One* 8 (2): e56758.

JinHyeob, Kwak, S. X. Chang, M. A. Naeth, and W. Schaaf. 2015. Coarse woody debris increases microbial community functional diversity but not enzyme activities in reclaimed oil sands soils. *Plos One* 10 (11): e0143857.

Jung, Kangho, Scott X. Chang, Yong Sik Ok, and M. A. Arshad. 2013. Critical loads and H+ budgets of forest soils affected by air pollution from oil sands mining in Alberta, Canada. *Atmospheric Environment* 69 (04/11): 56-64.

Kabzems, R. 2012. Aspen and white spruce productivity is reduced by organic matter removal and soil compaction. *Forestry Chronicle* 88 (3): 306-16.

Kabzems, R., and G. J. Harper. 2015. Conifer and vegetation responses to pre-planting applications of glyphosate and hexazinone on a boreal backlog site, sx trial 82502G-2. Ministry of Forests, Lands and Natural Resource Operations, British Columbia. Technical Report 087.

Kaluthota, Sobadini, D. W. Pearce, L. M. Evans, M. G. Letts, T. G. Whitham, and S. B. Rood. 2015. Higher photosynthetic capacity from higher latitude: Foliar characteristics and gas exchange of southern, central and northern populations of *Populus angustifolia*. *Tree* Physiology 35 (9): 936-48.

Kamorina, G., F. Tremblay, B. Bussière, E. Smirnova, and N. Thiffault. 2015. Bluejoint is an effective bio-barrier species on mine covers. *Journal of Environmental Quality* 44 (6): 1791-9.

KangHo, Jung, and S. X. Chang. 2013. Soil and tree chemistry reflected the cumulative impact of acid deposition in *Pinus banksiana* and *Populus tremuloides* stands in the Athabasca oil sands region in western Canada. *Ecological Indicators* 25: 35-44.

KangHo, Jung, Choi WooJung, S. X. Chang, and M. A. Arshad. 2013. Soil and tree ring chemistry of *Pinus banksiana* and *Populus tremuloides* stands as indicators of changes in atmospheric environments in the oil sands region of Alberta, Canada. *Ecological Indicators* 25: 256-65.

Kaufmann, J., E. W. Bork, M. J. Alexander, and P. V. Blenis. 2014. Effects of open-range cattle grazing on deciduous tree regeneration, damage, and mortality following patch logging. *Canadian Journal of Forest Research* 44 (7): 777-83.

Kaufmann, J., E. W. Bork, M. J. Alexander, and P. V. Blenis. 2013. Habitat selection by cattle in foothill landscapes following variable harvest of aspen forest. *Forest Ecology and* Management 306: 15-22.

Kavanagh, Richard J., Richard A. Frank, Keith R. Solomon, and Der Kraak Van. 2013. Reproductive and health assessment of fathead minnows (*Pimephales promelas*)

inhabiting a pond containing oil sands process-affected water. *Aquatic Toxicology* 130-131: 201-9.

Kebli, H., S. Brais, G. Kernaghan, and P. Drouin. 2012. Impact of harvesting intensity on wood-inhabiting fungi in boreal aspen forests of eastern Canada. *Forest Ecology and Management* 279: 45-54.

Kebli, H., G. Kernaghan, P. Drouin, and S. Brais. 2014. Development and activity of early saproxylic fungal communities in harvested and unmanaged boreal mixedwood stands. *European Journal of Forest Research* 133 (5): 905-18.

Kelleher, C. T., J. Wilkin, Zhuang Jun, A. J. Cortés, Á. L. P. Quintero, T. F. Gallagher, J. Bohlmann, C. J. Douglas, B. E. Ellis, and K. Ritland. 2012. SNP discovery, gene diversity, and linkage disequilibrium in wild populations of *Populus tremuloides*. *Tree Genetics and Genomes* 8 (4): 821-9.

Kelly, J. W. G., S. M. Landhäusser, and P. S. Chow. 2015. The impact of light quality and quantity on root-to-shoot ratio and root carbon reserves in aspen seedling stock. *New Forests* 46 (4): 527-45.

Kishchuk, B. E., S. Quideau, Wang YongHe, and C. Prescott. 2014. Long-term soil response to variable-retention harvesting in the EMEND (ecosystem management emulating natural disturbance) experiment, northwestern Alberta. *Canadian Journal of Soil Science* 94 (3): 263-79.

Kishchuk, B. E., E. Thiffault, M. Lorente, S. Quideau, T. Keddy, and D. Sidders. 2015. Decadal soil and stand response to fire, harvest, and salvage-logging disturbances in the western boreal mixedwood forest of Alberta, Canada. *Canadian Journal of Forest Research* 45 (2): 141-52.

Knudson, Robert, and Gilles Brunette. 2015. Evaluation of Canadian prairie-grown hybrid poplar for high value solid wood products. *Forestry Chronicle* 91 (2): 141.

Ko, C., G. Sohn, T. K. Remmel, and J. Miller. 2014. Hybrid ensemble classification of tree genera using airborne LiDAR data. *Remote Sensing* 6 (11): 11225-43.

Kuzmina, M. L., K. L. Johnson, H. R. Barron, and P. D. N. Hebert. 2012. Identification of the vascular plants of Churchill, Manitoba, using a DNA barcode library. *BMC Ecology* 12 (25): 28 November 2012.

La Mantia J, Klapsté J, El-Kassaby YA, Azam S, Guy RD, Douglas C, Mansfield SD, Hamelin RC. 2013. Association analysis identifies *Melampsora* x*columbiana* poplar leaf rust resistance SNPs. *PLoS ONE* 8 (11): e78423.

Lacourse, Terri, J. M. Delepine, Elizabeth H. Hoffman, and Rolf W. Mathewes. 2012. A 14,000 year vegetation history of a hypermaritime island on the outer pacific coast of Canada based on fossil pollen, spores and conifer stomata. *Quaternary Research* 78: 572-82.

Lafleur, B., M. Labrecque, A. A. Arnold, and N. Bélanger. 2015. Organic carbon accumulation in topsoil following afforestation with willow: Emphasis on leaf litter decomposition and soil organic matter quality. *Forests* 6 (3): 769-93.

Lafleur, B., D. Paré, Y. Claveau, É. Thiffault, and N. Bélanger. 2013. Influence of afforestation on soil: The case of mineral weathering. *Geoderma* 202/203: 18-29.

Lafleur, B., E. Thiffault, D. Paré, C. Camiré, M. Bernier-Cardou, and S. Masse. 2012. Effects of hog manure application on the nutrition and growth of hybrid poplar (*Populus* spp.) and

on soil solution chemistry in short-rotation woody crops. *Agriculture, Ecosystems & Environment* 155: 95-104.

Laganière, J., X. Cavard, B.W. Brassard, D. Paré, Y. Bergeron, H.Y.H. Chen. 2015. The influence of boreal tree species mixtures on ecosystem carbon storage and fluxes. For. Ecol. Manag. 354:119-129.

Laganière, J., D. Paré, Y. Bergeron, H. Y. H. Chen, B. W. Brassard, and X. Cavard. 2013. Stability of soil carbon stocks varies with forest composition in the Canadian boreal biome. *Ecosystems* 16 (5): 852-65.

Lamb, Eric G., and Digit D. Guedo. 2012. The distribution, abundance, and environmental affinities of the endemic vascular plant taxa of the Athabasca sand dunes of northern Saskatchewan. *Ecoscience* 19 (2): 161-9.

Landhäusser, S. M., J. Rodriguez-Alvarez, E. H. Marenholtz, and V. J. Lieffers. 2012. Effect of stock type characteristics and time of planting on field performance of aspen (*Populus tremuloides* Michx.) seedlings on boreal reclamation sites. *New Forests* 43 (5): 679-93.

Landhäusser, S. M., B. D. Pinno, V. J. Lieffers, and P. S. Chow. 2012. Partitioning of carbon allocation to reserves or growth determines future performance of aspen seedlings. *Forest Ecology and Management* 275: 43-51.

Landry, Jean-Sébastien, Eric Neilson, Werner Kurz, and Kevin Percy. 2013. The impact of tropospheric ozone on landscape-level merchantable biomass and ecosystem carbon in Canadian forests. *European Journal of Forest Research* 132 (1): 71.

Lantz, V. A., Chang WeiYew, and C. Pharo. 2014. Benefit-cost analysis of hybrid willow crop production on agricultural land in eastern Canada: Assessing opportunities for on-farm and off-farm bioenergy use. *Biomass and Bioenergy* 63: 257-67.

LaRade, S. E., E. W. Bork, and W. D. Willms. 2012. Assessment of soil biological activity in northern aspen parkland native and seeded pasture using bait lamina. *Journal of Agricultural Science* 4 (5): 83-90.

Larchevêque M, Desrochers A, Bussière B, Cimon D. 2014. Planting trees in soils above non-acid-generating wastes of a boreal gold mine. *Écoscience* 21(3): 217-31.

Larocque, G. R., A. DesRochers, M. Larchevêque, F. Tremblay, J. Beaulieu, A. Mosseler, J. E. Major, *et al*. 2013. Research on hybrid poplars and willow species for fast-growing tree plantations: Its importance for growth and yield, silviculture, policy-making and commercial applications. *Forestry Chronicle* 89 (1): 32-41.

Latutrie, M., P. Mérian, S. Picq, Y. Bergeron, and F. Tremblay. 2015. The effects of genetic diversity, climate and defoliation events on trembling aspen growth performance across Canada. *Tree Genetics and Genomes* 11 (5): 96.

Lauron-Moreau, A., F. E. Pitre, L. Brouillet, and M. Labrecque. 2013. Microsatellite markers of willow species and characterization of 11 polymorphic microsatellites for *Salix eriocephala* (Salicaceae), a potential native species for biomass production in Canada. *Plants* 2 (2): 203-10.

Lawrence, D. J., N. Luckai, W. L. Meyer, C. Shahi, A. J. Fazekas, P. Kesanakurti, and S. Newmaster. 2012. Distribution of white spruce lateral fine roots as affected by the presence of trembling aspen: Root mapping using simple sequence repeat DNA profiling. *Canadian Journal of Forest Research* 42 (8): 1566-76.

Laxton, Dayna, Shaun Watmough, and Julian Aherne. 2012. Nitrogen cycling in *Pinus banksiana* and *Populus tremuloides* stands in the Athabasca oil sands region, Alberta, Canada. *Water, Air & Soil Pollution* 223 (1): 1-13.

Lazorko, Heidi, and Ken Rees. 2012. Root distributions of planted boreal mixedwood species on reclaimed saline-sodic overburden. *Water, Air & Soil Pollution* 223 (1): 215-31.

LeBlanc, P. A. 2014. Incorporating multi-cohort old aspen and mixedwood dynamics into a long-term forest management plan. *Forestry Chronicle* 90 (1): 50-8.

LeBoldus, J. M., N. Isabel, K. D. Floate, P. Blenis, and B. R. Thomas. 2013. Testing the 'hybrid susceptibility' and 'phenological sink' hypotheses using the *P. balsamifera* - *P. deltoides* hybrid zone and *Septoria* leaf spot [*Septoria musiva*]. *Plos One* 8 (12): e84437-.

Lemieux, C. J., P. A. Gray, D. J. Scott, D. W. McKenney, and S. MacFarlane. 2012. Climate change and the Lake Simcoe watershed: A vulnerability assessment of natural heritage areas and nature-based tourism. Ontario Forest Research Institute. Climate Change Research Report 28.

LiHong, Zhai, Y. Bergeron, Huang JianGuo, and F. Berninger. 2012. Variation in intra-annual wood formation, and foliage and shoot development of three major Canadian boreal tree species. *American Journal of Botany* 99 (5): 827-37.

Lilies, E. B., B. G. Purdy, S. E. Macdonald, and S. X. Chang. 2012. Growth of aspen and white spruce on naturally saline sites in northern Alberta: Implications for development of boreal forest vegetation on reclaimed saline soils. *Canadian Journal of Soil Science* 92 (1): 213-27.

Lilles, E. B., B. G. Purdy, S. E. Macdonald, and S. X. Chang. 2012. Growth of aspen and white spruce on naturally saline sites in northern Alberta: Implications for development of boreal forest vegetation on reclaimed saline soils. *Canadian Journal of Soil Science* 92 (1): 213-27.

Link, C. M., N. V. Thevathasan, A. M. Gordon, and M. E. Isaac. 2015. Determining tree water acquisition zones with stable isotopes in a temperate tree-based intercropping system. *Agroforestry Systems* 89 (4): 611-20.

Lockwell, Jérémie, Werther Guidi, and Michel Labrecque. 2012. Soil carbon sequestration potential of willows in short-rotation coppice established on abandoned farm lands. *Plant & Soil* 360 (1): 299-318.

Lu, J. F., and L. J. Zhang. 2012. Geographically local linear mixed models for tree height-diameter relationship. *Forest Science* 58 (1): 75-84.

Luckai, N., G. R. Larocque, L. Archambault, D. Paré, R. Boutin, and A. Groot. 2012. Using the carbon budget model of the Canadian forest sector (CBM-CFS3) to examine the impact of harvest and fire on carbon dynamics in selected forest types of the Canadian boreal shield. *Forestry Chronicle* 88 (4): 426-38.

Lupi, C., G. Larocque, A. Desrochers, M. Labrecque, A. Mosseler, J. Major, J. Beaulieu, et al. 2015. Evaluating sampling designs and deriving biomass equations for young plantations of poplar and willow clones. *Biomass and Bioenergy* 83: 196-205.

Luppold, William G., and Matthew S. Bumgardner. 2013. Factors influencing changes in U.S. hardwood log and lumber exports from 1990 to 2011. *Bioresources* 8 (2): 1615-24.

Macdonald, S. E., A. E. K. Snively, J. M. Fair, and S. M. Landhäusser. 2015. Early trajectories of forest understory development on reclamation sites: Influence of forest floor placement and a cover crop. *Restoration Ecology* 23 (5): 698-706.

Maganti, Harinad, David Bartfai, and Jianping Xu. 2012. Ecological structuring of yeasts associated with trees around Hamilton, Ontario, Canada. *FEMS Yeast Research* 12 (1): 9-19.

Mamashita, T., G. R. Larocque, A. DesRochers, J. Beaulieu, B. R. Thomas, A. Mosseler, J. Major, and D. Sidders. 2015. Short-term growth and morphological responses to nitrogen availability and plant density in hybrid poplars and willows. *Biomass and Bioenergy* 81: 88-97.

Man, Rongzhou, James A. Rice, and G. B. MacDonald. 2013. Performance of planted spruce and natural regeneration after pre- and post-harvest spraying with glyphosate and partial cutting on an Ontario (Canada) boreal mixedwood site. *Forestry* 86 (4): 475-80.

Mantia JL, Klápste J, El-Kassaby YA, Azam S, Guy RD, Douglas CJ, Mansfield SD, Hamelin R. 2013. Association analysis identifies *Melampsora* ×*columbiana* poplar leaf rust resistance SNPs. *PLoS One* 8(11): E78423.

Masse, S., P. P. Marchand, and M. Bernier-Cardou. 2014. Forecasting the deployment of short-rotation intensive culture of willow or hybrid poplar: Insights from a delphi study. *Canadian Journal of Forest Research* 44 (5): 422-31.

Masse, S., P. P. Marchand, M. Bernier-Cardou, and C. Delisle. 2015. Research, development, and deployment needs for short-rotation plantation and agroforestry systems: An experts' assessment of landowners' perceptions. *Canadian Journal of Forest Research* 45 (1): 101-10.

Maurin V, DesRochers A. Physiological and growth responses to pruning season and intensity of hybrid poplar. 2013. *Forest Ecology and Management* 304: 399-406.

McKenney, D. W., A. Weersink, D. Allen, D. Yemshanov, and M. Boyland. 2014. Enhancing the adoption of short rotation woody crops for bioenergy production. *Biomass and Bioenergy* 64: 363-6.

McKown, A. D., R. D. Guy, J. Klápšte, A. Geraldes, M. Friedmann, Q. C. B. Cronk, Y. El-Kassaby, S. D. Mansfield, and C. J. Douglas. 2014. Geographical and environmental gradients shape phenotypic trait variation and genetic structure in *Populus trichocarpa*. *New Phytologist* 201 (4): 1263-76.

McKown, A.D., Klápště, J, Guy, R.D., Geraldes, A., Porth, I., Hannemann, J., Friedmann, M., Muchero, W., Tuskan, G.A., Ehlting, J., *et al*. 2014. Genome-wide association implicates numerous genes underlying ecological trait variation in natural populations of *Populus trichocarpa*. *New Phytologist* 203(2): 535-53.

Mehes-Smith, M., and K. K. Nkongolo. 2015. Physiological and cytological responses of *Deschampsia cespitosa* and *Populus tremuloides* to soil metal contamination. *Water, Air, and Soil Pollution* 226 (4): 125.

Mimura, M., A. S. Mori, M. Uchida, and H. Kanda. 2013. Colonization of vegetation-rich moraines and inference of multiple sources of colonization in the high arctic for *Salix arctica*. *Conservation Genetics* 14 (1): 223-9.

Mimura, Makiko, Akira Mori, Masaki Uchida, and Hiroshi Kanda. 2013. Colonization of vegetation-rich moraines and inference of multiple sources of colonization in the high arctic for *Salix arctica*. *Conservation Genetics* 14 (1): 223-9.

MingBin, Huang, J. D. Zettl, S. L. Barbour, A. Elshorbagy, and Si BingCheng. 2013. The impact of soil moisture availability on forest growth indices for variably layered coarse-textured soils. *Ecohydrology* 6 (2): 214-27.

MingFang, Zhang, and Wei XiaoHua. 2014. Contrasted hydrological responses to forest harvesting in two large neighbouring watersheds in snow hydrology dominant environment: Implications for forest management and future forest hydrology studies. *Hydrological* Processes 28 (26): 6183-95.

Minter, D. W., B. Aguirre-Hudson, and P. F. Cannon. 2015. *Arthopyrenia cerasi*. [descriptions of fungi and bacteria]. *IMI Descriptions of Fungi and Bacteria* 206: Sheet 2051.

Minter, D. W., B. Aguirre-Hudson, and P. F. Cannon. 2015. *Leptorhaphis atomaria*. [descriptions of fungi and bacteria]. *IMI Descriptions of Fungi and Bacteria* 206: Sheet 2054.

Mirck, J. 2013. Biomass potential and stand structure of native willows on the Canadian prairies. In Poppy, L., Kort, J., Schroeder, B., Pollock, T. and Soolanayakanahally, R. (Eds.) Proceedings of the 13th North American Agroforestry Conference, June 19-21, 2013, Charlottetown, Prince Edward Island, Canada. p. 49. Available from University of Missouri Digital Library http://dl.mospace.umsystem.edu/mu/islandora/object/mu%3A90378#page/1/mode/2up.

Mirck, J., and W. Schroeder. 2013. Composition, stand structure, and biomass estimates of "willow rings" on the Canadian prairies. *BioEnergy Research* 6 (3): 864-76.

Miville, V., N. Gélinas, and M. A. Côté. 2013. Evaluation of the profitability of poplar cultivation in Quebec. *Forestry Chronicle* 89 (4): 538-48.

Mompremier, R., G. Pelletier, Ó. A. F. Mariles, and K. Ghebremichael. 2015. Impact of incomplete mixing in the prediction of chlorine residuals in municipal water distribution systems. *Journal of Water Supply: Research and Technology - Aqua* 64 (8): 904-14.

Mosseler, A. and Major, J.E. 2015. Revegetation of highly acidic mine spoils with native North American willows. *Reclamation Matters* 15: 48-52.

Mosseler, A. and Major, J.E. 2015. Reclamation and woody biomass production on disturbed sites with willow (*Salix interior*). *Reclamation Matters* 15: 22-27.

Mosseler, A., and J. E. Major. 2015. Biomass and root stem production of a colony-forming willow (*Salix interior*) on highly disturbed, low fertility sites. *Biomass and Bioenergy* 74: 202-12.

Mosseler, A., and J. E. Major. 2014. Coppice growth responses of two North American willows in acidic clay soils on coal mine overburden. *Canadian Journal of Plant Science* 94 (7): 1269-79.

Mosseler, A., J. E. Major, and M. Labrecque. 2014. Genetic by environment interactions of two North American *Salix* species assessed for coppice yield and components of growth on three sites of varying quality. *Trees - Structure and Function* 28 (5): 1401-11.

Mosseler, A., J. E. Major, and M. Labrecque. 2014. Growth and survival of seven native willow species on highly disturbed coal mine sites in eastern Canada. *Canadian Journal of Forest Research* 44 (4): 340-9.

Mosseler, A., J. E. Major, M. Labrecque, and G. R. Larocque. 2014. Allometric relationships in coppice biomass production for two North American willows (*Salix* spp.) across three different sites. *Forest Ecology and Management* 320: 190-6.

Moukoumi, J., R. E. Farrell, K. J. C. Rees, R. K. Hynes, and N. Bélanger. 2012. Intercropping *Caragana arborescens* with *Salix miyabeana* to satisfy nitrogen demand and maximize growth. *BioEnergy Research* 5 (3): 719-32.

Moulinier, J., F. Lorenzetti, and Y. Bergeron. 2014. Growth and mortality of trembling aspen (*Populus tremuloides*) in response to artificial defoliation. *Acta Oecologica* 55: 104-12.

Moulinier, Julien, François Lorenzetti, and Yves Bergeron. 2013. Effects of a forest tent caterpillar outbreak on the dynamics of mixedwood boreal forests of eastern Canada. *Ecoscience* 20 (2): 182-93.

Muchero, W., Guo, J., DiFazio, S.P., Chen, J., Ranjan, P., Slavov, G.T., Gunter, L.E., Jawdy, S., Bryan, A.C., Sykes, R., *et al*. 2015. High-resolution genetic mapping of allelic variants associated with cell wall chemistry in *Populus*. *BMC Genomics* 16(1): 24.

Murphy, E. K., R. Y. Soolanayakanahally, S. J. Hanley, A. Karp, and W. R. Schroeder. 2013. Canada-wide genetic variation of *Salix eriocephala* populations. *Proceedings of the 13th* In Poppy, L., Kort, J., Schroeder, B., Pollock, T. and Soolanayakanahally, R. (Eds.) Proceedings of the 13th North American Agroforestry Conference, June 19-21, 2013, Charlottetown, Prince Edward Island, Canada. p. 52. Available from University of Missouri Digital Library http://dl.mospace.umsystem.edu/mu/islandora/object/mu%3A90378#page/1/mode/2up.

Myers-Smit, I., and D. S. Hik. 2012. Uniform female-biased sex ratios in alpine willows. *American Journal of Botany* 99 (7): 1243-8.

Neufeld, B. A., D. M. Morris, N. Luckai, D. E. B. Reid, F. W. Bell, C. Shahi, W. L. Meyer, and S. Adhikary. 2014. The influence of competition and species mixture on plantation-grown white spruce: Growth and foliar nutrient response after 20 years. *Forestry Chronicle* 90 (1): 70-9.

Newsome, Teresa A., Jean L. Heineman, and Amanda F. Linnell Nemec. 2012. Identifying and characterizing important trembling aspen competitors with juvenile lodgepole pine in three south-central British Columbia ecosystems. *International Journal of Forestry Research* 2012: Article 573640.

Nieman, D. C., R. A. Shanely, Luo BeiBei, D. Dew, M. P. Meaney, and W. Sha. 2013. A commercialized dietary supplement alleviates joint pain in community adults: A double-blind, placebo-controlled community trial. *Nutrition Journal* 12 (154): 25 November 2013.

Nigh, G. 2012. A biophysical model for estimating site index for the major commercial tree species in British Columbia. BC Ministry of Forests, Lands and Natural Resource Operations, Forest Science Program. Technical Report 073.

Nigh, G., and R. Jong. 2015. Validating the site productivity layer for British Columbia with equivalence testing. British Columbia Ministry of Forests, Lands and Natural Resource Operations. Technical Report 085.

Nissim, W. G., S. Hasbroucq, H. Kadri, F. E. Pitre, and M. Labrecque. 2015. Potential of selected Canadian plant species for phytoextraction of trace elements from selenium-rich soil contaminated by industrial activity. *International Journal of Phytoremediation* 17 (8): 745-52.

Nissim, W. G., and M. Labrecque. 2012. The use of willow to address environmental issues: The Canadian experience on phytotechnology. / il salice nel controllo del degrado ambientale: L'esperienza canadese nell'ambito delle fitotecnologie. *Sherwood - Foreste ed Alberi Oggi* 184: 40-5.

Nissim, W. G., F. E. Pitre, T. I. Teodorescu, and M. Labrecque. 2013. Long-term biomass productivity of willow bioenergy plantations maintained in southern Quebec, Canada. *Biomass and Bioenergy* 56: 361-9.

Nlungu-Kweta, P., A. Leduc, and Y. Bergeron. 2014. Conifer recruitment in trembling aspen (*Populus tremuloides* Michx.) stands along an east-west gradient in the boreal mixedwoods of Canada. *Forests* 5 (11): 2905-28.

Norris, A. R., and K. Martin. 2012. Red-breasted nuthatches (*Sitta canadensis*) increase cavity excavation in response to a mountain pine beetle (*Dendroctonus ponderosae*) outbreak. *Écoscience* 19 (4): 308-15.

Norris, C. E., J. A. J. Dungait, A. Joynes, and S. A. Quideau. 2013. Biomarkers of novel ecosystem development in boreal forest soils. *Organic Geochemistry* 64: 9-18.

Norris, C. E., S. A. Quideau, and D. E. Macey. 2013. Processing of 13C glucose in mineral soil from aspen, spruce and novel ecosystems in the Athabasca oil sands region. *Applied Soil Ecology* 71: 24-32.

Oort, H., D. J. Green, M. Hepp, and J. M. Cooper. 2015. Do fluctuating water levels alter nest survivorship in reservoir shrubs? *Condor* 117 (3): 376-85.

Ostaff, D. P., J. S. Ascher, S. Javorek, and A. Mosseler. 2015. New records of *Andrena* (Hymenoptera: Andrenidae) in New Brunswick, Canada. *Journal of the Acadian Entomological* Society 11 (2): 5-8.

Ostaff, D. P., A. Mosseler, R. C. Johns, S. Javorek, J. Klymko, and J. S. Ascher. 2015. Willows (*Salix* spp.) as pollen and nectar sources for sustaining fruit and berry pollinating insects. *Canadian Journal of Plant Science* 95 (3): 505-16.

Oubida, R. W., D. Gantulga, M. Zhang, L. C. Zhou, R. Bawa, and J. A. Holliday. 2015. Partitioning of multivariate phenotypes using regression trees reveals complex patterns of adaptation to climate across the range of black cottonwood (*Populus trichocarpa*). *Frontiers in Plant Science* 6: 181.

Palomo-Ríos, E., W. Macalpine, I. Shield, J. Amey, C. Karaoğlu, J. West, S. Hanley, R. Krygier, A. Karp, and H. D. Jones. 2015. Efficient method for rapid multiplication of clean and healthy willow clones via in vitro propagation with broad genotype applicability. *Canadian Journal of Forest Research* 45 (11): 1662-7.

Panfil, M., R. Jassal, R. Ketler, Z. Nesic, N. Grant, A. Black, C. Arevalo, J. Bhatti, D. Sidders, and J. Leśny. 2012. Carbon dioxide and water vapour flux measuring methods used in hybrid poplar plantation. *Przeglad Geofizyczny* 57 (2): 245-54.

Patterson, J. E. H. 2012. Nest site characteristics and nest tree use by northern flying squirrels (*Glaucomys sabrinus*) in southwestern Alberta, Canada. *Northwest Science* 86 (2): 144-50.

Paudel, S. K., C. R. Nitschke, S. W. Simard, and J. L. Innes. 2015. Regeneration dynamics of white spruce, trembling aspen, and balsam poplar in response to disturbance, climatic, and edaphic factors in the cold, dry boreal forests of the southwest Yukon, Canada. *Journal of Forestry* 113 (5): 463-74.

Périnet, P., U. Thériault, and F. Tremblay. 2013. Evaluation of hybrid poplar clones under intensive cultivation for biomass production in Québec. In Poppy, L., Kort, J., Schroeder, B., Pollock, T. and Soolanayakanahally, R. (Eds.) Proceedings of the 13th North American Agroforestry Conference, June 19-21, 2013, Charlottetown, Prince Edward Island, Canada. p. 56-60. Available from University of Missouri Digital Library http://dl.mospace.umsystem.edu/mu/islandora/object/mu%3A90378#page/1/mode/2up.

Perrette, G., F. Lorenzetti, J. Moulinier, and Y. Bergeron. 2014. Site factors contribute to aspen decline and stand vulnerability following a forest tent caterpillar outbreak in the Canadian clay belt. *Forest Ecology and Management* 323: 126-37.

Petre B, Hecker A, Germain H, Tsan P, Sklenar J, Pelletier G, Séguin A, Duplessis S, Rouhier N. 2016. The poplar rust-induced secreted protein (RISP) inhibits the growth of the leaf rust pathogen *Melampsora larici-populina* and triggers cell culture alkalinisation. *Frontiers in Plant Science* 7: 97.

Pinno, B. D., and R. C. Errington. 2015. Maximizing natural trembling aspen seedling establishment on a reclaimed boreal oil sands site. *Ecological Restoration* 33 (1): 43-50.

Pinno, B. D., S. M. Landhäusser, M. D. MacKenzie, Sylvie A. Quideau, and Pak S. Chow. 2012. Trembling aspen seedling establishment, growth and response to fertilization on contrasting soils used in oil sands reclamation. *Canadian Journal of Soil Science* 92 (1): 143-51.

Pitt, D. G., P. G. Comeau, W. C. Parker, M. K. Hoepting, D. MacIsaac, S. McPherson, and M. Mihajlovich. 2015. Early vegetation control for the regeneration of a single-cohort, intimate mixture of white spruce and aspen on upland boreal sites - 10th year update. *Forestry Chronicle* 91 (3): 238-51.

Plante, P. M., D. Rivest, A. Vézina, and A. Vanasse. 2014. Root distribution of different mature tree species growing on contrasting textured soils in temperate windbreaks. *Plant and Soil* 380 (1): 429-39.

Plante, S., E. Champagne, P. Ropars, S. Boudreau, E. Lévesque, B. Tremblay, and J. P. Tremblay. 2014. Shrub cover in northern Nunavik: Can herbivores limit shrub expansion? *Polar Biology* 37 (5): 611-9.

Plett, J. M., M. Williams, G. LeClair, S. Regan, and T. Beardmore. 2014. Heterologous over-expression of ACC SYNTHASE8 (ACS8) in *Populus tremula* x *P. alba* clone 717-1B4 results in elevated levels of ethylene and induces stem dwarfism and reduced leaf size through separate genetic pathways. *Frontiers in Plant Science* 5: 514.

Popp, J. N., D. N. C. McGeachy, and J. Hamr. 2013. Elk (*Cervus elaphus*) seasonal habitat selection in a heterogeneous forest structure. *International Journal of Forestry Research*: Article 415913.

Porth, I., Klapšte, J., Skyba, O., Hannemann, J., McKown, A.D., Guy, R.D., DiFazio, S.P., Muchero, W., Ranjan, P., Tuskan, G.A., *et al*. 2013. Genome-wide association mapping for wood characteristics in populus identifies an array of candidate single nucleotide polymorphisms. *New Phytologist* 200(3): 710-26.

Porth, I., Klápště, J., Skyba, O., Lai, B.S.K., Geraldes, A., Muchero, W., Tuskan, G.A., Douglas, C.J., El-Kassaby, Y.A., Mansfield, S.D. 2013. *Populus trichocarpa* cell wall chemistry and ultrastructure trait variation, genetic control and genetic correlations. *New Phytologist* 197 (3): 777-90.

Portillo-Quintero, Carlos, Arturo Sanchez-Azofeifa, and Darius Culvenor. 2014. Using VEGNET in-situ monitoring LiDAR (IML) to capture dynamics of plant area index, structure and phenology in aspen parkland forests in Alberta, Canada. *Forests* 5 (9): 1053-68.

Prévost, M., and J. DeBlois. 2014. Shelterwood cutting to release coniferous advance growth and limit aspen sucker development in a boreal mixedwood stand. *Forest Ecology and Management* 323: 148-57.

Prévost, M., and D. Dumais. 2014. Shelterwood cutting in a boreal mixedwood stand: 10-year effects of the establishment cut on growth and mortality of merchantable residual trees. *Forest Ecology and Management* 330: 94-104.

Pruski, K., R. V. Young, and W. Wang. 2012. In vitro propagation, organ regeneration protocols and DNA markers for new plants of PlantAtlantic development programme for the Atlantic Canada nursery trade. *Acta Horticulturae* 937: 121-7.

Purton, K., D. Pennock, P. Leinweber, and F. Walley. 2015. Will changes in climate and land use affect soil organic matter composition? Evidence from an ecotonal climosequence. *Geoderma* 253/254: 48-60.

Randall, M. J., J. Karst, G. J. Pec, C. S. Davis, J. C. Hall, and J. F. Cahill J. 2014. A molecular identification protocol for roots of boreal forest tree species. *Applications in Plant Sciences* 2 (11): 1400069.

Rea, R., O. Hjeljord, and M. Gillingham. 2015. Factors influencing the use of willow and birch by moose in winter. *European Journal of Wildlife Research* 61 (2): 231-9.

Rea, R. V. 2012. The influence of willow salix sp. rose insect galls on moose *Alces alces* winter browsing. *Canadian Field-Naturalist* 126 (3): 189-93.

Reithmeier, L., and G. Kernaghan. 2013. Availability of ectomycorrhizal fungi to black spruce above the present treeline in eastern Labrador. *Plos One* 8 (10): e77527.

René, W., B. Côté, C. Camiré, M. Burgess, and J. W. Fyles. 2013. Development and application of CVA, DRIS, and CND norms for three hybrids of *Populus maximowiczii* planted in southern Quebec. *Journal of Plant Nutrition* 36 (1): 118-42.

Reyes-Hernández, V. J., and P. G. Comeau. 2015. The influence of stocking and stand composition on productivity of boreal trembling aspen-white spruce stands. *Forests* 6 (12): 4573-87.

Reyes-Hernández, V., and P. G. Comeau. 2014. Survival probability of white spruce and trembling aspen in boreal pure and mixed stands experiencing self-thinning. *Forest Ecology and Management* 323: 105-13.

Reyes-Hernandez, Valentin, Philip G. Comeau, and Mike Bokalo. 2013. Static and dynamic maximum size–density relationships for mixed trembling aspen and white spruce stands in western Canada. *Forest Ecology & Management* 289 (02): 300.

Richard, T. 2014. Characteristics of the breeding habitat of endangered kirtland's warblers on a Canadian military installation. *Journal of Field Ornithology* 85 (3): 301-9.

Richardson, J., and J. G. Isebrands. 2013. Multiple social and environmental benefits of poplars and willows - mini review. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources* 8 (059): 1-3.

Roach, J., and S. M. Berch. 2014. A compilation of forest biomass harvesting and related policy in Canada. British Columbia Ministry of Forests, Lands and Natural Resource Operations. Technical Report 081.

Robinson, J., and L. Hermanutz. 2015. Evaluating human-disturbed habitats for recovery planning of endangered plants. *Journal of Environmental Management* 150: 157-63.

Roe, A. D., C. J. K. Macquarrie, M. -C Gros-Louis, J. D. Simpson, J. Lamarche, T. Beardmore, S. L. Thompson, P. Tanguay, and N. Isabel. 2014. Fitness dynamics within a poplar hybrid zone: I. prezygotic and postzygotic barriers impacting a native poplar hybrid stand. *Ecology and Evolution* 4 (9): 1629-47.

Roe, A. D., C. J. K. MacQuarrie, M. Gros-Louis, J. D. Simpson, J. Lamarche, T. Beardmore, S. L. Thompson, P. Tanguay, and N. Isabel. 2014. Fitness dynamics within a poplar hybrid zone: II. Impact of exotic sex on native poplars in an urban jungle. *Ecology and Evolution* 4 (10): 1876-89.

Rogers, P. C., S. M. Landhäusser, B. D. Pinno, and R. J. Ryel. 2014. A functional framework for improved management of western North American aspen (*Populus tremuloides* Michx.). *Forest Science* 60 (2): 345-59.

Rollins, C. L., P. C. Boxall, and M. K. Luckert. 2015. Public preferences for planting genetically improved poplars on public land for biofuel production in western Canada. *Canadian Journal of Forest Research* 45 (12): 1785-94.

Ronald, Wilbert G. 2012. Morden research station - its impact on prairie gardens. *Prairie Garden* 73 (02): 183.

RongZhou, Man, H. Y. H. Chen, and A. Schafer. 2013. Salvage logging and forest renewal affect early aspen stand structure after catastrophic wind. *Forest Ecology and Management* 308: 1-8.

RongZhou, Man, and G. B. MacDonald. 2015. Growth of planted jack pine (*Pinus banksiana*) and natural regeneration ten years after pre- and post-harvest spraying and partial cutting in an Ontario boreal mixedwood forest. *Forestry Chronicle* 91 (1): 52-9.

Rood, S. B., S. G. Bigelow, M. L. Polzin, K. M. Gill, and C. A. Coburn. 2015. Biological bank protection: Trees are more effective than grasses at resisting erosion from major river floods. *Ecohydrology* 8 (5): 772-9.

Saarela, J. M., L. J. Gillespie, L. L. Consaul, and R. D. Bull. 2012. Balsam poplar (*Populus balsamifera*; Salicaceae) beyond the tree line in the western Canadian mainland arctic (northwest territories). *Arctic* 65 (1): 1-12.

Saarela, Jeffery M., Paul C. Sokoloff, Lynn J. Gillespie, Laurie L. Consaul, and Roger D. Bull. 2013. DNA barcoding the Canadian arctic flora: Core plastid barcodes (rbcL + matK) for 490 vascular plant species. *Plos One* 8 (10): 1.

Sattler, D. F., P. G. Comeau, and A. Achim. 2014. Within-tree patterns of wood stiffness for white spruce (*Picea glauca*) and trembling aspen (*Populus tremuloides*). *Canadian Journal of Forest Research* 44 (2): 162-71.

Savoie, P., D. Current, F. S. Robert, and P. L. Hébert. 2012. Harvest of natural shrubs with a biobaler in various environments in Québec, Ontario and Minnesota. *Applied Engineering in Agriculture* 28 (6): 795-801.

Schafer, A., Man RongZhou, H. Y. H. Chen, and Lu PengXin. 2014. Effects of post-windthrow management interventions on understory plant communities in aspen-dominated boreal forests. *Forest Ecology and Management* 323: 39-46.

Schott, K. M., B. D. Pinno, and S. M. Landhäusser. 2013. Premature shoot growth termination allows nutrient loading of seedlings with an indeterminate growth strategy. *New Forests* 44 (5): 635-47.

Schreiber, S. G., Ding Chen, A. Hamann, U. G. Hacke, B. R. Thomas, and J. S. Brouard. 2013. Frost hardiness vs. growth performance in trembling aspen: An experimental test of assisted migration. *Journal of Applied Ecology* 50 (4): 939-49.

Schreiber, S. G., U. G. Hacke, and A. Hamann. 2015. Variation of xylem vessel diameters across a climate gradient: Insight from a reciprocal transplant experiment with a widespread boreal tree. *Functional Ecology* 29 (11): 1392-401.

Schreiber, Stefan G., Andreas Hamann, Uwe G. Hacke, and Barbara R. Thomas. 2013. Sixteen years of winter stress: An assessment of cold hardiness, growth performance and survival of hybrid poplar clones at a boreal planting site. *Plant, Cell & Environment* 36 (2): 419-28.

Schroeder, W., H. Gooijer, J. Mirck, R. Soolanayakanahally, and B. Murray. 2013. Willow riparian buffers for biomass feedstock and nutrient export. In Poppy, L., Kort, J., Schroeder, B., Pollock, T. and Soolanayakanahally, R. (Eds.) Proceedings of the 13th North American Agroforestry Conference, June 19-21, 2013, Charlottetown, Prince Edward Island, Canada. p. 106-8. Available from University of Missouri Digital Library http://dl.mospace.umsystem.edu/mu/islandora/object/mu%3A90378#page/1/mode/2up.

Schroeder, W., R. Soolanayakanahally, and C. Lindquist. 2013. AC Sundancer™ poplar. *Canadian Journal of Plant Science* 93 (6): 1285-7.

Schroeder, W., R. Soolanayakanahally, and C. Lindquist. 2013. Okanese poplar. *Canadian Journal of Plant Science* 93 (6): 1281-3.

ShouQin, Sun, J. S. Bhatti, R. S. Jassal, S. X. Chang, C. Arevalo, T. A. Black, and D. Sidders. 2015. Stand age and productivity control soil carbon dioxide efflux and organic carbon dynamics in poplar plantations. *Soil Science Society of America Journal* 79 (6): 1638-49.

Sloan, Joshua, and Douglass Jacobs. 2013. Fertilization at planting influences seedling growth and vegetative competition on a post-mining boreal reclamation site. *New Forests* 44 (5): 687-701.

Smith, Sharon L., Daniel W. Riseborough, and Philip P. Bonnaventure. 2015. Eighteen year record of forest fire effects on ground thermal regimes and permafrost in the central Mackenzie Valley, NWT, Canada. *Permafrost & Periglacial Processes* 26 (4): 289-303.

Soolanayakanahally, R. Y., R. D. Guy, S. N. Silim, and Song MingHua. 2013. Timing of photoperiodic competency causes phenological mismatch in balsam poplar (*Populus balsamifera* L.). *Plant, Cell and Environment* 36 (1): 116-27.

Steelandt, S., D. Marguerie, Najat Bhiry, and A. Delwaide. 2015. A study of the composition, characteristics, and origin of modern driftwood on the western coast of Nunavik (Quebec, Canada). *Journal of Geophysical Research: Biogeosciences* 120 (3): 480-501.

Stephen, J. D., W. E. Mabee, and J. N. Saddler. 2013. Lignocellulosic ethanol production from woody biomass: The impact of facility siting on competitiveness. *Energy Policy* 59: 329-40.

St-Onge, B., F. A. Audet, and J. Bégin. 2015. Characterizing the height structure and composition of a boreal forest using an individual tree crown approach applied to photogrammetric point clouds. *Forests* 6 (11): 3899-922.

Strong, Wayne L., and Thomas S. Jung. 2012. Stand-level attributes of snowshoe hare (*Lepus americanus*) habitat in a post-fire trembling aspen (*Populus tremuloides*) chronosequence in central Yukon. *Canadian Field-Naturalist* 126 (4): 295-305.

Strukelj, M., S. Brais, and D. Paré. 2015. Nine-year changes in carbon dynamics following different intensities of harvesting in boreal aspen stands. *European Journal of Forest Research* 134 (5): 737-54.

Strukelj, Manuella, Suzanne Brais, Sylvie A. Quideau, and Se-Woung Oh. 2012. Chemical transformations of deadwood and foliar litter of mixed boreal species during decomposition. *Canadian Journal of Forest Research* 42 (4): 772-88.

Sun, S. -Q, J. S. Bhatti, R. S. Jassal, S. X. Chang, C. Arevalo, T. A. Black, and D. Sidders. 2015. Stand age and productivity control soil carbon dioxide efflux and organic carbon dynamics in poplar plantations. *Soil Science Society of America Journal* 79 (6): 1638-49.

Swallow, M., and S. A. Quideau. 2013. Moisture effects on microbial communities in boreal forest floors are stand-dependent. *Applied Soil Ecology* 63: 120-6.

Swift, D. E., A. L. Ruff, C. Leger, G. Comeau, I. Duchesne, and J. MacKenzie. 2012. Annotated bibliography on the impact of silviculture and management on wood fibre attributes for eight major Canadian commercial tree species. Natural Resources Canada, Canadian Forest Service, Canadian Wood Fibre Centre. Information Report FI-X-007.

Talbot, P., W. R. Schroeder, J. Bousquet, and N. Isabel. 2012. When exotic poplars and native *Populus balsamifera* L. meet on the Canadian prairies: Spontaneous hybridization and establishment of interspecific hybrids. *Forest Ecology and Management* 285: 142-52.

Taylor, A. R., T. Hart, and H. Y. H. Chen. 2013. Tree community structural development in young boreal forests: A comparison of fire and harvesting disturbance. *Forest Ecology and Management* 310: 19-26.

Taylor, A. R., M. Seedre, B. W. Brassard, and H. Y. H. Chen. 2014. Decline in net ecosystem productivity following canopy transition to late-succession forests. *Ecosystems* 17 (5): 778-91.

Terrier, A., M.P. Girardin, C. Périé, P. Legendre, Y. Bergeron. 2013. Potential changes in forest composition could reduce impacts of climate change on boreal wildfires. 2013. Ecol. Appl. 23:21-35.

Thevathasan, N., A. Gordon, J. Simpson, Peng XiaoBang, S. Silim, R. Soolanayakanahally, and H. Gooijer. 2014. Sustainability indicators of biomass production in agroforestry systems. *The Open Agriculture Journal* 8: 1-11.

Thomas, B., D. Kamelchuk, E. Macdonald, R. Krygier, and B. Hu. 2013. Screening *Populus balsamifera* clones for use in reclamation on challenging sites. In Poppy, L., Kort, J., Schroeder, B., Pollock, T. and Soolanayakanahally, R. (Eds.) Proceedings of the 13th North American Agroforestry Conference, June 19-21, 2013, Charlottetown, Prince Edward Island, Canada. p. 53. Available from University of Missouri Digital Library http://dl.mospace.umsystem.edu/mu/islandora/object/mu%3A90378#page/1/mode/2up.

Thompson, C., C. A. Mendoza, K. J. Devito, and R. M. Petrone. 2015. Climatic controls on groundwater-surface water interactions within the boreal plains of Alberta: Field observations and numerical simulations. *Journal of Hydrology* 527: 734-46.

Thompson, S. D., T. A. Nelson, J. C. White, and M. A. Wulder. 2015. Mapping dominant tree species over large forested areas using Landsat best-available-pixel image composites. *Canadian Journal of Remote Sensing* 41 (3): 203-18.

Ting, Bai, Yu FangYuan, and R. D. Guy. 2014. Analysis on difference in carbohydrate accumulation in *Populus balsamifera* seedlings among different provenance. *Journal of Southwest Forestry University* 34 (1): 27-30.

Toor, Imran A., Elwin G. Smith, Joann K. Whalen, and Anwar Naseem. 2012. Tree-based intercropping in southern Ontario, Canada. *Canadian Journal of Agricultural Economics* 60 (2): 141-54.

Townsend, Lise, and Richard J. Hebda. 2013. Pollen and macro-fossil assemblages in disturbed urban wetlands on south Vancouver Island reveal recent invasion of reed canarygrass (*Phalaris arundinacea*) and guide restoration. *Restoration Ecology* 21 (1): 114-23.

Tranquada, G. C., J. J. Victor, and U. Erb. 2015. Early season development of micro/nano-morphology and superhydrophobic wetting properties on aspen leaf surfaces. *American Journal of Plant Sciences* 6 (13): 2197-208.

Tremblay, J. A., J. P. L. Savard, and J. Ibarzabal. 2015. Structural retention requirements for a key ecosystem engineer in conifer-dominated stands of a boreal managed landscape in eastern Canada. *Forest Ecology and Management* 357: 220-7.

Trottier-Picard, A., E. Thiffault, A. DesRochers, D. Paré, N. Thiffault, and C. Messier. 2014. Amounts of logging residues affect planting microsites: A manipulative study across northern forest ecosystems. *Forest Ecology and Management* 312: 203-15.

Truax, B., D. Gagnon, J. Fortier, and F. Lambert. 2014. Biomass and volume yield in mature hybrid poplar plantations on temperate abandoned farmland. *Forests* 5 (12): 3107-30.

Truax, B., D. Gagnon, F. Lambert, and J. Fortier. 2015. Multiple-use zoning model for private forest owners in agricultural landscapes: A case study. *Forests* 6 (10): 3614-64.

Truax B, Gagnon D, Fortier J, Lambert F. 2012. Yield in 8 year-old hybrid poplar plantations on abandoned farmland along climatic and soil fertility gradients. *Forest Ecology and Management* 267: 228-39.

Uehling, J. K., T. W. Henkel, R. Vilgalys, and M. E. Smith. 2012. *Membranomyces* species are common ectomycorrhizal symbionts in northern hemisphere forests. *Mycorrhiza* 22 (7): 577-81.

Vandal, J., M.M. Abou-Zaid, G. Ferroni, L.G. Leduc. 2015. Antimicrobial activity of natural products from the flora of Northern Ontario, Canada. Pharmaceutical Biology 7p.

Vialle, A., N. Feau, P. Frey, L. Bernier, and R. C. Hamelin. 2013. Phylogenetic species recognition reveals host-specific lineages among poplar rust fungi. *Molecular Phylogenetics and Evolution* 66 (3): 628-44.

Vyse, A., M. R. Cleary, and I. R. Cameron. 2013. Tree species selection revisited for plantations in the interior cedar hemlock zone of southern British Columbia. *Forestry Chronicle* 89 (3): 382-91.

Wang, D., Jaiswal, D., Lebauer, D., Wertin, T., Bollero, G., Leakey, A., Long, S. 2015.A physiological and biophysical model of coppice willow (*Salix* spp.) production yields for the contiguous USA in current and future climate scenarios. *Plant, Cell and Environment* 38(9): 1850-65.

Wang Z, Du S, Dayanandan S, Wang D, Zeng Y, Zhang J. 2014. Phylogeny reconstruction and hybrid analysis of *Populus* (Salicaceae) based on nucleotide sequences of multiple single-copy nuclear genes and plastid fragments. *PloS One* 9(8): e103645.

WeiDan, Ding, A. Koubaa, and A. Chaala. 2013. Mechanical properties of MMA-hardened hybrid poplar wood. *Industrial Crops and Products* 46: 304-10.

WeiDan, Ding, A. Koubaa, and A. Chaala. 2012. Dimensional stability of methyl methacrylate hardened hybrid poplar wood. *Bioresources* 7 (1): 504-20.

WeiFeng, Wang, Peng ChangHui, D. D. Kneeshaw, G. R. Larocque, Song XinZhang, and Zhou XiaoLu. 2012. Quantifying the effects of climate change and harvesting on carbon dynamics of boreal aspen and jack pine forests using the TRIPLEX-management model. *Forest Ecology and Management* 281: 152-62.

Weir, Richard D., Mark Phinney, and Eric C. Lofroth. 2012. Big, sick, and rotting: Why tree size, damage, and decay are important to fisher reproductive habitat. *Forest Ecology and Management* 265 (02): 230.

Whiklo, Todd M., and James R. Duncan. 2014. Characteristics of barred owl (*Strix varia*) nest sites in Manitoba, Canada. *Canadian Field-Naturalist* 128 (1): 38-43.

White, P. J. T. 2013. Testing two methods that relate herbivorous insects to host plants. *Journal of Insect Science* 13 (92): 29.

Wiebe, K. L., and E. A. Gow. 2013. Choice of foraging habitat by northern flickers reflects changes in availability of their ant prey linked to ambient temperature. *Écoscience* 20 (2): 122-30.

Williams, M., L. Lowndes, S. Regan, and T. Beardmore. 2015. Overexpression of CYCD1;2 in activation-tagged *Populus tremula* x *Populus alba* results in decreased cell size and altered leaf morphology. *Tree Genetics and Genomes* 11 (4).

Wilson, Matthew J., Andrew S. Forrest, and Suzanne E. Bayley. 2013. Floristic quality assessment for marshes in Alberta's northern prairie and boreal regions. *Aquatic Ecosystem Health & Management* 16 (3): 288-99.

Winans, K., J. K. Whalen, A. Cogliastro, D. Rivest, and L. Ribaudo. 2014. Soil carbon stocks in two hybrid poplar-hay crop systems in southern Quebec, Canada. *Forests* 5 (8): 1952-66.

Winans, K. S., A. S. Tardif, A. E. Lteif, and J. K. Whalen. 2015. Carbon sequestration potential and cost-benefit analysis of hybrid poplar, grain corn and hay cultivation in southern Quebec, Canada. *Agroforestry Systems* 89 (3): 421-33.

Winder, R. S., J. Lamarche, C. Peter Constabel, and R. C. Hamelin. 2013. The effects of high-tannin leaf litter from transgenic poplars on microbial communities in microcosm soils. *Frontiers in Microbiology* 4: 290.

Wotherspoon, A., I. Mohammed, N. V. Thevathasan, A. M. Gordon, and R. P. Voroney. 2013. Carbon sequestration potential of a 27-year-old tree-based intercropping system in southwestern Ontario. In Poppy, L., Kort, J., Schroeder, B., Pollock, T. and Soolanayakanahally, R. (Eds.) Proceedings of the 13th North American Agroforestry Conference, June 19-21, 2013, Charlottetown, Prince Edward Island, Canada. p. 25-9. Available from University of Missouri Digital Library http://dl.mospace.umsystem.edu/mu/islandora/object/mu%3A90378#page/1/mode/2up.

Wotherspoon, Amy, Naresh Thevathasan, Andrew Gordon, and R. Voroney. 2014. Carbon sequestration potential of five tree species in a 25-year-old temperate tree-based intercropping system in southern Ontario, Canada. *Agroforestry Systems* 88 (4): 631-43.

Worrall, J. J., G. E. Rehfeldt, A. Hamann, E. H. Hogg, S. B. Marchetti, M. Michaelian, and L. K. Gray. 2013. Recent declines of *Populus tremuloides* in North America linked to climate. *Forest Ecology and Management* 299: 35-51.

Wu, Chaoyang, David Gaumont-Guay, T. Andrew Black, Rachhpal S. Jassal, Shiguang Xu, Jing M. Chen, and Alemu Gonsamo. 2014. Soil respiration mapped by exclusively use of MODIS data for forest landscapes of Saskatchewan, Canada. *ISPRS Journal of Photogrammetry & Remote Sensing* 94 (08): 80-90.

Xiao, He, A. Lau, Shahab Sokhansanj, J. Lim, and Bi XiaoTao. 2015. Application of a model to simulate the wetting and drying processes of woody biomass in the field. *Drying Technology* 33 (4): 434-42.

XiaoBang, Peng, N. V. Thevathasan, A. M. Gordon, I. Mohammed, and Gao PengXiang. 2015. Photosynthetic response of soybean to microclimate in 26-year-old tree-based intercropping systems in southern Ontario, Canada. *Plos One* 10 (6): e0129467-.

YaLin, Hu, Yan EnRong, Choi WooJung, F. Salifu, Tan Xiao, Z. C. Chen, Zeng DeHui, and S. X. Chang. 2014. Soil nitrification and foliar δ15N declined with stand age in trembling aspen and jack pine forests in northern Alberta, Canada. *Plant and Soil* 376 (1): 399-409.

Yan, Yang, Wang ShuSen, A. P. Trishchenko, Luo Yi, and Geng XiaoYuan. 2012. Variations of absorbed photosynthetically active radiation over the Canadian prairie in 2000-2008. *Journal of Agricultural Science* 4 (2): 57-68.

Yannikos, N., P. Leinweber, B. L. Helgason, C. Baum, F. L. Walley, and K. C. J. Rees. 2014. Impact of *Populus* trees on the composition of organic matter and the soil microbial community in orthic gray luvisols in Saskatchewan (Canada). *Soil Biology & Biochemistry* 70: 5-11.

Yemshanov, D., J. Biggs, D. W. McKenney, and T. Lempriere. 2012. Effects of permanence requirements on afforestation choices for carbon sequestration for Ontario, Canada. *Forest Policy and Economics* 14 (1): 6-18.

Young, Ian W. R., Christian Naguit, Sara J. Halwas, Sylvie Renault, and John H. Markham. 2013. Natural revegetation of a boreal gold mine tailings pond. *Restoration Ecology* 21 (4): 498-505.

YuQing, Yang, and Huang ShongMing. 2015. Two-stage ingrowth models for four major tree species in Alberta. *European Journal of Forest Research* 134 (6): 991-1004.

YuQing, Yang, and Huang ShongMing. 2013. On the statistical and biological behaviors of nonlinear mixed forest models. *European Journal of Forest Research* 132 (5): 727-36.

Zeen, Huang, and Yan Ning. 2014. Characterization of major components in barks from five Canadian tree species. *Wood and Fiber Science* 46 (2): 167-74.

Zhang, J., S. Huang, E. H. Hogg, V. Lieffers, Y. Qin, and F. He. 2014. Estimating spatial variation in Alberta forest biomass from a combination of forest inventory and remote sensing data. *Biogeosciences* 11 (10): 2793-808.