Activities Related to the Cultivation and Utilization of Poplars, Willows and other Fast-Growing Trees in Canada

CANADIAN REPORT TO THE 26TH SESSION OF THE INTERNATIONAL COMMISSION ON POPLARS AND OTHER FAST-GROWING TREES

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Activities Related to the Cultivation and Utilization of Poplars, Willows and other Fast-Growing Trees in Canada

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For:

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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, willows and other fast-growing trees. These fast-growing woody species 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 *Populus*, *Salix* and *Alnus* in Canada and elsewhere have indicated a great demand for plywood and pellet production, phytoremediation of marginal lands, dedicated bioenergy crops as well as biofuel conversion. As demand for fast-growing trees 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 stakeholders.

I am very pleased that the Council for Agricultural Research and Economics, Italy and FAO are actively engaged in organising the 26th session of the IPC on "*The role of Salicaceae and other fast-growing trees in sustainable wood supplies and climate change mitigation*".

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, Canadian Wood Fibre Centre without which production of this report would not have been possible.

I extend my good wishes for the success of this global meeting on fast-growing trees to serve our common challenges.

Sincerely,

Raju Soolanayakanahally

Chair, Poplar and Willow Council of Canada

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I. POLICY AND LEGAL FRAMEWORK

1. Introduction

Jurisdiction over forestry, agriculture and environmental policy in Canada mainly rests with the provinces. The provinces have constitutional authority for most laws, policies and regulations affecting natural resources like forests and determine land use priorities, grant logging licensces and set harvest levels. The Federal government is responsible for transboundary issues like migartogry birds, fish and fisheries and for international environment and trade agreements. Responsibility for resource issues is being devolved to the three northern territories (Yukon Territory, Northwest Territories and Nunavut.

Most of Canada's forest land – approximately 90%, accounting for 85% of the annual wood harvested – is publicly owned (called 'Crown Land") by the provinces and territories. Timber supply agreements are made with forest companies who must abide by forest management plans agreed to with the Provinces. Forest management plans commit the companies to manage sustainably the forests according to provincial or territorial laws, regulations and policies. The companies pay royalties for the use of the land and the wood supply from it.

The degree to which poplars and willows are used or managed on Crown lands depends on the companies' business plans, their manufacturing processes and the forest management plans. Other industrial or economic activities on Crown land (grazing or other agriculture uses, mining, infrastructure such as roads, power lines, pipelines, etc.) also must be approved by the province or territory.

Many forest companies also voluntarily have their forest management practices certified the Forest Stewardship Council (FSC) and/or the Sustainable Forestry Initiative (SFI). These internationally recognized standards, in some cases may be additional to those agreed to with the respective provinces in the forest management agreements (The State of Canada's Forests Annual Report 2018).

Privately owned land accounts for about 6% of forest land nationally, but accounts for almost 15% of the national wood harvest. Landowners, as long as they abide by applicable provincial and federal laws, such as those that protect waterways, can make their own decisions about the planting or management of trees on their land.

The remainder of forest land is administered by the federal government. It includes land held on behalf of aboriginal peoples and for national parks, national defence and other purposes. Less than 1% of the wood harvested nationally is from federal land.

No particular federal or provincial regulations seek to increase the use of poplars or willows on Crown or private land. The planting of introduced poplars or willows and hybridized or selected clonal material on Crown land is discouraged in many provinces because provincial governments generally regard their Crown land forests as natural preserves in which, although the forests can be harvested sustainably, their natural ecology should be preserved as much as possible. Nevertheless, according to Rivera et al (2016), "six out of ten Canadian provinces do not have specific legislations to control the use of exotic tree species for reforestation within their borders"[1]. On private land, there are fewer regulations

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[1] Rivera, B., Barrette, M., and Thiffault, N. 2016. Issues and perspectives on the use of exotic species in the sustainable management of Canadian forests. Reforesta 1: 261-280.

restricting the use of selected clonal varieties of poplar or willow. Private land plantations of poplar or willow, like other agricultural production, must comply with federal and provincial regulations that apply, especially those that seek to protect fish bearing habitat.

Most harvested poplar in Canada is trembling aspen (*Populus tremuloides*), which grows naturally on the Boreal Plain and the Boreal Shield ecozones, mostly on the southern fringe of the boreal forest[2]. It often grows in association with balsam poplar (*Populus balsamifera*). Both species occur naturally, from Newfoundland to the Yukon Territory. They are harvested commercially, mainly for pulp or oriented strandboard (OSB) and, to a much smaller extent for sawn wood for pallets, containers or fuelwood. Aspen forests naturally regenerate through regrowth of from root suckers. Thus, it is not necessary to replant harvested aspen stands.

The volume of poplar (balsam poplar and trembling aspen) harvested varies by province/territory (Table 1). It is directly related to the proportion of the natural forest in each province that includes poplar in its compostion and the developemnts of industries to utlize it.

Willow species are not currently considered commercial forest hardwood species and are not harvested on Crown Land as such. The degree to which they are used cannot be determined from the National Forest Database but the harvest of willow is likely negligible. Willows occur naturally, largely, in wetlands (lotic or lentic) and are thus protected by laws that protect riparian zones and are not harvested in such areas.

Complexities arise around the susutianble manangment of poplar when provincially owned Crown Lands are used for agricultural purposes – usually for grazing. Where lands have value for both commercial wood production and as pasture, provinces must devise regulations that allow both livestock producers and forest industries to use land to their mutual benefit. This arises particularly in the interior of British Columbia where the provincial Agroforestry Unit works with ranchers and forest companies to devise mutually beneficial silvopastoral sysytems. These joint use sysytems do not often involve poplars.

Poplar or willow hybrids are generally grown on privately owned agricultural lands, rather than on forested Crown Lands. The production and harvest of these trees for industrial products (wood, bioenenrgy or other commercial purposes) is generally not affected by federal or provincial regulations.

When poplar and willow are grown for purposes such as phytoremediation or riparian protection, there are usually additional regulations or restrictions – especially provincial regulations for the safe management of landfill sites, municipal effluent, industrial sites and other areas that may contain water or other substances considered hazardous to human health or to the environment.

[2] Government of Canada. National Forest Inventory. https://nfi.nfis.org/en/data_and_tools (Accessed January 25, 2020)

Table 1. Harvested volumes for 2017 by province/territory for softwoods/hardwoods/poplars

	Harvested volumes in 2017 (m^3 in 1000s)		
	Softwoods	Hardwoods	Poplars
British Columbia	62,587	1,771	1,523
Alberta	17,510	9,615	9,269
Saskatchewan	1,432	2,457	2,309
Manitoba	929	421	396
Ontario	12,110	3,705	2,742
Quebec	21,560	8,454	3,212
New Brunswick	6,212	3,135	596
Nova Scotia	2,638	655	59
Prince Edward Island	95	248	47
Newfoundland/Labrador	1,036	97	88
Yukon Territory	16	0	0
Northwest Territories	38	1	1
Nunavut	0	0	0
TOTAL	126,163	30,559	20,242

2. Canadian National Laws and Policies

The Government of Canada conducts forestry-based research through Natural Resources Canada (NRCan) and agriculture-based research through Agriculture and Agri-Food Canada (AAFC) and environmental research through Environment and Climate Change Canada (ECCC). Much collaborative research is done by scientists in these departments (see Section III.2. Relevant Literature).

The Government of Canada works in partnership with provinces in forestry, agriculture and the environment. In 2017, the Canadian Council of Forest Ministers (CCFM) published "A Forest Bioeconomy Framework for Canada"[3], which included: "Potential forest biomass comes from a variety of sources such as sustainable wood supply and biomass plantations (e.g., fast-growing willow species) …

[3] Canadian Council of Forest Ministers (CCFM). 2017. A Forest Bioeconomy Framework for Canada. 30pp. https://cfs.nrcan.gc.ca/publications?id=39162

Private woodlot owners can offer flexibility and innovative approaches to supplying fibre as well as offering long term supply contracts."

The "Federal Sustainable Development Act"[4], passed in 2008, includes an intergovernmental "Sustainable Development Advisory Council". The resulting 2016-2019 Federal Sustainable Development Strategy sets out Canada's sustainable development priorities, which are linked to the United Nations "2030 Agenda for Sustainable Development" - particularly SDG 7 (affordable and clean energy), SDG 13 (climate action), SDG 14 (life below water) and SDG 15 (life on land).

Canada joined 194 other countries in the December 12, 2015, Paris Agreement to fight climate change. Its follow-up "Mid-century Strategy" delivered to the UN Framework Convention on Climate Change (UNFCCC) in late 2016, included the following: "Various levels of afforestation using mixes of fast-growing species and slower-growing species could be used."[5]

A particular federal government commitment currently under development is the public pronouncement by Prime Minister Justin Trudeau, made in the fall of 2019 that Canada would undertake to plant 2 billion trees from 2020 to 2030[6].

Programs derived from such national and international frameworks and strategies have a direct effect on the use of poplars and willows in Canada. For example, a $5 million investment through the NRCan-administered Investments in Forest Industry Transformation (IFIT) program, helped Louisiana-Pacific convert its oriented strandboard (OSB) mill in Minitonas, Manitoba, supplied by trembling aspen from natural stands, to produce "Smartside" exterior siding using the same aspen supply[7]. At the landowner level, Forests Ontario's 50 Million Tree Program received funding support from the Government of Canada to help landowners in Ontario plant poplars, willows and other species on their farms and other landholdings for shelter, afforestation, riparian protection and other uses.[8]

Through these and other funding programs and initiatives focused on climate change, environmental sustainability and the development of new products and processes – whether through Natural Resources Canada[9], or other federal departments, the Government of Canada encourages the planting, harvesting and utilization of poplars and willows. An opportunity for agroforestry research/application

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[4] Government of Canada. 2013. Federal Sustainable Development Act (S.C. 2008, c. 33) 16pp https://laws-lois.justice.gc.ca/eng/acts/f-8.6/

[5] Government of Canada. 2016. News Release: Canada submits Mid-Century Strategy for a Clean Growth Economy. https://www.canada.ca/en/environment-climate-change/news/2016/11/canada-submits-century-strategy-clean-growth-economy.html

[6] Kuitenbrouwer, Peter, 2019. Planting two billion trees in Canada will be a tall order – Op-ed article: Special to the Globe and Mail. Publ. Nov. 29, 2019.

[7] The Valley Online. 2015. Ribbon Cutting Held For LP Siding Conversion. http://swanriver.valleybiz.ca/news/2015/09/24/ribbon-cutting-held-for-lp-siding-conversion/(accessed Feb 24, 2020); Government of Canada – Canadian Forest Service. 2017. Investments in Forest Industry Transformation (IFIT) – Performance Report 2015–2016. 40 p. https://cfs.nrcan.gc.ca/publications?id=38854

[8] Forests Ontario. 50 Million Tree Program https://www.forestsontario.ca/planting/programs/50-million-tree-program/ (accessed Feb 24, 2020).

[9] Natural Resources Canada. https://www.nrcan.gc.ca/funding-grants-incentives/4943(accessed Feb 24, 2020).

may be found in a new program by Agriculture and Agri-Food Canada is the Living Laboratories Initiative, which will commence in 2020[10] and be similar in concept to the European Network of Living Labs[11].

Although jurisdiction for forestry and agriculture rests mainly with the various provinces, these are considered shared jurisdictions. The Government of Canada, by making international agreements, creating national legislation, conducting research, collaborating with provinces and by funding industries and other organizations, can have a significant effect on the planting and use of poplars, willows and other fast-growing tree species.

3. British Columbia

British Columbia (BC) is the most heavily forested province in Canada. Of the 157 million m^3 of total wood volume harvested from forests in Canada in 2016, 66 million m^3 (42%) came from BC[12]. Crown land forests accounted for 79% of BC's 2017 harvest. However, hardwoods comprise only 2.5% of BC's annual harvest. About 85% of the hardwood harvested in BC consists of poplar (aspen and cottonwood)[13] with the remainder being alder, birch and maple. From 2015 to 2019, red alder (*Alnus rubra*), harvested in BC's coastal regions, made up over 9% of the hardwood harvest[14].

In BC, the 2002 Forest and Range Practices Act (Chapter 69)[15] governs the use of provincially owned Crown land and sets criteria for Forest Stewardship Plans and Woodlot Licence Plans. Although BC allows for selected poplars to be planted on Crown land for research or demonstration purposes, clonal poplar plantings are limited to a maximum of 10 hectares[16]. The question has also been raised by Rivera et al. (2016) as to whether hybrid poplar should be allowed on or near native forests due to a concern about genetic spread[17].

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[10] Agriculture and Agri-Food Canada. https://www5.agr.gc.ca/eng/science-and-innovation/living-laboratories-initiative/?id=1551383721157 (accessed Feb 24, 2020).
[11] European Network of Living Labs. https://enoll.org/about-us/ (accessed Feb 24, 2020).
[12] Government of Canada - NRCan. 2018. The State of Canada's Forest – Annual Report 2018 https://www.nrcan.gc.ca/our-natural-resources/forests-forestry/state-canadas-forests-report/16496 (accessed February 24, 2020).
[13]Government of British Columbia – Forest Analysis and Inventory Branch 2008. Reporting British Columbia Forest Resource and Its Changes from the National Forest Inventory PhotoPlot Database. https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/stewardship/forest-analysis-inventory/inventory-analysis/provincial-monitoring/nfi_changes_photoplot_2008.pdf (accessed February 24, 2020)
[14] Fong, Edward – pers. comm. – Excel spreadsheet of scaled harvest by species 2015-2019
[15] Government of British Columbia. 2002. Forest and Range Practices Act – Chapter 69. http://www.bclaws.ca/civix/document/id/complete/statreg/02069_01#division_d2e18760 (accessed February 24, 2020).
[16] Zabek, Lisa – pers. comm.; Doornbos, J., Richardson, J, van Oosten, C. 2016. Activities related to poplar and willow cultivation and utilization in Canada 2012-2015. Poplar and Willow Council of Canada Publication.
[17] Rivera, B., Barrette, M. Thiffault, N. 2016. Issues and perspectives on the use of exotic species in the sustainable management of Canadian forests. Reforesta 1: 261-280; Derbowka, Dave - pers. comm.

The Government of British Columbia continues to support an Agroforestry Unit in the Ministry of Agriculture[18], which partners with the Federation of British Columbia Woodlot Associations[19]. There are regulatory considerations for the planting of poplars or willows on land classified as agricultural since the BC Assessment Authority specifies that "Only fast-growing cottonwood/poplar/aspen and willow cultivated in planting will qualify as long as they mature within 12 years."[20] This has tax implications for landowners[21]. Shelterbelts are not affected by this 12-year limitation, regardless of species composition, because they are considered to be agriculture infrastructure plantings. The use of hybrid poplar for phytoremediation projects in BC presents additional requirements, including the need for liability insurance[22].

4. Alberta

Over 96% of the hardwood component of Alberta's harvest is poplar (81.3% trembling aspen; 15.1% balsam poplar)[23]. Over 81% of the poplar harvested comes from provincial Crown land[24].

The annual allowable cut on Crown land is set by the Alberta government and is more than 12 million m^3 for hardwoods[25]. The 7.8 million m^3 harvested from Crown lands in 2017 are well below this number, indicating that Alberta's hardwood resources are not being overharvested.

In Alberta, there are 26 sawmills, 4 pulp mills, 9 mills making panels and engineered wood products, and 4 integrated mills. Alberta aspen and balsam poplar are used mainly for oriented strandboard (OSB) and pulp. Poplar, as sawnwood, is used mainly for making pallets and containers[26].

The Province of Alberta classifies land as the "White Area" (intensively managed and privately owned agricultural or urban land) and the "Green Area" (extensively managed and mostly forested Crown land). Forest Management Agreements in the Green Area between the Province of Alberta and the various

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[18] Government of British Columbia. https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/agricultural-land-and-environment/agroforestry

[19] https://woodlot.bc.ca/ (accessed February 24, 2020).

[20] Government of British Columbia – BC Assessment. Farm Classification in British Columbia. 32pp. https://info.bcassessment.ca/services-and-products/_layouts/15/WopiFrame.aspx?sourcedoc=/services-and-products/Shared%20Documents/BCAL15102%20BCA_farm_brochure_digital.pdf&action=default&DefaultItemOpen=1 (accessed February 24, 2020).

[21] Derbowka, Dave – pers. comm.

[22] Derbowka, Dave – pers. Comm.

[23] Government of Alberta - Alberta's Forest Products Buyers' Guide. 50pp. https://www.alberta.ca/assets/documents/AB-Forest-Products-Buyers-Guide-ENGLISH.pdf (accessed February 24, 2020).

[24] Canadian Council of Forest Ministers. National Forestry Database. http://nfdp.ccfm.org/en/index.php (accessed February 24, 2020).

[25] Government of Alberta - Alberta's Forest Products Buyers' Guide. 50pp. https://www.alberta.ca/assets/documents/AB-Forest-Products-Buyers-Guide-ENGLISH.pdf (accessed February 24, 2020).

[26] Government of Alberta - Alberta's Forest Products Buyers' Guide. 50pp. https://www.alberta.ca/assets/documents/AB-Forest-Products-Buyers-Guide-ENGLISH.pdf (accessed February 24, 2020).

forest companies prohibit the planting of non-native species, such as hybrid poplar or non-native willows, on its Crown lands. Clonal material of native species, to a maximum of 5,000 plants per clone, may be planted on Crown land as long as it is a locally collected, naturally occurring species (i.e. balsam poplar, trembling aspen or other species)[27]. The agreements also specify the buffer widths for various riparian areas (rivers, streams, wetlands and lakes)[28]. This limits the degree to which species associated with riparian zones, such as willows, can be harvested.

Alberta-Pacific Forest Products of Boyle, Alberta, a pulpmill primarily using poplar is among other forest industries in Canada that are Forest Stewardship Council (FSC) – certified[29]. FSC criteria are stringent with respect to environmental management of forests and address many aspects of environmental stewardship and sustainability.

Government of Alberta programs such as Alberta Innovates[30] and Emission Reductions Alberta[31] provide funding for projects that seek to diversify the province's economy or reduce its net greenhouse gas emissions. By 2030, the province plans to discontinue the use of coal for energy within the province. This may encourage the use of poplars and willows for bioenergy. There may also be an increased demand for poplars and willows for the revegetation and reclamation of coal mine sites (see Section II.6.a. Phytoremediation Projects and Initiatives).

5. Saskatchewan

Harvested hardwood in Saskatchewan was 2,457 thousand m^3, 63% of the total wood harvested in the province. Trembling aspen (83%) and balsam poplar (11%) account for almost all (94%) of the hardwood harvested [32]. Almost all wood harvested in Saskatchewan comes from Crown land[33].

Management of forests on Saskatchewan Crown land is regulated through the Forest Resources Management Act, Forest Resources Management Regulations and the Saskatchewan Environmental Code.[34] Forest companies sign 20-year Forest Management Agreements with the Government of Saskatchewan whereby they acquire long-term harvesting rights as well as responsibilities for sustainable forest management. Although these documents do not address particular species, the regulations say that "No person shall introduce … any exotic plant ... on any provincial forest land." However, "… a person may be granted a licence to conduct research activities involving the introduction

[27] Government of Alberta. 2009. Alberta Genetic Resource Management and Conservation Standards. ISBN 978-0-7785-8466-7. 126 pp. https://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/formain15749/$file/FGRMS-GeneticConservationStandards-2009.pdf?OpenElement

[28] Kamelchuk, Dave – pers. comm.

[29] Forest Stewardship Council (FSC). https://ca.fsc.org/en-ca (accessed February 24, 2020); Dave Kamelchuk Pers. Comm.

[30] Alberta Innovates. https://albertainnovates.ca/ (accessed February 24, 2020).

[31] Emissions Reduction Alberta. https://www.eralberta.ca/ (accessed February 24, 2020).

[32] Government of Saskatchewan, 2019, Saskatchewan Forest Product Buyers' Guide. 30pp.

[33] Canadian Council of Forest Ministers. National Forestry Database. http://nfdp.ccfm.org/en/data/harvest.php (accessed February 24, 2020).

[34] Canadian Council of Forest Ministers. Sustainable Forest Management in Canada - Province of Saskatchewan https://www.sfmcanada.org/images/Publications/EN/SK_info_Provinces_and_territories_EN.pdf (accessed February 24, 2020).

and propagation of exotic plants on provincial forest land."[35] Thus, commercial plantations of hybrid poplar or willows, unless they are native to Saskatchewan, are limited to agricultural or other private land.

On private land, there are no restrictions on the use of poplars or willows throughout the province. There has been research and program support for their use through federal and provincial sources as well as partnerships and collaboration with industry, universities and landowners. The planting of hybrid poplar and willows in shelterbelts in the past was supported by stock (mostly rooted cuttings) and expertise from the Agriculture and Agri-Food Canada Agroforestry Development Centre at Indian Head, Saskatchewan (closed in 2014). The Saskatchewan Forestry Centre at Prince Albert (closed in 2009) actively provided support, over an 8-year period, for the planting of hybrid poplar in plantations for industrial and other purposes. The University of Saskatchewan's Centre for Northern Agroforestry and Afforestation[36] conducted trials and research in Meadow Lake and other Saskatchewan sites and the Saskatchewan Research Council collaborated in many poplar/willow related projects. A notable research/demonstration site is at the Saskatchewan Conservation Learning Centre (53.023˚N; -105.769˚W)[37] which has research/demonstration plantings of alley-cropping, a balsam poplar common garden of genetic resources from all across North America, a hybrid willow demonstration/trial, a poplar/willow biomass trial and a hybrid poplar clonal trial.

Genetic testing and selections of both poplar and willow were also done by the AAFC Agroforestry Development Centre and a poplar breeding program resulted in several improved poplar clones that were used in shelterbelts and poplar plantations.

6. Manitoba

Manitoba's 2017 wood harvest (1,350 thousand m^3), reported to the National Forest Database, was entirely from Crown land. The hardwood component of that (421 thousand m^3) was mainly trembling aspen (94%), while the remainder was balsam poplar and white birch[38]. As for other provinces, forest companies operate in Crown forests under provincially approved Forest Management Plans. Manitoba considers the long-term sustainable level of hardwood harvest in the areas currently being utilized to be 1,037 thousand m^3, while the provincial total, including areas not currently utilized is estimated at 2,708 thousand m^3.[39]

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[35] Government of Saskatchewan. F-19.1 Reg 1 - The Forest Resources Management Regulations https://publications.saskatchewan.ca/#/products/1124 (accessed February 24, 2020)

[36] Centre for Northern Agroforestry and Afforestation – University of Saskatchewan http://www.saskagroforestry.ca/news.php (accessed February 24, 2020)

[37] Saskatchewan Conservation Learning Centre. http://www.conservationlearningcentre.com/Home.aspx (accessed February 24, 2020)

[38] Canadian Council of Forest Ministers. National Forestry Database. http://nfdp.ccfm.org/en/data/harvest.php (accessed February 24, 2020)

[39] Government of Manitoba - Department of Sustainable Development: Five-Year Report on the Status of Forestry April 2011 – March 2016. 56pp – p25 https://www.gov.mb.ca/sd/pubs/forest_lands/5yr_report.pdf (accessed February 24, 2020)

The Government of Manitoba, in the period 2008-2012, ran the “Trees For Tomorrow” program, under which 6,234,100 trees were planted, mostly on private land[40]. Pine, spruce, willow and hybrid poplar were provided to the public, schools, First Nations, industries and municipal governments. Shelterbelts, woodlots, and new plantations were established on farmland and other lands throughout rural and urban Manitoba. These new trees will help sequester carbon, reduce soil erosion and help support native wildlife.

The Manitoba Forestry Association provides seedlings and rooted cuttings to private landowners, schools and environmental groups in rural or urban settings. Poplars and willows were among the 98 thousand seedlings distributed to landowners across Manitoba and northwestern Ontario in 2017[41].

In February, 2019, the Province of Manitoba closed and sold its provincial forest nursery at Hadashville, Manitoba, expecting private nurseries to supply the required tree seedlings for future plantings on private land[42]. As Manitoba’s conservation districts had difficulty accessing the species/clones that they required for their projects, some foresters began to access materials from the United States (North Dakota – Lincoln-Oakes Nursery)[43] On January 1, 2020, Manitoba’s 18 conservation districts were reorganized into 14 watershed districts with the proclamation of the Watershed Districts Act[44]. Manitoba Agriculture provides funding to these districts[45] through the Ag Action Manitoba Program to provide/protect Watershed Ecological Goods and Services[46]. The program provides funding to conservation districts to work with farmers to implement practices that conserve and enhance ecological goods and services (EGS) on the agricultural landscape and it includes provisions for financial support for tree planting projects.

As with farming in Saskatchewan and Alberta, current large-scale precision farming is based on large field machinery traveling in straight lines. This has resulted in the clearing of small copses of trees and shrubs (mostly aspen and willow) that would otherwise impede or cause more turning by these machines. Also, as with other agricultural areas in Canada, widespread use of tile drainage in Manitoba’s Red River Valley and other regions has also resulted in the removal of trees – either native trees or planted shelterbelts – whose roots might invade the drainage tiles[47].

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[40] Government of Manitoba - Department of Sustainable Development: Five-Year Report on the Status of Forestry April 2011 – March 2016. 56pp – p33 https://www.gov.mb.ca/sd/pubs/forest_lands/5yr_report.pdf (accessed February 24, 2020)

[41] Manitoba Forestry Association Annual Report 2017. 27pp https://www.thinktrees.org/wp-content/uploads/2019/11/2017-Book-of-Reports.pdf (accessed February 24, 2020)

[42] CBC News Feb 22, 2019. New hemp company buys Manitoba's Pineland Forest Nursery, plans to become major cannabidiol producer. https://www.cbc.ca/news/canada/manitoba/botanist-organic-hemp-cbd-pineland-1.5030508

[43] English, Blair – pers. comm.

[44] Manitoba Association of Watersheds. January 7, 2020. Manitoba’s conservations districts renamed watershed districtswith new tools to protect our watersheds. https://manitobawatersheds.org/news/manitobas-conservation-districts-renamed-watershed-districts (accessed February 24, 2020)

[45] Manitoba Association of Watersheds. https://manitobawatersheds.org/ (accessed February 24, 2020)

[46] Government of Manitoba. Financial Assistance - Ag Action Manitoba Program https://www.gov.mb.ca/agriculture/environment/ecological-goods-and-services/watershed-egs.html (accessed February 24, 2020)

[47] English, Blair – pers. comm.

7. Ontario

Poplar (trembling aspen and balsam poplar) constitutes approximately 74% of the hardwood harvested in Ontario in 2018 and 13% of the total wood harvested[48]. The other main hardwood species is white birch. Eight percent of Ontario's hardwood harvest was from private land in 2017. Because the more southern, mostly agricultural Mixedwood Plains have a relatively greater proportion of hardwoods, especially the more valuable oaks and maples, private land hardwood harvest is proportionally greater in southern Ontario.

Ontario grants Crown harvesting rights to forest companies under Sustainable Forest Licences, by which the companies agree to manage and harvest the forest land under agreed-to management plans, including replanting or maintenance of harvested lands. Most of this Crown land is in the Boreal Shield ecozone, in which trembling aspen constitutes the major hardwood species.

Many trees are planted, maintained or harvested on the predominantly agricultural or otherwise privately owned land in the Mixedwood Plains[49]. Landowners can qualify for support under the 50 Million Tree Program, administered by Forests Ontario. Until recently, this program was funded by the Government of Ontario, but is now funded by the Government of Canada until 2023[50]. The jurisdictions of Ontario's 36 conservation authorities include most of the land in the Mixedwood Plains and the conservation authorities have tree-planting projects for agriculture, urban, recreation and conservation purposes[51]. For example, the Grand River Conservation Authority plants about 150 thousand trees per year, of which about 20% are poplars or willows[52]. Funding for tree-planting projects also come from sources other than the 50 Million Tree Program, including purchase of the seedlings by the landowners and the internal revenue generated by the parks operated by the conservation authorities[53]. The conservation authorities also have responsibility for regulating development activities that affect riparian areas according to federal, provincial and municipal laws and policies[54].

8. Québec

Poplar (trembling aspen) constitutes approximately 30% of the hardwood component of Québec's Annual Allowable Cut (1999 data) and 38% of the hardwoods actually harvested in 1999[55]. The other hardwood species consist primarily of maple and birch species. About 20% of Québec's total wood harvest in 2017 was from private land, but 42% of the provincial hardwood harvest was from private

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[48] Government of Ontario, Analysis of Regional Wood Supply. https://data.ontario.ca/dataset/analysis-of-regional-wood-supply (accessed February 25, 2020)

[49] Government of Canada. National Forest Inventory. https://nfi.nfis.org/en/data_and_tools (Accessed January 25, 2020)

[50] Forests Ontario. 50 Million Tree Program. https://www.forestsontario.ca/planting/programs/50-million-tree-program/ (Accessed January 25, 2020)

[51] Conservation Ontario. https://conservationontario.ca/ (Accessed January 25, 2020)

[52] Wu-Winter, Ron - pers. comm.; Grand River Conservation Authority. https://www.grandriver.ca/en/index.aspx (Accessed January 25, 2020)

[53] Wu-Winter, Ron; Enright, John - pers. comm.

[54] Wu-Winter, Ron; Enright, John; Shaw, Steve - pers. comm.; Grand River Conservation Authority. Planning and development. https://www.grandriver.ca/en/Planning-Development/Planning-and-Development.aspx

[55] Government of Quebec, 1999, Quebec's Forest Resources and Industry – A Statistical Report.

land[56]. This is because much of the southerly Mixedwood Plains ecozone and a significant proportion of the mixed forest of the Atlantic Maritime ecozone is private land. These ecozones in southern Québec contain a greater percentage of valuable hardwood, like maple and oak, than the Crown lands, which are predominantly in the Boreal Shield to the north.

The Sustainable Forest Development Act governs the harvest and use of wood and management of forests in Québec[57]. The "Regulation respecting standards of forest management for forests in the domain of the State" (RSFM) sets out almost 400 standards designed to protect the Crown land forests. Industries must have approved General Forest Management Plans (GFMPs) which incorporate the RSFM regulations[58]. Additional standards are set by forest certification organizations – primarily the Forest Stewardship Council (FSC) and the Sustainable Forest Institute (SFI). Domtar and other forest companies have their operations certified by one or both of these organizations.

The Government of Québec Ministry of Energy and Resources initiated a hybrid poplar breeding and selection program in 1969, with testing of clonal material throughout Québec[59]. A 2008 Green Paper produced for the Ministry of Natural Resources and Wildlife recommended the designation of "intensive silviculture zones" in which fast-growing trees like hybrid poplar and hybrid larch could be grown in pure stands, with the benefit of reducing harvesting pressure on sensitive ecological zones. This would result in a "Triad" system of forest management, consisting of intensive silviculture forests, protected areas and ecosystemic management areas[60].

Some of the poplar plantations by various companies in Québec have been on Crown land[61] but most poplar plantations have been established on private land for sawlogs or pulpwood. Private land poplar plantations that are grown over a longer rotation for roundwood are not considered to be an agricultural crop, while short-rotation poplars and willows (i.e. grown for bioenergy or other purposes), are recognized by the Government of Québec as agricultural crops.

9. New Brunswick

Forestry land in New Brunswick consists of Crown land, privately owned industrial forest lands and private woodlots. Hardwoods constituted 40% of New Brunswick's total harvest in 2017, mainly consisting of maple and birch. Poplar (trembling aspen and largetooth aspen) accounted for 19% of the

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[56] Canadian Council of Forest Ministers. National Forestry Database. http://nfdp.ccfm.org/en/index.php (accessed February 24, 2020).

[57] Government of Quebec,. Sustainable Forest Development Act. http://legisquebec.gouv.qc.ca/en/ShowDoc/cs/A-18.1 (Accessed January 25, 2020)

[58] Government of Quebec. Québec's Forest System. https://mffp.gouv.qc.ca/english/forest/understanding/understanding-system.jsp (Accessed January 25, 2020)

[59] Réseau ligniculture Québec. Poplar. http://www.rlq.uqam.ca/populiculture_en.php (Accessed January 25, 2020)

[60] Government of Quebec. 2008. Forests: Building a future for Quebec. ISBN 978-2-550-52051-1 74pp.

[61] Doornbos, J., Richardson, J. and van Oosten, C. 2016. Activities related to poplar and willow utilization in Canada 2012-2015 p19.

hardwoods harvested and 7% of the total wood supply[62]. The total harvested area in 2017 was 80.1 thousand ha.

Crown forests in New Brunswick make up 70% of the forest land that is annually harvested. These forests are harvested by companies under Forest Management Agreements that include specific Forest Management Plans[63]. Under the province's Forest Act, planting of non-native trees, such as hybrid poplar is prohibited on provincially owned Crown lands.

Private woodlots, as defined in New Brunswick's Forest Products Act[64], account for 30% of the province's forests or 1.9 million hectares. Through the voluntary Private Woodlot Silviculture Program, the provincial government partners with woodlot owners by providing 90% funding for silviculture treatments (site preparation, planting, weed management and thinning), with the intent of producing more valuable wood products sooner. Woodlot owners must meet certain criteria, including compliance with all applicable legislation, including laws dealing with water bodies, forest fires and pesticide applications. In addition, eligible projects must follow Best Management Practices according to "A Practical Guide to BMP's in New Brunswick Private Woodlots" and take into consideration, adaptation to climate change: "Building Capacity of New Brunswick Woodlot Owners to Adapt to Climate Change."[65]

Planting of trees on private land is not controlled and may include poplar or willows according to the landowner's decisions. Private land forests must, however, follow provincial and federal regulations to protect the environment, especially pertaining to wetlands and watercourses[66].

10. Prince Edward Island

Of the wood harvested annually on Prince Edward Island (PEI), 96% comes from private land[67]. Of the island's total area of 568,600 hectares, forests occupy 263,000 hectares and 86% of this is privately

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[62] Canadian Council of Forest Ministers. National Forestry Database. http://nfdp.ccfm.org/en/index.php (accessed February 24, 2020).
[63] Government of New Brunswick, 2014. Forest Management Manual for New Brunswick Crown Lands 26pp https://www2.gnb.ca/content/dam/gnb/Departments/nr-rn/pdf/en/ForestsCrownLands/ScheduleE_FMM_En.pdf
[64] Government of New Brunswick. 2012. Forest Products Act https://www.canlii.org/en/nb/laws/stat/rsnb-2012-c-105/latest/rsnb-2012-c-105.html (Accessed January 25, 2020)
[65]Government of New Brunswick. 2019, Private Woodlot Silviculture Program 2019-2020 https://www2.gnb.ca/content/dam/gnb/Departments/nr-rn/pdf/en/ForestsCrownLands/WoodlotSilvicultureManual.pdf (Accessed January 25, 2020)
[66] Bourgoin, Anthony – pers. comm.
[67] Canadian Council of Forest Ministers. National Forestry Database. http://nfdp.ccfm.org/en/index.php (accessed February 24, 2020).

owned.[68] The hardwood harvest constituted 84% of the total wood harvest in 2017, with the majority of that being red maple (*Acer rubrum*)[69]. Poplar constitutes about 10-20% of the PEI's hardwood harvest.

Although the Government of PEI encourages the use of biomass for energy, woody biomass from willow or poplar has not yet been a major practice. A pilot/research project to protect riparian areas on agricultural land with selected willow clones has been on-going but riparian buffer widths of 15 m legislated by the provincial government apply to agricultural and forest lands alike and mean that only willows planted more than 15 m from the water's edge can be harvested (see Section II.6.b. - Riparian and Streambank Protection).

11. Nova Scotia

Private land forestry is dominant in Nova Scotia (71% of total wood harvested in 2017). Hardwoods account for 20% of the total harvest (655 thousand m^3). Merchantable hardwood in Nova Scotia consists mainly of maple and birch with aspen poplar accounting for only 9% of all hardwoods and 3.5% of the total wood supply[70].

Riparian buffer zones in Nova Scotia, in which wood harvesting is not permitted, are fixed at 20 metres on both Crown and privately owned forest land by the Wildlife Habitat and Watercourse Protection Regulations[71]. This limits the degree to which species associated with riparian zones are available for harvest (i.e. willows, balsam poplar).

Although fast-growing plantations occur on both private and Crown land, the species used are native softwoods (spruce or pine). Nova Scotia recently adopted a "Triad" system of forest management which categorizes three forest zones – high-production forest, protection forest, and the ecological matrix[72]. A review is currently being conducted on the nature of "High-Production Forestry" but this deals only with fast-growing native softwoods[73].

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[68] Government of Nova Scotia. Wildlife Habitat and Watercourses Protection Regulationshttps://novascotia.ca/natr/wildlife/habitats/protection/ (Accessed January 25, 2020); Government of Prince Edward Island. 2002. State of the Forest Report. 1990 – 2000 https://www.princeedwardisland.ca/sites/default/files/publications/2000_state_of_the_forest_report.pdf (Accessed January 25, 2020)

[69] Government of Prince Edward Island. 2002. State of the Forest Report. 1990 – 2000. https://www.princeedwardisland.ca/sites/default/files/publications/2000_state_of_the_forest_report.pdf (Accessed January 25, 2020)

[70] Townsend, Peter, 2004, Nova Scotia Forest Inventory Based on Permanent Sample Plots Measured between 1999 and 2003 Report FOR 2004 – 3.

[71] Lahey, William. 2018. An Independent Review of Forest Practices in Nova Scotia: Executive Summary - Conclusions and Recommendations. https://novascotia.ca/natr/forestry/Forest_Review/Lahey_FP_Review_Report_ExecSummary.pdf (Accessed January 25, 2020)

[72] Lahey, William. 2018. An Independent Review of Forest Practices in Nova Scotia: Executive Summary - Conclusions and Recommendations. https://novascotia.ca/natr/forestry/Forest_Review/Lahey_FP_Review_Report_ExecSummary.pdf (Accessed January 25, 2020)

[73] Government of Nova Scotia. 2019. High-Production Forestry (Leg of the Triad). https://novascotia.ca/natr/forestry/Forest_Review/docs/06252019/June_25_High_Production_Forestry

12. Newfoundland and Labrador

The forest industry in Newfoundland and Labrador is small compared to some of the other provinces with just over 1 million m^3 harvested in 2017, approximately 1% of the national total[74]. Of this, only 97 thousand m^3 derive from hardwoods – mostly white birch and aspen[75]. Therefore, Newfoundland and Labrador laws and policies regarding poplar and willow were not considered in this report.

13. Yukon Territory

Although both trembling aspen and balsam poplar grow naturally in the Yukon Territory in northwestern Canada, no hardwood harvest was recorded in the National Forest Database for 2017. Therefore, Yukon laws and policies regarding poplar and willow were not considered in this report.

14. Northwest Territories

The National Forest Database gives 38,847 m^3 as the total amount of wood harvested in the Northwest Territories (NWT) in 2017, with only 2% of that being recorded as hardwoods[76]. Therefore, NWT laws and policies regarding poplar and willow were not considered in this report.

Nevertheless, the Government of the NWT has developed a Biomass Energy Strategy[77] in which it explicitly recognizes fast-growing willow or poplar as a possible source of biomass.

15. Nunavut

The territory of Nunavut in northcentral/northeastern Canada is mostly treeless and has no recorded wood harvest according to the National Forest Database and few poplars or willows grow naturally in the territory. Laws and policies regarding poplar and willow were therefore not considered in this report.

16. Summary

Although Canada's ten provinces have jurisdiction over forest management, their legislation and regulation for the management of native forest, especially on Crown land, are very similar and have similar provisions for ecosystem-based management of forest resources, and for the protection of riparian areas and other especially sensitive parts of the forest. The harvest of native poplars (mostly aspen and balsam poplar) is considered in setting Annual Allowable Cuts and this is critical for areas in

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.pdf; https://novascotia.ca/ecological-forestry/Triad-A-New-Vision-for-NS-Forests.pdf (Accessed January 25, 2020)

[74] Canadian Council of Forest Ministers. National Forestry Database. http://nfdp.ccfm.org/en/index.php (accessed February 24, 2020).

[75] Canadian Council of Forest Ministers. National Forestry Database. http://nfdp.ccfm.org/en/index.php (accessed February 24, 2020); https://www.faa.gov.nl.ca/forestry/our_forest/forest_types.html (Accessed January 25, 2020)

[76] Canadian Council of Forest Ministers. National Forestry Database. http://nfdp.ccfm.org/en/index.php (accessed February 24, 2020).

[77] Government of the NorthWest Territories. 2010. NWT Biomass Energy Strategy. http://www.grrb.nt.ca/pdf/forestry/NWT_Biomass_Energy_Strategy.pdf (Accessed January 25, 2020)

which aspen is the primary harvested species in the Boreal Plains of the Prairie Provinces and the BC Peace River region. Generally, within these Crown land areas, the planting of hybrid poplars or other exotic species is not done or done only for research purposes or under special arrangement. Recommendations in papers produced in Québec and Nova Scotia have suggested that forest land be categorized in a Triad classification in which designated areas be made available for intensive wood production similar to crop production on agricultural land. This may result in some further hybrid poplar plantations in the future, especially in Québec, where industrial poplar plantations have routinely been established.

On privately owned land, there are fewer regulations with respect to establishing poplar plantations, as long as they avoid protected riparian areas. Even so, the classification of plantations as either forest or agriculture presents some financial considerations for landowners in terms of taxation.

The use of poplars or willows for phytoremediation introduces other factors because effluent or leachates from landfills, water from municipal sewage treatment facilities, or reclaimed land requires careful monitoring as well as considerations such as liability insurance. As such, these systems need to be carefully planned.

Forest companies throughout Canada can operate on Crown lands only if they meet provincial forest management criteria in their management plans. Nevertheless, companies across Canada choose to be certified under the Forest Stewardship Council and/or Sustainable Forests Initiative. These certifications impose some additional conditions but, since the companies operate internationally, further internationally recognized certification is beneficial to them.

II. TECHNICAL INFORMATION

1. Taxonomy, Nomenclature and Registration

a) *Salix*

The genus *Salix* includes about 450 species distributed worldwide with 76 found in Canada. The genus is found in all regions of Canada and is one of the most diverse woody genera in the country.[78]

The taxonomy and systematics of *Salix* can be difficult because of their dioecious reproduction, simple flowers, common natural hybridization, and large intraspecific phenotypic variation. Hybridization, introgression, and polyploidy have led to complex variability and the 'blurring' of species boundaries. Normally the genus is easy to recognize, however species identification in the field can be challenging. Several valuable identification keys have been developed by George Argus, the dean of Canadian willow taxonomy. A 2016 key, Argus describes introduced and naturally occurring *Salix* species in Saskatchewan.[79]. In Alberta, an illustrated key to the *Salicaceae* of Alberta covering both poplar and willow was published in 2019.[80]

Most naturally occurring *Salix* species found in Canada are shrubs with limited commercial value but play major roles in ecosystems by stabilizing disturbed sites preventing erosion, and providing wildlife food and habitat. In the prairies, naturally occurring willow rings surrounding ephemeral wetlands provide valuable bio-filtering roles and can help control salinization. Their use as a source of energy biomass is being investigated worldwide. Canadian Indigenous peoples have used willows for fuel, construction, basketry, medicines, tools and weapons, and ceremonially[81].

b) *Alnus*

The genus *Alnus* belongs to the *Betulaceae* family and worldwide there are about 25 species. In Canada there are seven *Alnus* species and subspecies growing naturally. Taxonomically, two of the naturally occurring *Alnus* species are divided into subspecies that are separated geographically and have distinctive features. *A. incana* consists of two subspecies: ssp. *rugosa* and ssp. *tenufolia*; whereas *A. viridis* has three recognized subspecies: ssp. *sinuata*, ssp. *crispa and* ssp. *fruticosa*. The other naturally occurring species are *A. rubra* and *A. serrulata*.

c) *Populus*

Taxonomically, the *Populus* genus has six sections, of which three occur in Canada: balsam poplars [sect. *Tacamahaca* (*P. angustifolia*, *P. balsamifera*, and *P. trichocarpa*)]; cottonwoods [sect. *Aigeiros* (*P.*

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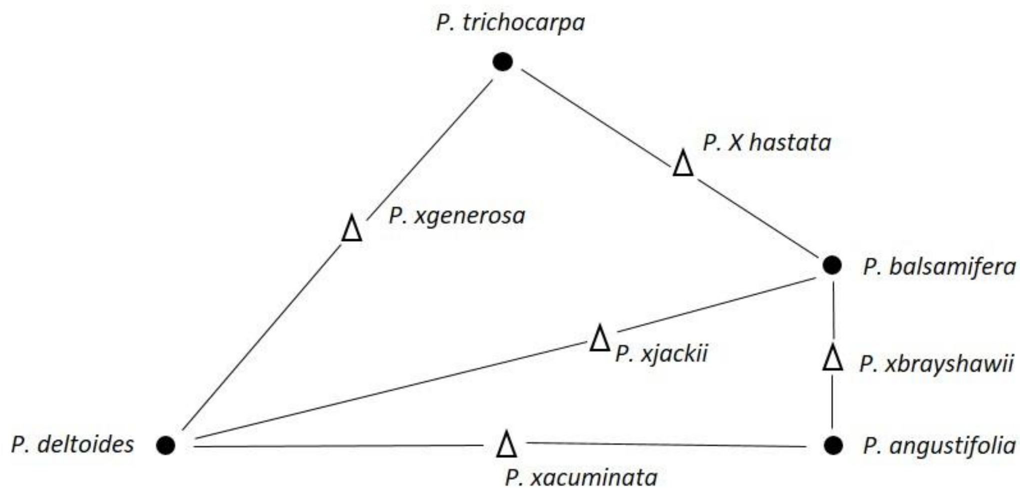
[78] Argus, G. W. (2007). *Salix* (*Salicaceae*) distribution maps and a synopsis of their classification in North America, north of Mexico. *Harvard Paper in Botany*, *12*, 335–368 https://doi.org/10.3100/1043-4534(2007)12[335:SSDMAA]2.0.CO;2 (Accessed February 18, 2020)

[79] Argus G, Harms V, Leighton A and Vetter M. 2016. Conifers and Catkin-Bearing Trees and Shrubs of Saskatchewan, Nature Saskatchewan

[80] An Illustrated Key to the *Salicaceae* of Alberta: https://anpc.ab.ca/wp-content/uploads/2019/04/Salicaceae-2019-04.pdf (Accessed February 20, 2020)

[81] MacKinnon A, Kershaw L and Arnason J. 2016. Edible and Medicinal Plants of Canada. Parners Publishing. 448pp.

deltoides)]; and aspens [sect. *Leuce* (*P. grandidentata* and *P. tremuloides*)]. Species within a section usually hybridize freely where they come in contact. Species of different sections often have overlapping ranges and do not hybridize, except that members of sect. *Aigeiros* hybridize with all species of sect. *Tacamahaca*. Some of these natural hybrids were originally described as species. Because they can persist for decades by clonal growth, hybrids are often found in the absence of one or both parents.



Populus hybridization in natural *Populus* populations in Canada[82]

d) ***Registration***

In Canada there are no federal regulations governing registration and deployment of *Salix*, *Populus* or *Alnus*. The Plant Breeders Rights Act does not apply to *Populus*, *Salix* or *Alnus* in Canada when planted in forests. However cultivars can be registered under Plant Breeders Rights. The only *Salix* cultivar currently registered under Plant Breeder's Rights (PBR) in Canada is the cultivar 'Preble' (*Salix viminalis x S. ×euerata*).[83] Its rights are held by the Research Foundation for the State University of New York. Any plant bred and owned outside Canada must be registered by an agent in Canada. For 'Preble' the Canadian agent is Moffat and Company. One poplar is registered with PBR, it is a *Populus temuloides* selection named 'Prairie Skyrise'.[84] This poplar is intended for the ornamental market and not used for forestry or plantations. There are no *Alnus* cultivars registered with PBR in Canada.

In British Columbia, when using seeds or vegetative material from a registered lot collected from parent trees, for the purposes of establishing a tree stand, planters must use seeds or vegetative material that are representative of the contribution of the parent trees to the lot. However in the case of poplar a person may use vegetative material collected from a single parent tree to establish a hybrid poplar

[82] Modified after Argus G.W., Eckenwalder J.E., Kiger R.W. Salicaceae. In: Flora of North America Editorial Committee, editor. Flora of North America. Oxford and New York: Oxford University Press; 2010.
[83] Plant Breeders Rights Variety Description for Preble willow https://www.inspection.gc.ca/english/plaveg/pbrpov/cropreport/wil/app00009178e.shtml (Accessed February 20, 2020)
[84] Plant Breeders Rights Variety Description for Prairie Skyrise trembling aspen https://www.inspection.gc.ca/english/plaveg/pbrpov/cropreport/asptr/app00008776e.shtml (Accessed February 20, 2020)

stand, if the stand does not exceed 10 hectares.[85] In British Columbia, there are restrictions on the use and importation of hybrid poplar clones known to be susceptible to the disease *Septoria musiva*.[86]

Populus and Salix Clone Directory for Canada

The Poplar and Willow Council of Canada has created an electronic database containing poplar and willow germplasm (pollen, seedlot, progeny or clone) data for Canada.[87] The directory has been in existence for more than 30 years. Over the period 2016 to 2018, the Genetics and Breeding Working Group of the Poplar and Willow Council of Canada updated and revised the database that is available on the Council's website. The database currently includes 26,419 records, organized in Microsoft Access®. The database provides a forum for Canadian breeders to archive breeding lines and released cultivars in a searchable format.

2. Domestication and Conservation of Genetic Resources

a) Populus

There are six species of *Populus* found in Canada. *Populus deltoides* is divided into two subspecies ssp. *deltoides* and ssp. *monolifera.* Subsp. *monilifera* is the abundant cottonwood of Saskatchewan and Manitoba and extends sparsely into southwestern Alberta. It intergrades with ssp. *deltoides* in western Ontario, ssp. *deltoides* extends east to Québec.

Aigeiros section

P. deltoides ssp. *deltoides* (Eastern cottonwood) – Southern Ontario and Québec
P. deltoides ssp. *monolifera* (Plains cottonwood) – Southern Saskatchewan and Manitoba and southeastern Alberta

Leuce section

P. tremuloides (Trembling aspen, Quaking aspen) – All provinces and territories
P. grandidentata (Bigtooth aspen) – Southern Manitoba, Ontario, Québec, New Brunswick and Nova Scotia

Tacamahaca section

P. balsamifera (Balsam poplar) – All provinces and territories
P. trichocarpa (Black cottonwood) – British Columbia and Southwest Alberta
P. angustifolia (Narrowleaf cottonwood) – Southeast British Columbia and Southwest Alberta

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[85] Chief Forester's Standards for Seed Use https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/tree-seed/legislation-standards/consolidated_cf_stds__amended_5apr2018.pdf (Accessed February 18, 2020)
[86] Yanchuk, Alvin – Pers. Comm.
[87] Poplar and Willow Council of Canada - *Populus* and *Salix* Clone Directory for Canada. http://www.poplar.ca/clone-directory (Accessed February 16 2020)

Populus Breeding and Testing

The Agriculture and Agri-Food Canada (AAFC) at Indian Head, Saskatchewan, poplar breeding program has been ongoing for over 75 years.[88] Activity increased significantly in 2000 and the current breeding program includes over 12,000 genetic lines within 125 full sib families. Seventy-five percent of the lines were propagated and planted in replicated field trials starting in 2006. In 2014, improved inter-specific hybrid selections were planted in a common garden at Indian Head along with intra-specific *P. balsamifera* hybrids. Overall, the program aims to develop "ideal poplar ideotypes" with fast growth rates; adaptation to short summers and the risk of growing-season frost; winter hardy to -50C; drought resistant, insect and disease resistant and optimum form/architecture for maximizing carbon storage. In addition, screening efforts focus on resource use efficiencies (particularly, water and nutrients) and growth responsive to increasing atmospheric CO_2. In the spring of 2020, two new hybrid poplar clones will be released for agroforestry planting.

The short-term goal of the current AAFC breeding program is development of F_1 hybrids in support of ecological services (e.g. farm and field shelterbelts, intercropping, odour/particulate control, enhancement of pollinator habitat, riparian restoration, riparian protection). The long-term goal is to solidify the genetic resources of *P. deltoides* and *P. balsamifera* to serve recurrent breeding efforts. Overall, poplar breeding efforts focus on exploitation of within-species population level genetic variation that would best serve current and future climates of the Canadian prairies and beyond. In addition, exploratory efforts are evaluating new intra-specific F_1 combinations with *P. deltoides* and *P. balsamifera* and their pure species state. The latter focuses on provenance, family, or clone tests. The secondary long-term goal is to conduct exploratory evaluations of additional non-native species (e.g. *P. laurifolia., P. nigra, P. maximowiczii*, and *P. simonii*).

Balsam poplar (*P. balsamifera*) is the preferred species for oil sands reclamation planting in northern Alberta. Balsam is a native species to the region (a regulated requirement), easy to propagate and has rapid growth. There is appropriate genetic material developed by previous Alberta-Pacific poplar breeding programs. The reclamation work with balsam poplar is done in partnership between Alberta-Pacific Forest Industries and Syncrude as the energy company dispositions and the forest company's forest management agreement areas (FMAs) overlap.[89]

In Québec, the Ministère des Forêts, de la Faune et des Parcs (MFFP) poplar breeding programme has been under way since 1969 and is one of two active programs in Canada. The program includes over 11,000 clones and approximately 3,750 families obtained from five species. Since 2016, efforts have focused on intra-specific breeding of parental populations (*P. deltoides* and *P. maximowiczii*) in order to diversify their gene pool and to allow the production of advanced generation of hybrids. The breeding goal is development of high-performing F_1 hybrids adapted to Québec bioclimatic conditions and tolerant or resistant to major diseases (e.g. *Septoria musiva* [*Sphaerulina musiva*]). New progenies of parental lines (*P. deltoides* × *P. deltoides*, *P. maximowiczii* × *P. maximowiczii*, and *P. maximowiczii* × *P. suaveolens*) have been obtained through intra-specific breeding for propagation and testing beginning in

[88] Soolanayakanahally, Raju - Pers. Comm
[89] Barb Thomas presentation in Uppsala Sweden September 2017: Poplar Breeding in North America - What are we breeding for? http://www.poplar.ca/upload/documents/thomas-uppsala-presentation-sep-2017.pdf (Accessed February 20, 2020)

2020. For the 2016-2019 period, two new tested MN clones (*P. maximowiczii* × *P. nigra*) and one DM clone (*P. deltoides* x *P. maximowiczii)* were deployed for commercial planting in Québec. [90]

In British Columbia, the current program has been under way since 1989, with testing of native and hybrid poplars.[91] With the demise of poplar activity in British Columbia no additional work is planned. A poplar clone bank situated at the Puckle Road Seed Orchard, in Saanichton BC, has about 300 clones archived. Approximately one-half of the clones at this site will not be re-propagated (some are being damaged by poplar borer), due to susceptibility to *Septoria* leaf rust.

Populus Ex Situ Conservation

At Agriculture and Agri-Food Canada (AAFC), the primary purpose of poplar conservation efforts is to obtain a genetically representative sample of *P. balsamifera* and *P. deltoides ssp. monolifera* germplasm over a wide geographic region for building breeding populations. Their intent is to sample the geographic range of each species.[92] Current collections at AAFC include *P. balsamifera* (AgCanBaP collection – Agriculture Canada Balsam Poplar), *P. deltoides ssp. monolifera, P.* × *petrowskyana,* and *Populus* hybrids

Since the beginning of the Quebec poplar breeding program, diverse and multiple populations have been tested and conserved in different tests across the province.[93] Since 2016, new material has been incorporated into the programme to diversify the gene pool of some of the parental lines (*P. maximowiczii* and *P. deltoides*). In 2017, a conservation plantation was established with selected material from the *P. maximowiczii*, *P. trichocarpa* and *P. deltoides* populations.

In British Columbia, the Ministry of Forests, Lands and Natural Resource Operations maintains two clone banks of *P. trichocarpa, P. balsamifera,* and some hybrids.[94]

Populus Genomics

During the past five years, Canadian genomic approaches have generated baseline data about the genetic structure and long distance gene flow of *Populus* species across their ranges. In addition, a number of climate/edaphic and biotic factors that have contributed to shape their diversity were listed. Candidate genomic regions involved in growth- and wood-related traits, and gender determination were also identified. Indeed, sympatric zones between species may have permitted some of them to acquire adaptive traits. These findings will allow the testing of new hypotheses and the disentanglement of phenotype-genotype-environment relationships useful for breeding programmes. The development of genomic resources has also provided cost-effective markers to distinguish genotypes that can help address specific forest management or restoration questions.

Predicting the response of trees to the natural environment has traditionally been one of the main goals of breeding programs. When considering global change, the acquisition of knowledge about key environmental drivers and the adaptive capacity of tree species is necessary to guide breeding and conservation programmes as well as for forest management and ecosystem restoration. In order to

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[90] Prud'homme, Guillaume – Pers. Comm.
[91] Yanchuk, Alvin – Pers. Comm.
[92] Soolanayakanahally, Raju - Pers. Comm.
[93] Prud'homme, Guillaume – Pers. Comm.
[94] Yanchuk, Alvin – Pers. Comm.

understand better how species adapt to their environment, Canadian researchers are using different genomic approaches alone or in combination, including: i) genotype-environment association (GEA) when phenotypes are not available and ii) genotype-phenotype association (GPA) based on common gardens.[95]

Populus species have benefited greatly from the 'omics era over the past 15 years. As a result, several studies have been carried out on Canadian species: *P. trichocarpa*, *P. balsamifera*, *P. angustifolia*, *P. deltoides* and *P. tremuloides*. Moreover, genomic resources (e.g. transcriptomes, gene copy number variants) and new approaches (rare variants to explain phenotypic variation) are being developed that will lead to a better understanding of the genomic architecture of tree resistance to biotic and abiotic stresses[96].

Recent Agriculture and Agri-Food Canada (AAFC) efforts include modelling poplar traits using DNA methylation to capture tissue-specific epigenetic mechanisms including total biomass, wood density, soluble lignin and cell wall carbohydrate. AAFC also investigated F_1 progenies of an intra-provenance cross (north-north cross, 58th parallel) and an inter-provenances cross (north-south cross, 58th/49th parallels) for gene copy number variations (CNVs) using comparative genomic hybridization on arrays of probes targeting gene sequences *P. balsamifera*.[97] One-to-five gene CNVs were found to be related to each of the measured adaptive traits and annotated for both biotic and abiotic stress responses. These annotations can be related to the occurrence of a higher pathogenic pressure in the southern parts of *P. balsamifera* distribution, and higher photosynthetic assimilation rates and water-use efficiency at high-latitudes. Overall, findings at AAFC suggest that gene CNVs typically having higher mutation rates than SNPs and may in fact represent efficient adaptive variations against fast-evolving pathogens.[98]

GEA approach

Population genetics studies and genotype-environment associations (GEA) have been conducted in *P. balsamifera*, *P. deltoides*, and their hybrids. The genotyping of cpSNPs and ncSNPs of 1200 individuals from across the *P. balsamifera* range revealed 2-3 genetic clusters that likely derive from three refugia in the Pleistocene ice age. In the Eastern cluster, endogenous genomic barriers have led to a sharp border that prevents the disentanglement of local adaptation from historical processes.[99]

A large scale genome project led by Canadian researchers studied the extent of genetic variation within and among *P. balsamifera* populations in phenology, ecophysiology and resource-use traits, using single nucleotide polymorphism (SNP). The ability of individuals within a species to adapt to different

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[95] Sork, V.L., Aitken, S.N., Dyer, R.J., A. J. Eckert, A.J., Legendre. P. and Neale. D.B. 2013. Putting the landscape into the genomics of trees: approaches for understanding local adaptation and population responses to changing climate. *Tree Genetics & Genomes* **9,** 901–911. https://link.springer.com/article/10.1007/s11295-013-0596-x
[96] Piot, A., Prunier, J., Isabel, N., Klapste, J., El-Kassaby, Y. A., Villarreal Aguilar, J. C., & Porth, I. (2019). Genomic Diversity Evaluation of Populus trichocarpa Germplasm for Rare Variant Genetic Association Studies. *Frontiers in Genetics*, *10*, 1384. https://doi.org/10.3389/fgene.2019.01384
[97] Prunier, J., Giguère, I., Ryan, N., Guy, R., Soolanayakanahally, R., Isabel, N., MacKay, J., and Porth, I. 2019. Gene copy number variations involved in balsam poplar (*Populus balsamifera* L.) adaptive variations. *Molecular Ecology* 28 (6): 1476-1490. https://doi.org/10.1111/mec.14836
[98] Soolanayakanahally, Raju - Pers. Comm.
[99] Meirmans, P. G., Godbout, J., Lamothe, M., Thompson, S. L., and Isabel, N. (2017). History rather than hybridization determines population structure and adaptation in Populus balsamifera. *Journal of Evolutionary Biology*, *30*(11), 2044–2058. https://doi.org/10.1111/jeb.13174

environments resides in their genetic diversity. This diversity, most commonly manifested as SNPs, can provide clues to the adaptive strategies and population histories that have played roles in species' evolution and migration northwards. Agriculture and Agri-Food Canada's (AAFC) AgCanBaP collection exhibits great phenotypic variations both in a common garden and greenhouse conditions. The availability of a *P. balsamifera* sequenced genome makes it possible to direct attention to candidate genes of interest. The candidate genes of interest in the AAFC poplar breeding program involves phenology, carbon gain, resource-use (water and nitrogen), and disease resistance. [100]

For *P. deltoides*, three distinct lineages were detected across the majority of the species' range, and their current distribution was associated with abiotic and biotic variations (Godbout et al. 2019). The comparison between both cpDNA and ncDNA patterns showed that gene flow between the lineages is unbalanced. The southern and northeastern populations may benefit from the input through river flow of novel alleles located upstream of their local gene pools. These "pre-adapted" incoming alleles may help to cope with maladaptation in populations facing changing conditions.[101]

Genotype-phenotype association (GPA)

Both GEA and GPA were conducted in 433 *P. trichocarpa* genotypes originating across western North America and growing in common gardens. All trees were genotyped with nearly 30 000 SNPs and measured for growth- and wood-related traits and disease resistance. To determine the molecular basis of climate adaptation, the authors also looked for signatures of selection (comparing Q_{ST} -F_{ST}) using the clustering by climate of origin (temperature and precipitation) of the individuals. More than 10% of SNPs tested showed signals of diversifying selection and a number of them were found to be associated with adaptive traits. Many SNPs were putatively pleiotropic for functionally uncorrelated adaptive traits, such as autumn phenology, height, and disease resistance.[102]

Using a British Columbia Ministry of Forests *P. trichocarpa* collection, researchers at the University of British Columbia conducted GWAS studies using 2.2M SNPs generated through whole-genome sequencing (Suarez-Gonzalez et al. 2016). They studied variation in bud-break under outdoor and indoor conditions. Despite phenotypic similarities, genetic profiles between the southern- and northern-most genotypes were dissimilar based on SNPs.[103] A later GWAS study, at the University of British Columbia, was conducted to verify the presence of trade-offs between growth and disease resistance in *P. trichocarpa*. Almost 300 SNPs were found to be associated with adaxial stomatal traits. The authors

[100] Soolanayakanahally, Raju - Pers. Comm.

[101] Godbout, J., Gros-Louis, M.-C., Lamothe, M., and Isabel, N. (2020). Going with the flow: Intraspecific variation may act as a natural ally to counterbalance the impacts of global change for the riparian species Populus deltoides. *Evolutionary Applications*, *13*(1), 176–194. https://doi.org/10.1111/eva.12854

[102] Porth, I., Klapste, J., McKown, A. D., La Mantia, J., Guy, R. D., Ingvarsson, P. K., Richard Hamelin, R., Mansfield, S.D., Ehlting, J., Douglas, C.J. and El-Kassaby, Y. A. 2015. Evolutionary Quantitative Genomics of Populus trichocarpa. *PloS One*, *10*(11), e0142864. https://doi.org/10.1371/journal.pone.0142864

[103] McKown, A. D., Klapste, J., Guy, R. D., El-Kassaby, Y. A., & Mansfield, S. D. 2018. Ecological genomics of variation in bud-break phenology and mechanisms of response to climate warming in Populus trichocarpa. *The New Phytologist*, *220*(1), 300–316. https://doi.org/10.1111/nph.15273

proposed that the occurrence of amphistomaty (stomata on both leaf surfaces) in *P. trichocarpa* reflects selection for supporting rapid growth over investment in immunity.[104]

Hybridization as a source of variation and adaptation

Hybrid zones among the different sexually compatible *Populus* species were studied to look for adaptive introgression that can affect not only the trees but also other trophic levels such as gall-forming arthropods (Floate et al. 2016). In the latter case, stand diversity, in terms of the number of trees representing different classes of hybrids, affects the diversity of arthropod species present and their number. One explanation could be that the diversity of tree genotypes offers a larger window of opportunity to their associated arthropods. Asymmetric patterns of introgression across the whole genome of *P. trichocarpa* and *P. balsamifera* were also observed along the British Columbia/Alberta north-south border, with stronger introgression from *P. balsamifera* to *P. trichocarpa* than vice versa. These regions are enriched for genes involved in disease resistance. A complementary study also suggested that the northern range extension of *P. trichocarpa* depends, at least in part, on introgression from *P. balsamifera*. However, admixture with *P. balsamifera* can lead to potentially maladaptive early phenology and a reduction in growth and disease resistance in *P. trichocarpa*. [105] Contact zones between species are of interest since the development of new allelic combinations at the whole genome level offers huge potential for evolutionary adaptation (Rieseberg et al. 2003).[106]

Gender determination

A whole-genome resequencing approach of 52 *P. trichocarpa* (black cottonwood) and 34 *P. balsamifera* (balsam poplar) individuals of known sex permitted the identification of the sex-determining region.[107] A GWAS approach found that sexual homomorphism (no non-reproductive trait differences between the sexes) suggests that gender is functionally neutral with respect to non-reproductive features that affect plant survival and fitness.[108] Using the same *P. trichocarpa* collection, a Genome Canada funded project at the University of Toronto later assessed a subset of these genes for differential methylation using whole methylome sequencing of the xylem tissue of individuals growing under field conditions. They found that one gene, PbRR9, has a role in poplar sex determination that is mediated through epigenetic mechanisms. The discovery of the sex determining region (SDR) of *P. balsamifera*, pinpointed 13 genes with differentiated X and Y copies. The only SDR gene to show a marked pattern of gender-specific methylation is PbRR9, a member of the two component response regulator gene family, involved in

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[104] McKown, A. D., Klápště, J., Guy, R. D., Corea, O. R. A., Fritsche, S., Ehlting, J., El-Kassaby, Y. A., and Mansfield, S. D. 2019. A role for SPEECHLESS in the integration of leaf stomatal patterning with the growth vs disease trade-off in poplar. *New Phytologist* 223 (4): 1888-1903. https://doi.org/10.1111/nph.15911

[105] Suarez-Gonzalez, A., Hefer, C. A., Lexer, C., Cronk, Q. C. B., and Douglas, C. J. 2018. Scale and direction of adaptive introgression between black cottonwood (Populus trichocarpa) and balsam poplar (P. balsamifera). *Molecular Ecology*, *27*(7), 1667–1680. https://doi.org/10.1111/mec.14561

[106] Rieseberg, L.H., Raymond, O., Rosenthal, D.M., Lai, Z., Livingstone, K., Nakazato, T., Durphy, J.L., Schwarzbach, A.E., Donovan, L.A., and Lexer, C. 2003. Major ecological transitions in wild sunflowers facilitated by hybridization. Science, 301(5637): 1211–1216. https://science.sciencemag.org/content/301/5637/1211

[107] Geraldes, A., Hefer, C., Capron, A., Kolosova, N., Martinez-Nunez, F., Soolanayakanahally, R.., Stanton B., Guy R., Mansfield S., Douglas C.J. and Cronk, Q. (2015). Recent Y chromosome divergence despite ancient origin of dioecy in poplars (Populus). *Molecular Ecology*, *24*(13), 3243–3256. https://doi.org/10.1111/mec.13126

[108] McKown, A. D., Klapste, J., and Guy, R. D. 2017. Sexual homomorphism in dioecious trees: extensive tests fail to detect sexual dimorphism in Populus. *Scientific Reports* 7. https://doi.org/10.1038/s41598-017-01893-z

cytokinin signalling. Here, they paired work in *P. trichocarpa* and *P. balsamifera* describing one of the smallest sex-determining regions known thus far in complex eukaryotes (~ 100 kbp) with comprehensive tests for sexual dimorphism using> 1300 individuals from two *Populus* species and assessing 96 non-reproductive functional traits. They found sexual homomorphism (no non-reproductive trait differences between the sexes), suggesting that gender is functionally neutral with respect to non-reproductive features that affect poplar survival and fitness. [109]

b) *Alnus*

Alders are divided into two subgenera *Alnus* and *Alnobetula*.[110] One species, *Alnus rubra* (red alder) is commercially significant as a fast-growing tree species in Canada. In western British Columbia it is the main harvested hardwood species with a rotation age of approximately 30 years.[111]

Alnus subgenus

A. rubra (Red alder) – Western British Columbia and Vancouver Island
A. incana ssp. *rugosa* (Speckled alder) – All provinces and territories
A. incana ssp. *tenufolia* (Mountain alder) – Eastern British Columbia, Western Alberta and Yukon

Alnobetula subgenus

A. viridis ssp. *sinuata* (Sitka alder) – British Columbia and Western Alberta
A. viridis ssp. *crispa* (Green alder) – Eastern Canada
A. viridis ssp. *fruticosa* (Siberian alder) – Northern British Columbia
A. serrulata (Hazel alder) – New Brunswick, Nova Scotia and Quebec

Alnus Breeding and Testing

On the west coast of British Columbia (BC) red alder (*Alnus rubra*) produces, in a short time, (about 30 years or less) high yields of wood. It is a medium-sized tree, up to 24 metres tall with a slightly tapered trunk extending up to a narrow, rounded crown. Trees in the open have crowns that start near the ground giving it a broad cone shape. Considering its productivity, easy regeneration (prolific annual seed crops), and low risk of being affected by damaging agents, it is a suitable species for intensive management on some BC coastal sites, especially those where the establishment of conifers is difficult (e.g., on riparian sites). Red alder is also suitable as a nurse crop species on nitrogen-poor sites (although the more shrubby and shade-tolerant Sitka alder may be more appropriate) and severely disturbed sites (landslides, landings, etc.). It has been suggested as a nurse species for Sitka spruce, as its shade and visual diversion will deter spruce weevil. [112]

In British Columbia, 14 red alder research trials have been established around Vancouver Island and the lower mainland to expand breeding populations and provide more data for climate based seed transfer

[109] Bräutigam, K., Soolanayakanahally, R., Champigny, M., Mansfield, S., Douglas, C., Campbell, M. M., and Cronk, Q. 2017. Sexual epigenetics: gender-specific methylation of a gene in the sex determining region of *Populus balsamifera*. *Scientific Reports.* 7: 45388. https://www.nature.com/articles/srep45388
[110] Trees in Canada. 1995. Farrar, J.L. Natural Resources Canada, Canadian Forest Service, Ottawa, Co-published by Fitzhenry and Whiteside Limited, Markham, Ontario. 502 p.
[111] Yanchuk, Alvin – Pers. Comm.
[112] Yanchuk, Alvin – Pers. Comm.

functions. Four of these sites are for red alder selections. The British Columbia breeding program focuses on recurrent selection, and maintaining production populations in seed orchards. The program relies on open pollinated progeny along with some controlled polymix crosses. The first selection cycle was used to develop a seed orchard with concurrent field trial evaluations. This phase has generated 19 selected clones with a 30 percent volume increase projected after 30 growing years. The progeny testing program, started in 2011 has over 25,000 trees in 14 tests. The second selection is scheduled for 2022 and establishment to phase 2 seed orchard in 2024. The breeding population will be established with an effective population size of approximately 80 lines. Screening for western tent caterpillar resistance will be incorporated into the next selection cycle. 19 clones (OP seed from a seed orchard-30% gain in volume projected by age 30. [113]

[113] Yanchuk, Alvin – Pers. Comm.

c) *Salix*

Traditionally, the subgenera classification of *Salix* was based on morphological characteristics. In the recent classification, five subgenera are recognized.[114]

Distribution of *Salix* subgenera in Canada[115]			
Species	**Distribution**	**Species**	**Distribution**
Subgenus *Protitea*		**Subgenus *Vetrix***	
amygdaloides	BC AB SK MB ON QC	*alaxensis alaxensis*	BC YK NT NU
nigra	ON QC NB	*alaxensis longistylis*	BC YK NT
Subgenus *Salix*		*arbusculoides*	BC AB SK MB YK NT NU
lasiandra lasiandra	YK NT BC AB SK	*argyrocarpa*	QC NF
lasiandra caudate	BC	*barclayi*	BC YK AB
lucida	SK MB ON QC NS NB PE NL	*barrattiana*	BC AB YK NT
maccalliana	BC YK NT AB SK M ON	*bebbiana*	All Provinces
serissima	NT AB SK MB ON QC	*calcicola calcicola*	NU QC NF
Subgenus *Longifoliae*		*calcicola glandulosior*	BC AB
exigua exigua	BC AB	*candida*	YK BC AB SK MB ON QC NB
interior	NT BC AB SK MB ON QC NB	*commutata*	BC YK
Subgenus *Chamaetia*		*cordata*	ON QC
arctica	YK BC NU NT	*discolor*	BC AB SK MB ON QC NB PE NS NF
arctophila	NT NU QC	*drummondiana*	BC AB
athabasensis	YK BC AB SK MB	*eriocephala*	SK MB ON QC NB PE NS NF
brachycarpa brachycarpa	YK BC AB SK ON	*famelica*	AB SK MB ON
brachycarpa psammophila	SK	*farriae*	YK BC AB
cascadensis	BC	*geyeriana*	BC
chamissonis	YK	*hastata*	YK
fuscescens	YK NT NU	*hookeriana*	BC
glauca	BC YU NT NU QC NF	*humilis humilis*	MB ON QC NB PE NS NF
jejuna	NF	*myricoides*	ON QC NB NF
niphoclada	YK NT NU	*myrtillifolia*	YK NT BC AB SK MB ON
nivalis	BC AB	*pellita*	SK MB QC NB NF
ovalifolia	YK	*petiolaris*	BC AB SK MB ON QC NB PE NS
pedicellaris	All Provinces	*planifolia*	All Provinces
petrophila	BC AB	*prolixa*	YK NT BC AB
polaris	BC YK NU	*pseudomonticola*	YK NT BC AB SK MB ON
raupii	BC YK NT	*pseudomyrsinites*	YK NT BC AB SK MB ON
reticulate	BC YK NT NU QC	*pyrifolia*	YK NT BC AB MB ON QC NB PE NS NF
rotundifolia dodgeana	YK NT	*richardsonsii*	YK NT NU
setchelliana	YK	*scouleriana*	YK NT BC AB SK MB
sphenophylla	YK NT	*sericea*	QC NB
stolonifera	BC	*silicicola*	SK
uva-ursi	NU QC NF	*sitchensis*	BC
vestita	BC AB ON QC NF	*turnorii*	SK
		tyrrellii	NT NU SK

[114] Argus GW, Eckenwalder JE, Kiger RW. Salicaceae. In: Flora of North America Editorial Committee, editor. Flora of North America. Oxford and New York: Oxford University Press; 2010.
[115] Argus, G. W. (2007). *Salix* (Salicaceae) distribution maps and a synopsis of their classification in North America, north of Mexico. *Harvard Paper in Botany*, *12*, 335–368.

Salix Breeding and Testing

Willow clones have an accepted role for shelterbelts, nutrient management, carbon sequestration, phytoremediation, bioenergy plantations, riparian protection and fibre production in Canada. Willow selection and breeding traditionally have focused on high biomass production under optimum environmental conditions. Apart from the fact that optimum conditions are not realized in most of the potential willow plantations in western Canada, new willow genotypes are being screened for the needs of multi-purpose agroforestry as well as biomass production. Any evaluation of potential suitability of the plant material for multi-purpose applications requires characterization in terms of biomass production, nutrient accumulation and nutrient turnover and adaptability to local growing conditions.

In the last two decades, major willow breeding efforts in Sweden, the United Kingdom and United States have resulted in the development and deployment of both intra- and inter-specific hybrids with important agronomical traits necessary for bioenergy plantations. The first *Salix* breeding programs in Canada were by Alex Mosseler in Dr. Lou Zuffa Lab at the University of Toronto in the 1980s. Some of the genetic material from this program was transferred to the State University of New York at Syracuse where it was used in their breeding programs. Mosseler's early research generated several *Salix viminalis x miyabeana* hybrids still in use today.

The majority of *Salix* cultivars used commercially in Canada are produced at two nurseries, Agro Energie in Quebec and Double A Vineyards Nursery in Fredonia, New York.[116] Numerous willow clones have been tested at multiple locations across Canada. These trials are determining optimum clones for different regions of the country. The following willow clones are currently being deployed or tested in Canadian plantings.

Clone	**Species**	**Clone**	**Species**
Allegany	*S. purpurea*	Vim 5027	*S. viminalis*
Millbrook	*S. viminalis x S. miyabeana*	India	*S. gmelinii*
Olof	*S. viminalis x (S. viminalis x S. scherwinii)*	Nigra 5005	*S. nigra*
Otisco	*S. viminalis x S. miyabeana*	Alba 5044	*S. alba*
Owasco	*S. viminalis x S. miyabeana*	Eriocephala S25	*S. ericephala*
Preble	*S. viminalis x S. miyabeana*	Discolor S365	*S. discolor*
SV1	*S. gmelinii (dasyclados)*	Fish Creek	*S. purpurea*
Sx61	*S. viminalis x S. miyabeana*	Fabius	*S. viminalis x S. miyabeana*
Sx64	*S. viminalis x S. miyabeana*	Sanguinea	*S. xfragilis*
Sx67	*S. viminalis x S. miyabeana*	Acute	*S. acutifolia*
Tully	*S. viminalis x S. miyabeana*	White	*S. alba sericea*
Tora	*S. viminalis x S. scherwinii*	Laurel	*S. pentandra*

Bionera, a contracting company specializing in short rotation intensive culture willow plantations, and the CFS will be establishing new common garden clonal willow trials at Beaverlodge, Ohaton, Forestburg and Keoma Alberta testing a selection of 17 clones from the list above. An additional four sites ranging to the 60th parallel, with two in Saskatcheewan are proposed. At the Keoma site, Bionera has an existing

[116] Krygier, Richard – Pers. Comm.

trial with 13 cultivars under evalution. These include: Allegany, Bjorn, Millbrook, Myst4, Olof, Otisco, Owasco, Preble, SV1, Tora, Tully and Viminalis. Both trials were harvested in 2016.[117]

As phosphorus levels in surface water runoff increase, algal blooms (eutrophication) manifest in downstream lakes, resulting in decreased water quality, aquatic species mortality and loss of recreational space.[118] A practical solution may lie in current agroforestry practices. Willow trees are often planted on marginal lands surrounding agricultural fields to act as riparian buffers. Harnessing the ability of these willow trees for uptake, storage and remobilization of nutrients in above-ground tissue could facilitate the long-term management of phosphorus levels in both water and soil, while providing a reliable source of biomass for fibre, biofuel production and even biochar. In addition, to amend soil quality, revegetate salt-affected fields and recover economic loss associated with soil salinization, the establishment of short rotation coppice plantations with willows has been suggested as a possible solution. Native willows showed higher potential for long-term survival under severe salinity treatment, showing lower Na:K ratio in roots and better photosynthetic performance.[119] The increasing importance of managing phosphorus in agroecosystems has given rise to *Salix* domestication and breeding efforts at Agriculture and Agri-Food centred out of Indian Head and Saskatoon, Saskatchewan.

At Agriculture and Agri-Food Canada (AAFC), *Salix* breeding efforts focus on exploitation of within- and between species genetic variation of genotypes planted in common garden or clone tests.[120] The short term goal of the breeding program is development of F_1 hybrids in support of ecological services (e.g. enhancement of pollinator habitat, riparian protection, wetland restoration, municipal wastewater management, short rotation dedicated bioenergy crop on marginal lands, salinity management). The long-term goal is primarily to solidify the genetic resources in *S. eriocephala* that would serve a recurrent breeding effort. Overall, the breeding program aims to develop the “ideal willow ideotype” with rapid biomass accumulation; adapted to short summers and the risk of growing-season frost; be winter hardy to temperatures as low as –50˚C; be drought resistant, insect and disease resistant; optimum form/architecture for maximizing machine harvesting. In addition, screening efforts focus on phosphorus mitigation via cultivar selection.

AAFC breeding methods include qualitative selection of parents for intra- and inter-specific hybridization, typically with only one generation. This is followed by nursery scoring for leaf rust, branch habit, and vigour; screening for cold hardiness and drought hardiness on a 3-year coppice rotation and finally field testing for site adaptability, growth, form and pest resistance. The current AAFC program has been under way since 2003 with activity increased significantly between 2008 and 2013. Between 2016 and 2019 the breeding program included over ~2,500 genetic lines with ~60 controlled pollination families. About 60 percent of the lines have been propagated and are planted in common gardens. In 2020, three new hybrid willow clones are planned to be released for salinity management, bioenergy purposes and phosphorus mitigation along riparian zones.[121]

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[117] Krygier, Richard – Pers. Comm.
[118] Soolanayakanahally, Raju - Pers. Comm.
[119] Da Ros, L. M., Soolanayakanahally, R. Y., Guy, R. D., and Mansfield, S. D. 2018. Phosphorus storage and resorption in riparian tree species: Environmental applications of poplar and willow. *Environmental and Experimental Botany* 149: 1-8. https://doi.org/10.1016/j.envexpbot.2018.01.016
[120] Soolanayakanahally, Raju - Pers. Comm.
[121] Soolanayakanahally, Raju - Pers. Comm.

At the University of Saskatchewan, second rotation biomass yields and stem growth for 30 willow cultivars showed average 3-year cumulative biomass production across all cultivars was 8.1 oven-dry (OD) Mg ha^{-1} in the second rotation (ranging from 0.6 to 21.3 OD Mg ha^{-1}).[122] The three highest yielding cultivars were Taberg, Tully Champion, and Otisco, with annual biomass production of 6.4–7.1 OD Mg ha^{-1} $year^{-1}$ an increase by 12–44% from the first rotation, and more than double the average for all 30 cultivars (2.7 OD Mg ha^{-1} $year^{-1}$). High mortality was common among 20 of the 30 cultivars that had low biomass production.

LandSaga Biogeographical conducts selection and trials of F_1 willow hybrids in support of Sustainable Multi-use Coppice (patent pending to LandSaga). One of their selections, *Salix x rubens*, is a robust tree form hybrid willow (*S. fragilis x S. alba*) naturalized in southern Ontario. The selections will be field tested in Atlantic Canada with licensed grower in the near future. [123]

Willow testing has been under way in Quebec at the Institut de recherche en biologie végétale (Université de Montreal and Botanical Garden) since 2005. Recent research has addressed large areas of brownfield (> 4 ha) by using diverse remediation approaches including the use of willow microcuttings. Testing is under way to determine the best performing willow genotypes for growing on contaminated and harsh sites (brownfield) as well as the capacity to extract or degrade pollutants (inorganic and/or organic). Cultivars being evaluated include: *S. nigra* '5005'; *S. alba* '5044'; *S. eriocephala* 'S25'; *S. discolor* 'S365'; *S. dasyclados* 'SV1'; *S. viminalis* '5027'; *S. miyabeana* 'SX61'; 'SX64' and 'SX67'; *S. purpurea* 'Fish Creek'; *S. viminalis* x *S. miyabeana* 'Fabius'; *S. gmelinii* 'India'; *S. x fragilis* 'Sanguinea'[124]. In addition, Marie Guittonny-Larcheveque at UQAT is using willows for mine waste revegetation in soil layers of low sulphur wastes of a boreal gold mine in Northwestern Quebec (Guittonny-Larchevêque M and Pednault C., 2016).

In New Brunswick, willow domestication and conservation is being done at Canadian Forest Service (CFS) in Fredericton.[125] Development of selected, superior clones is being done in support of ecological services such as enhancement of pollinator habitat, riparian restoration, riparian protection, water quality, soil development, soil surface erosion control, and commercial biomass production on highly disturbed areas such as former mine sites.

The current CFS program started in 2005 with increased activity in 2010. The clonal selection program includes a base population of approximately 180 genotypes collected from approximately 40 natural populations located across Ontario, Quebec, and New Brunswick. These clones have been established at approximately 25 field tests associated primarily with former mine sites and blueberry growing operations. Several clones are selected annually based on these field tests and some of these clones have been registered with the database on poplar and willow clonal selections maintained by the Poplar and Willow Council of Canada.

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[122] Amichev, B. Y., Volk, T. A., Hangs, R. D., Belanger, N., Vujanovic, V., and Van Rees, K. C. J. 2018. Growth, survival, and yields of 30 short-rotation willow cultivars on the Canadian Prairies: 2nd rotation implications. *New Forests* 49 (5): 649-665. https://link.springer.com/article/10.1007/s11056-018-9650-8
[123] Hendrickson, Cheryl - Pers. Comm.
[124] Labrecque, Michel – Pers. Comm.
[125] Mosseler, Alex – Pers. Comm.

Salix Ex situ Conservation

In Canada conservation of willow genetic resources is mainly done by AAFC in Saskatchewan. They have a national *ex situ* conservation program for selected *Salix* species native to Canada. Their *ex situ* collections and resulting common garden trials provide opportunities for a variety population genetic studies, climatic adaptation, long-term phenology responses of provenances and ecophysiology studies. In addition, the collections are providing foundation stock for basic research and trait assisted breeding. Their current research mainly uses *S. eriocephala* - a native willow as parental stock along with other native Canadian species such as *S. discolor* and *S. interior* and along with introduced species such as *S. dasyclados* and *S. viminalis*. Traits of interest for willow selection for Canada include coppice ability, height and biomass, growth form (compact, vertical growth), wood characterization (cellulose, hemicellulose, lignin), cold hardiness, salinity tolerance and hyper accumulator of heavy metals on roots.

The AAFC collection is referred to as the AgCan*Salix* collection (Agriculture Canada *Salix*) collection.[126] The primary purpose of the collection is to maintain a genetically representative sample of *S. eriocephala* and *S. discolor* germplasm from a wide geographic region for building breeding populations and for *ex situ* conservation. For this reason phenotypic selection during sampling was not important. The intent was to sample the geographic range of the species. Within each population, a minimal sample size of 15 distinct stools was collected. This sample size was adequate to capture a high proportion of the genetic variation recognizing that most of the genetic variation resided within populations and characterizes a provenance. The collection includes 33 populations collected along five North/South transects across the natural range of *S. eriocephala* in Canada. A common garden experiment with the 33 populations has been established at Indian Head, Saskatchewan.

Conservation efforts at Canadian Forest Service in Fredericton have involved maintaining native willow species and clones *in situ* within common garden field tests primarily in New Brunswick. *Salix* species included in the common garden trials include *S. amygdaloides, S. bebbiana, S. cordata, S. discolor, S. eriocephala, S. humilis, S. interior and S. nigra*.[127]

Salix Genomics

Recently a genetic study from a total of 324 naturally occurring *S. eriocephala* accessions from the AgCan*Salix* collection were analysed using 26,030 polymorphisms to reveal patterns of genetic diversity and population structure. The native *Salix eriocephala* Michx. *de novo* genome assembly is a work in progress. The female willow specimen "AAC-Oromocto" named after the Oromocto River in New Brunswick, was collected approximately 20 kilometers southeast of Fredericton. The name Oromocto is thought to have originated from the Maliseet word welamukotuk which means "deep water." The Maliseet, or Wolastoqiyik, are an Algonquian-speaking First Nation of the Wabanaki Confederacy located in Canada along the Saint John River and its tributaries. The draft genome will be made available in the fall of 2020. In addition, using Single Nucleotide Polymorphisms (SNPs) on a subset of 500 AgCanSalix collection, the genetic diversity, and population structure were explored. Simultaneously,

[126] Soolanayakanahally, Raju - Pers. Comm.
[127] Mosseler, Alex – Pers. Comm.

association mapping for adaptive (bud flush, leaf senescence, leaf rust) and wood traits (cellulose, hemicellulose, lignin, and microfibril angle) was carried out.[128]

3. Plant Health, Resilience to Threats and Climate Change

a) Biotic Factors

Insects and Disease

Numerous insects and diseases potentially threaten the success of poplar, willow and other fast growing trees by reducing productivity, function and/or quality of affected trees. Frequently insects and diseases, together with other biotic and abiotic agents, either kill trees or prevent them from reaching their potential growth. As tree culture becomes more intense, increased exchange of breeding and planting stock can introduce new insect pests and pathogens into Canada.

Two widely planted ornamental poplars in the Canadian Prairie Provinces, Tower poplar (*Populus xcanescens*) and Swedish aspen (*Populus tremula* 'Erecta'), have proved to be highly susceptible to a now common fungal disease known as bronze leaf (*Apioplagiostoma populi*).[129] The disease, specific to species and hybrids of aspens, grey and white poplars (Genus *Populus*, section *Populus*), is incited by the fungus *Apioplagiostoma populi* that results in a characteristic bronze to dark brown pigmentation of infected leaves in late summer and early fall. Branches on affected trees die over a period of several years, disfiguring trees and eventually leading to mortality of susceptible trees. In the Prairie Provinces this disease was first identified in Manitoba and has been moved westward and is now found in all the Prairie Provinces. The fastigiate hybrid poplar AC Sundancer[130] has proven to be resistant to the disease and is being used as a replacement in urban parks.

Septoria musiva[131] has been repeatedly detected in leaf spots and cankers on hybrid *Populus* in nursery and clonal plantations along the lower Fraser River of British Columbia.[132] *Septoria musiva* has also been detected and isolated from leaf spots and cankers of native black cottonwood (*Populus trichocarpa*). Surveys of over 400 different, young and mature *P. trichocarpa* trees, have been carried out along the Fraser River. Additionally, leaves were sampled from a provenance trial with over 180 families of *P. trichocarpa* collected throughout its native range in B.C. and from limited collections in Washington, Oregon and California. Over 40 families tested positive for *S. musiva*. These results indicate that *S. musiva* under favourable conditions can infect multiple families of *P. trichocarpa* from western North America. *P. trichocarpa* is an important riparian species, and the impact that *S. musiva* could have on its growth and ecology is currently unknown. In British Columbia stem cankers lead to significant stem breakage and negatively affect hybrid poplar productivity.[133] The negative impacts of the disease have

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[128] Soolanayakanahally, Raju - Pers. Comm.
[129] Be on the Lookout for Diseased Poplars. https://homes.winnipegfreepress.com/winnipeg-real-estate-articles/renovation-design/Be-on-the-lookout-for-diseased-poplars/id-5671 (Accessed February 20, 2020)
[130] AC Sundancer cultivar Factsheet http://www.poplar.ca/upload/documents/factsheets/ac-sundancer-factsheet-2015.pdf (Accessed February 20, 2020)
[131] The recognized scientifically name for the fungus *Septoria musiva* is *Sphaerulina musiva*
[132] Zeglen, Stefan and Kope, Harry - Pers. Comm.
[133] Zeglen, Stefan and Kope, Harry - Pers. Comm.

led British Columbia to restrict the use of and the importation of clones known to be susceptible to *S. musiva* into British Columbia[134].

Between 2016 and 2019 massive dieback of trembling aspen was reported in the northern half of Alberta. Two factors, extended drought and forest tent caterpillar (*Melacosoma disstria*) infestations, contributed to the extensive dieback. In Alberta the most damaging biotic agent affecting *Populus* was the forest tent caterpillar with over 1.3 million hectares of trembling aspen impacted. Other biotic damaging vectors in Alberta during the reporting period include: armillaria (*Armillaria spp*.) root disease (on *Populus*) - 13,450 ha; gray willow leaf beetle (*Micruapteryx salcifoliella*) (on *Salix*) – 6,990 ha; large aspen tortrix (*Choristoneura conflictana*) (on *Populus*) – 1,143,983 ha; linden looper (*Erannis tiliaria*) (on *Populus*) – 49,152 ha; serpentine leafminer (*Phyllocnistis populiella*) (on *Populus*) – 9, 130 ha, (on *Salix*) – 1,428 ha; tomentosus root rot (*Inonotus tomentosus*) (on *Populus*) – 234 ha, (on *Salix*) – 23 ha; aspen twoleaf tier (*Enargia decolor*) (on *Populus*) – 146,825 ha; willow leaf blotch miner (*Micrurapteryx salicifoliella*) (on *Salix*) – 349,206 ha.[135]

In Alberta the incidence of insects and disease in 15 different hybrid willow clones was evaluated at plantations near Calgary and Camrose, Alberta. *Calligrapha verrucosa* (a species of leaf beetle in the family Chrysomelidae) was the most serious insect pest found in the willow plantations.[136] Other insects found were *Tricholochmaea decora* (gray willow leaf beetle)*, Chryptorhynchus lapathi* (poplar and willow borer), *Chinodes mediofuscella* (leaf tiers), *Micrurapteryx salicifoliella* (willow leaf blotch miner), *Caloptilia stigmatella* (leaf rollers), eirphyid mites, *Trichiosoma triangulum* (willow sawfly) and aphids. Fortunately natural control agents such as birds, parasitic wasps and carabid beetles were also found in abundance. The major disease affecting the willows was Cytospora canker (*Valsa sordida*). It typically infected trees weakened by environmental stress. Severity of damage was realted to willow clone with some clones showing excellent resistance. However, even when insect pests were present willow growth was deemed acceptable. Of the 15 clones planted in these plantations only Preble, Owasco, Viminalis 5027 and Sx64 were not recommended for operational planting because of insect or disease issues.

In Saskatchewan damage surveys showed defoliation over an extensive area of the trembling aspen in the provincial crown forest and parkland areas of the province during the 2016-2019 period.[137] The surveys showed the following area affected: 2016 – 567,738 ha, 2017 – 650,122 ha, 2018 – 145,643 ha and 2019 – 48,875 ha. The surveys grouped all hardwood defoliation vectors together. Ground verification confirmed the causal agent as forest tent caterpillar or large aspen tortrix. Most damage was attributed to forest tent caterpillar. There was no control action in Provincial Forest. The surveys showed the defoliation peaked for two years then caterpillar populations declined rapidly to normal levels. For willow, an outbreak of *Micrurapteryx salicifoliella* (willow leaf blotch miner) was observed on natural willow trees in the provincial forest in 2016 but had subsided by 2017.

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[134] British Columbia Chief Forester Guidance, BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development

[135] Undershultz, Mike – Pers. Comm.

[136] Lee S.I., Pohle, G., Myrholm, C., Tomm, B., Ramsfiled, T. and Krygier R. 2019. Effects of insect pests and diseases in short rotation willow plantations. Presentation to Entomological Societies of Alberta and Saskatchewan, October 3-5, 2019.

[137] McIntosh, Rory and Poniatowski, Brian – Pers. Comm.

In Québec, there was a significant forest tent caterpillar outbreak from 2016 to 2018 in poplar. The outbreak covered 389,030 ha at its peak and caused heavy defoliation. No control measures were taken as forest tent caterpillar rarely results in tree mortality.[138] Fungus causing canker (*Septoria musiva*) has spread into the north-east of portion Québec, more specifically into the Bas-Saint-Laurent region. Over the past years, there has been increasing spread of Septoria canker in typically Septoria-free zones. No control measures are used, rather the goal is to develop and deploy resistant poplar clones.[139]

In Canada, imported cuttings are used as the propagation material to establish willow plantations. Profiling the disease diversity of willow cuttings is vital for early diagnosis, prevention or control of exotic diseases. In a study at the University of Saskatchewan, 82 fungal taxa were isolated and identified from asymptomatic willow cuttings imported in Canada. The most abundant phylum was *Ascomycota*, although some *Basidiomycota* (*Agaricales* and *Tremellales*) were also detected. The most abundant fungal taxa belonged to *Hypocreales*, while the most abundant species belonged to *Kabatiella* in *Dothideales*.[140]

Researchers at the Laurentian Forestry Centre, Canadian Forest Service, University of British Columbia, and Université Laval, Québec showed that biosurveillance can be a proactive approach that may help limit the spread of invasive fungal pathogens of trees, such as rust fungi on poplars. They used a bioinformatics approach, based on whole genome comparison, to identify genome regions that are unique to the poplar leaf rust fungi *Melampsora medusae* and *Melampsora larici-populina*. The procedure demonstrated that the genome-enhanced detection and identification approach could be translated into effective real-time PCR assays to monitor tree fungal pathogens.[141]

At the University of Lethbridge, researchers studied modification of the poplar defense pathway through pathogen-induced expression of an amphibian host defense peptide that modulates plant innate immunity and confers robust and reliable resistance against *Septoria musiva*. Their results provided an insight into development of new technologies for engineering durable disease resistance against major pathogens of poplar.[142]

In British Columbia, Passive Forest Remediation Services Inc. has discontinued using the common west coast poplar clones TXD53-242, DTac-7 due to susceptibility to *Septoria musiva*. They now use poplar clones referred to as Northern Natives from Mike Carlson's collection in the Okanagan Valley, specifically NN 407, NN 416, NN434 and NN457. Their preliminary testing has shown these poplar clones to be less susceptible to *Septoria* canker than DTac-7 and TXD53-242.[143]

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[138] Therrien, Pierre – Pers. Comm.

[139] Prud'homme, Guillaume – Pers. Comm.

[140] Hosseini-Nasabnia, Z., Van Rees, K., and Vujanovic, V. 2016. Preventing unwanted spread of invasive fungal species in willow (*Salix spp.*) plantations. *Canadian Journal of Plant Pathology* 38 (3): 325-337 https://doi.org/10.1080/07060661.2016.1228697

[141] Bergeron, M.-J., Feau, N., Stewart, D., Tanguay, P., and Hamelin, R. C. 2019. Genome-enhanced detection and identification of fungal pathogens responsible for pine and poplar rust diseases. *PLoS One* 14 (2): e0210952 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6364900/

[142] Yevtushenko, D. P., and Misra, S. 2019. Enhancing disease resistance in poplar through modification of its natural defense pathway. *Plant Molecular Biology* 100 (4-5): 481-494 https://link.springer.com/article/10.1007/s11103-019-00874-2

[143] Derbowka, David – Pers. Comm.

Major Biotic Vectors Reported 2016-2019					
			Genera and Area Affected		
Region	**Vector**	Common Name	*Populus*	*Salix*	*Alnus*
British Columbia	*Saperda spp.*	Poplar borers	x		
	Septoria musiva	Septoria canker	x		
	Alniphagus aspericollis	Alder bark beetle			x
	Malacosoma californicum	Western tent caterpillar			x
	Liriomyza brassicae	Serpentine leaf miner	x		
	Venturia macularis	Venturia blight	x		
	Valsa sordida	Cytospora canker	x		
	Valsa umbrina	Cytospora canker			x
	Chryptorhynchus lapathi	Poplar willow borer		x	
Alberta	*Armillaria root disease*	Armillaria root disease	x		
	Malacosoma disstria	Forest tent caterpillar	x		
	Tricholochmaea decora	Gray willow leaf beetle		x	
	Choristoneura conflictana	Large aspen tortrix	x		
	Erannis tiliaria	Linden looper	x		
	Liriomyza brassicae	Serpentine leafminer	x	x	
	Inonotus tomentosus	Tomentosus root rot	x	x	
	Micrurapteryx salicifoliella	Willow leaf miner	x	x	
	Calligrapha verrucosa	Leaf beetle		x	
	Chryptorhynchus lapathi	Poplar and willow borer		x	
	Caloptilia stigmatella	Leaf roller		x	
	Trichiosoma triangulum	Willow sawfly		x	
	Valsa sordida	Cytospora canker		x	
Saskatchewan	*Malacosoma disstria*	Forest tent caterpillar	x		
	Micrurapteryx salicifoliella	Willow leaf blotch miner		x	
	Calligrapha verrucosa	Leaf beetle		x	
	Chryptorhynchus lapathi	Poplar and willow borer		x	
	Septoria musiva	Septoria canker	x		
	Micrurapteryx salicifoliella	Willow leaf miner		x	
Quebec	*Malacosoma disstria*	Forest tent caterpillar	x		
	Septoria musiva	Septoria canker	x		

Ungulates and Rodents

Herbivory of poplars and willows by ungulates (mainly moose and deer) and rodents (beavers, rabbits and voles) have been reported in all Canadian provinces and territories. Damage can be severe and impact above-ground growth and biomass accumulation.[144]

Young poplars and willows are especially susceptible to damage by bark-eating ungulates and rodents during winter. Rabbits frequently clip young shoots during winters of heavy snowfall when other browse is scarce. Tall grass and other heavy ground cover around trees increase the likelihood of damage by mice and voles feeding on the bark during winter, especially in years of large populations. Stems are injured by ungulates rubbing their antlers on them or by gnawing or stripping bark off trees with their incisor teeth. Secondary infections of fungi often enter trees through wounds caused by animals, compounding the damage.

[144] Mosseler, Alex – Pers. Comm.

Control recommendations in all provinces include grass control to minimize damage by voles, applying physical barriers around tree stems to discourage small mammals from feeding and applying repellents to protect trees by discouraging animals from feeding on them. In some cases where ungulate populations are high and damage likely to occur, protective game fencing is installed.

In Saskatchewan, clonal variation in ungulate damage susceptibility was observed in several field trials with Okanese and Walker poplar. In the trials bark had been stripped off lower stems of all Okanese trees by moose (*Alces alces*) whereas the Walker trees were left untouched. In Alberta, Okanese poplar was also clearly favoured over other clones as browse by moose.[145] In Saskatchewan observations indicated the poplar clone Tristis was the preferred food choice of beaver (*Castor canadensis*) over other clones.

b) Abiotic Factors

Abiotic disturbances can produce symptoms that resemble those produced by insects, fungi, or other biotic agents. Careful observation is needed to distinguish issues caused by abiotic factors from those caused by biotic agents. Often abiotic stress is overlooked as a causal agent in poplar or willow decline. The most common abiotic stresses result from extremes in temperature, water supply, chemicals (both in the air and soil), nutrient imbalances, soil compaction, or various mechanical injuries.

In Canada, abiotic stress in poplar and willow are in three broad categories: human activity related (eg. de-icing salts, herbicides); soils related (eg. nutrient availability, drought, salinity) and weather related (eg. precipitation, snow load, temperature, wind). The most restricting abiotic factors affecting poplar and willow in Canada are drought, temperature and soil salinity.

The major abiotic disturbances reported in Saskatchewan during the reporting period were wind damage, flooding and drought. Wind damage was the most prevalent disturbance agent in natural stands of trembling aspen in Saskatchewan. Between 2016 and 2019 over 42,000 ha of aspen forest were affected. Flooded waterbodies resulted in tree mortality of 16,500 ha of trembling aspen between 2016 and 2019. High water levels killed root systems and weakened tree stands enabling colonization by wood-boring beetles. Drought stress together with bark beetles and woodborers led to trembling aspen decline on an estimated 14,000 ha in Saskatchewan between 2016 and 2019.[146] In Alberta, the major abiotic vectors were flooding (*Populus* - 4,100 ha; *Salix* - 14,500 ha); drought (*Populus* – 1,500 ha); and wind (*Populus* - 6,800 ha).[147]

c) Resilience to Threats and Climate Change

It is possible poplar and willow yields will be positively impacted by air temperature increase and negatively by decreasing precipitation. Higher temperature values might boost tree growth due to a prolonged vegetation period, or contrarily, it might hinder tree growth due to higher evapotranspiration and lower soil water availability. However, as the extreme weather events are projected to increase in their frequency and intensity within the framework of the anticipated climate changes, the investigation

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[145] Kamelchuk, Dave – Pers. Comm.
[146] McIntosh, Rory and Poniatowski, Brian – Pers. Comm.
[147] Undershultz, Mike Pers. Comm.

of the effects of extreme weather conditions will need more prominence in the future. In the forest, projections are that pioneer species including *Populus*, *Salix* and *Alnus* will increase.[148]

In view of increasing water stress with a changing climate, the deployment of well-adapted, water use efficient, and productive poplar and willow genotypes will be essential for the sustainability of both forests and wood supply for the forest industry, as climate change is increasing water stress around the world. A study in northern Alberta characterized key traits among new genotypes of hybrid poplars (*Populus* spp.) in water use efficiency (WUE) and evaluated the adaptive capacity of the genotypes to water deficits. This study showed hybrids between *Populus balsamifera* and *Populus maximowiczii* species showed a slightly greater adaptive potential to the geographic area of the study than the other tested cross types.[149]

Spring bud-break phenology is a critical adaptive feature common to temperate perennial woody plants such as poplar. Understanding the molecular underpinnings of variation in bud-break is important for elucidating adaptive evolution and predicting outcomes relating to climate change. Research at the University of British Columbia used field and controlled growth chamber tests to assess population-wide patterns in bud-break from wild-sourced black cottonwood (*Populus trichocarpa*) genotypes. They conducted a genome-wide association study (GWAS) with single nucleotide polymorphisms (SNPs) derived from whole genome sequencing to test for loci underlying variation in bud-break. The researchers proposed GWAS-identified loci underpinned the geographical pattern in *P. trichocarpa* and that variation in bud-break reflected different selection for winter chilling and heat sum accumulation, both of which can be affected by climate warming.[150]

4. Sustainable Livelihoods, Land-use, Production and Bioenergy

Federal and provincial programs and institutions or organizations that, in the past, supported and encouraged poplar and willow research, and their use on agricultural land, have declined in some areas of Canada in recent years. This includes, for example, the federal Prairie Shelterbelt Program, the Alberta Woodlot Extension Society, the Saskatchewan Forestry Centre and the Woodlot Group of Manitoba Agriculture. Rather, these activities have become the responsibility of more broadly focused conservation districts, industry or non-profit groups, for which funding may come from government and other sources.

Nevertheless, well-established practices, coupled with well-tested genetic sources, set the stage for successful new programs being launched.

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[148] Boulanger, Y., Arseneault, D., Boucher, Y., Gauthier, S., Cyr, D., Taylor, A. R., Price, D. T., and Dupuis, S. 2019. Climate change will affect the ability of forest management to reduce gaps between current and presettlement forest composition in southeastern Canada. *Landscape Ecology* 34 (1): 159-174. https://link.springer.com/article/10.1007/s10980-018-0761-6

[149] Niemczyk, M., Hu, Y., and Thomas, B. R. 2019. Selection of Poplar Genotypes for Adapting to Climate Change. *Forests, Trees and Livelihoods* 10 (11). https://doi.org/10.3390/f10111041

[150] McKown, A. D., Klápště, J., Guy, R. D., El-Kassaby, Y. A., and Mansfield, S. D. 2018. Ecological genomics of variation in bud-break phenology and mechanisms of response to climate warming in *Populus trichocarpa*. *New Phytologist* 220 (1): 300-316. https://doi.org/10.1111/nph.15273

a) Nursery Practices

The nursery production of selected clones of hybrid poplar and willow in the Canadian prairies was led by Agriculture and Agri-Food Canada's Agroforestry Development Centre at Indian Head, Saskatchewan from 1901 until the program was discontinued by the Government of Canada in 2013. Under the program, rooted poplar and willow cuttings were available to farmers, other landowners and environmental groups for use in shelterbelts and other environmental uses such as riparian protection. At times, unrooted cuttings were distributed, but low rooting and survival rates in the field mitigated against this.

In the absence of this well-known program, rooted poplars and willows of a suitable clone, price, size and quality are often difficult to obtain for prairie shelterbelts, causing some conservation districts to access these materials and other tree/shrub seedlings from Lincoln-Oakes Nurseries, a conservation nursery in Bismarck, North Dakota, USA[151].

Plantations by unrooted cuttings are successful for certain poplar or willow clones, especially under irrigated or moist conditions. Nurseries supplying stock for such applications need only grow healthy stooling beds from which shoots are collected annually or biennially to be processed into cuttings or whips. Several plantations established by the Swedish Egedal planter[152] require whips of about 2 m in length, which are then cut by the machine, during the time of planting, into 20 cm cuttings, which are planted directly into the ground. A new willow plantation in Forestburg, Alberta, will use unrooted short willow cuttings (10cm billets) buried horizontally using the Hendriksson HSAB Billet Planter[153]. The advantage of this system is that cuttings material can be sourced from plantations harvested with the Hendriksson Billet Harvester[154].

Nurseries with willow stooling beds that currently produce planting stock for bioenergy or other plantings are owned by Agro-Énergie of St-Roch de l'Achigan, Québec[155] and Double A Vineyards of Fredonia, New York, USA. Double A Vineyards has become a reliable source of willow clones that were developed or selected under the State University of New York's research program at Syracuse, NY[156].

Agro-Énergie is currently the main supplier of willow cuttings in Canada for phytoremediation or bioenergy projects and produces introduced and native clones that have been tested in Québec by the Institut de Recherche en Biologie Végétale in Montreal. The willow clones being propagated there include clones from Uppsala, Sweden and from Syracuse, New York. Native willow species are *Salix discolor*, *S. eriocephala*, and *S. interior*. Cuttings are sold as 20 cm dormant cuttings or 1-4 m rods[157]. Some clones were tested and performed well under prairie conditions and are currently being used in two major Alberta phytoremediation projects.

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[151] Lincoln-Oakes Nurseries. Bismarck, North Dakota. http://lincolnoakes.com/stock/pc/viewcontent.asp?idpage=22 (Accessed January 25, 2020)

[152] Egedal Maskinfabrik. Torring, Denmark. Energy Planter. http://www.egedal.dk/produkter/06/002410.html?__locale=en (Accessed January 25, 2020)

[153] Hendriksson Salix AB. Eslov, Sweden. HSAB Billet Planter http://salixab.se/default.asp?iId=GFLFFK (Accessed January 25, 2020)

[154] Krygier, Richard – pers. comm.

[155] Agro-Énergie. St-Roch de l'Achigan, Québec. http://agroenergie.ca/en (Accessed January 25, 2020)

[156] Double A Vineyards. Fredonia, New York. https://doubleavineyards.com/ (Accessed January 25, 2020)

[157] Barbeau, Louis-Clement – pers. comm.

Bionera Resources is a subsidiary of Pacific Regeneration Technologies (PRT) at Campbell River, British Columbia, that, in partnership with Double A Vineyards and Agro-Énergie, plants and maintains willow biomass or phytoremediation projects[158]. PRT's Red Rock Nursery at Prince George, BC, established stooling beds of selected poplar clones for plantation use[159]. Some of these clones as well as selected willow clones were established in stooling beds by Bionera at Campbell River, BC[160].

Conservation foresters in Ontario are able to access adapted clones of hybrid poplar from the Ferguson Tree Nursery in Kemptville, Ontario, which provides stock as either unrooted or rooted cuttings according to the clients' requirements[161]. The most common poplar clones ordered from the nursery are DN-2 and DN-74 which are less disease-prone than some of the other clones used in the past. The clone TN-2293-19 is now also distributed. The nursery also provides a selection of willow clones (SX-64, India, Hotel, Purpurea) usually as unrooted cuttings for environmental projects[162]. The Ferguson Nursery provided rooted poplars for the phytoremediation projects at the Twin Creeks landfill near Watford, Ontario, as well as at the West Carleton Landfill at Carp, Ontario.

Other Ontario nurseries provide small numbers of poplar and willow materials for conservation uses. The Grand River Conservation Authority in Cambridge, Ontario, propagates over 60,000 trees, including balsam poplar and black willow, in its own nursery at Burford, Ontario, for use within their region. Extra seedlings are made available to other conservation authorities[163]. Somerville Nursery, near Alliston, Ontario, also supplies seedlings to conservation authorities[164].

Deciduous seedlings, including poplar and willow cuttings, are available in Québec through the provincial nursery of the Ministère de Forêts, Faune et Parcs (MFFP) at Berthierville, Québec, (46.034, -73.183)[165]. The MFFP also lists private nurseries that produce forest seedlings[166].

Hybrid poplar selections adapted for use in shelterbelts or other applications in the Prairie Provinces (Alberta, Saskatchewan and Manitoba) are available as rooted plugs from Tree Time Services in Edmonton, Alberta[167] and from Prairie Shelterbelt Program in Sundre, Alberta[168]. Poplars can also be

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[158] Bionera Resources. Campbell River, BC. https://www.bionera.com/ (Accessed January 25, 2020)
[159] Van Oosten, Cees – pers. comm.
[160] Van Oosten, Cees – pers. comm.
[161] Ferguson Tree Nursery. Kemptville, Ontario. https://www.fergusontreenursery.ca/ (Accessed January 25, 2020)
[162] Patchell, Ed – pers. comm.
[163] Grand River Conservation Authority – Burford Tree Nursery. Burford, Ontario. https://www.grandriver.ca/en/our-watershed/Burford-Tree-Nursery.aspx (Accessed January 25, 2020)
[164] Somerville Nursery. Alliston, Ontario. https://www.somervillenurseries.com/home (Accessed January 25, 2020)
[165] Government of Quebec – La pépinière de Berthier. Berthierville, Quebec. https://mffp.gouv.qc.ca/forets/semences/semences-pepinieres-berthierville.jsp (Accessed January 25, 2020)
[166] Government of Quebec. Les pépinières forestières privies. https://mffp.gouv.qc.ca/forets/semences/semences-pepinieres-privees.jsp (Accessed January 25, 2020)
[167] Tree Time Services. Edmonton, Alberta. https://treetimeservices.ca/ and https://treetime.ca/ (Accessed January 25, 2020)
[168] Prairie Shelterbelt Program. Sundre, Alberta. https://prairieshelterbeltprogram.ca/store/contact-us (Accessed January 25, 2020)

obtained from many private commercial nurseries across Canada, but they are generally larger caliper stock for landscaping applications.

b) Planted Forests

A substantial area of hybrid poplar plantations have been established in Québec. The previous 5-year report said that 3,100 hectares had been planted in 2012-2015 for a total area of about 12,000 hectares in the province[169]. The largest single planter, Domtar Forest Industries, continues to manage hybrid poplar plantations and expects to meet its goal of having 8,000 hectares (5% of their private forest land) in hybrid poplar by 2020. Domtar began their hybrid poplar plantation program in 1998 and the first harvest was in 2012[170].

The planting of hybrid poplar as a source of wood has generally decreased in Canada following a several decades of pilot projects, clonal improvements and clonal testing and programs by government and industry to explore the use of poplar plantations for pulpwood, OSB, carbon sequestration and bioenergy.

One of the largest hybrid poplar planting programs in western Canada, the Hybrid Poplar Farming program of Alberta-Pacific Forest Products (Al-Pac) in Boyle, Alberta, discontinued new plantings in 2012 and has since maintained the existing stands. Of these, 75% have performed poorly for various reasons such as poor soil, disease, poorly performing clones or depredation by insects or mammals. One clone, Okanese poplar, was clearly favoured over other clones as browse by moose. The remaining 25% of the hybrid poplar plantations will be harvested within the next ten years and chipped as feedstock for pulp for the nearby mill[171].

Al-Pac also has 100 planted hectares of hybrid aspen. Although no new aspen plantings are being established, the existing plots and clonal materials are being monitored for growth, disease resistance and other selection criteria[172].

c) Naturally Regenerated Forest

Trembling aspen and balsam poplar are the main poplar species harvested in Canada and occur naturally across Canada's boreal forest regions from Newfoundland to British Columbia (see Section I – Table 1 and Section IV – Table 2. Wood Removals). Of these, trembling aspen has by far the greatest volume of harvestable wood. Aspen grows in nearly pure stands or dominates the stands in the southern edge of the boreal forest and grows in association with softwoods further to the north. Other naturally occurring poplar species that are harvested in smaller quantities in Canada are black cottonwood (*P. trichocarpa*)

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[169] Doornbos, J., Richardson, J, van Oosten, C. 2016. Activities related to poplar and willow cultivation and utilization in Canada 2012-2015. Poplar and Willow Council of Canada Publication.
[170] Domtar. Welcome to the forest properties of Domtar (virtual tour of several Domtar hybrid poplar plantings). https://www.terraspec.ca/Visite-Virtuelle/Peuplier-Hybride/tour.html (Accessed January 25, 2020)
[171] Kamelchuk, Dave – pers. comm.
[172] Kamelchuk, Dave - pers. comm.

in BC, plains and eastern cottonwood (*P. deltoides*) in the southern prairies and southern Ontario, and largetooth aspen (*P. grandidentata*) in eastern Canada[173].

Aspen forests are harvested by clear-cutting since the species regenerates prolifically from root suckers. It rapidly regrows from many suckers after harvest (or other disturbance such as forest fire) and the suckers self-thin as the stand matures and light becomes the limiting factor[174].

Red alder is a pioneer species in coastal BC and establishes quickly from seed following harvesting of a site and there is no requirement for planting[175]. Because it establishes quickly and grows rapidly, its occurrence has increased dramatically in the past century. However, modern practices of replanting conifers into suitable sites have reduced this somewhat.

d) Agroforestry and Trees Outside Forests

Poplars and willows growing outside of forests in agricultural zones occur naturally in many cases, growing in riparian zones or other areas not used for agricultural crop production. Trees planted, either for their co-benefits with agricultural production or as dedicated plantations, usually include hybrid poplars (often involving *P. deltoides* as one of the parents and other poplar species such as *P. balsamifera*, *P. trichocarpa* or *P. nigra* (European cottonwood)). In the Prairies Provinces, they or selected willow clones are often used as windbreaks, usually around farmyards or acreage homes built near cities (see Section III.6.c. Shelterbelts). Other types of tree plantings are established by conservation groups as wildlife habitat, riparian protection or other environmental purposes.

In the St. Clair Conservation Authority in southeastern Ontario, afforestation designs sometimes include poplars in a mixture as nurse trees to provide protection for more slow-growing hardwoods[176]. To qualify under the 50 Million Tree Program in any of Ontario's 36 conservation authorities, landowners must plant a minimum of 500 trees on their land[177]. In many cases, the tree-planting is done by the local conservation authority or a tree-planting service.

There were several poplar plantation establishment programs in the Prairie Provinces in the last two decades. The Saskatchewan Forestry Centre, which closed in 2009, established almost 60 plantings of various sizes throughout Saskatchewan[178], while the Canadian Wood Fibre Centre, Canadian Forest

[173] Farrar, J. 1995. Trees in Canada. Fitzhenry & Whiteside and the Canadian Forest Service. ISBN 1-55041-199-3 502pp.
[174] Doucet, R. 1989. Regeneration silviculture of aspen.The Forestry Chronicle. February 1989: 23-27. https://pubs.cif-ifc.org/doi/pdf/10.5558/tfc65023-1 (Accessed January 25, 2020)
[175] Carlwood Lumber. Maple Ridge, BC. What makes red alder lumber so unique? https://www.carlwood.com/carlwood-updates/what-makes-red-alder-lumber-so-unique/; Oregon State University – Oregon Wood Innovation Center. Corvallis, Oregon. Red Alder (Alnus rubra). http://owic.oregonstate.edu/red-alder-alnus-rubra (Accessed January 25, 2020)
[176] Shaw, Steve – pers. comm.
[177] Forests Ontario. 50 Million Tree Program. https://www.forestsontario.ca/planting/programs/50-million-tree-program/ (Accessed January 25, 2020)
[178] Woodward, Robin – pers. comm.

Service also established a variety of poplar plantations throughout the prairies and in other locations in Canada as part of their Forest 2020 program[179].

A major research/demonstration planting was developed over a five year period from 1998 at two sites near Meadow Lake, Saskatchewan, by Agriculture and Agri-Food Canada and the University of Saskatchewan (54.029 N Lat, -108.751 W Long and 53.964 N Lat, -108.828 W Long) that occupy almost 80 hectares. Neither of these sites has, as yet, been harvested but, at the former site, the original 1998 clonal block test of about 7 hectares is expected to be harvested within the next five years[180]. Another important research/demonstration site exists at the Saskatchewan Conservation Learning Centre (53.0232 N Lat, -105.769 W Long) south of Prince Albert, Saskatchewan, where a North America wide collection of balsam poplar exists.

Regional special projects continue across Canada. In 2014, an alley-cropping project on the Doig River First Nation, north of Fort St. John, BC, consisted of hybrid poplars and aspen, intercropped with a number of native grasses for grass seed production[181].

5. Application of New Knowledge, Technologies and Techniques

a) Harvesting of Poplars, Willows and Other Fast-Growing Trees

Aspen-dominated forests are often clear-cut and the poplars regenerate naturally from abundant root suckers. In some cases, it is considered more ecologically appropriate and more profitable to encourage softwood regeneration in mixed stands in which the aspen normally delay the regeneration of softwood species. In such cases, selective harvesting of mature aspen, while avoiding softwood undergrowth trees may hasten this process[182].

Details about the Anderson WB-55 "Biobaler", developed by Philippe Savoie of Agriculture and Agri-Food Canada, were not reported in the 2015 report[183]. This machine bales willows and other trees and shrubs. It can cut and bundle a variety of woody materials into standard-sized round bales. The machine, developed at Agriculture and Agri-Food Canada in Laval, Québec, is now manufactured by Groupe Anderson of Chesterville, Québec, and is available for sale[184]. According to Groupe Anderson's Christian

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[179] Dominy, S.W.J., Gilsenan, R.P., McKenney, D.W., Allen, D.J., Hatton, T., Loven, A., Cary, J., Yemshanov, D. and Sidders, D.M. 2010. A retrospective and lessons learned from Natural Resources Canada's Forest 2020 afforestation initiative. For. Chron. 86:339-347.

[180] Cubbon, Dave – pers. comm.

[181] Federation of BC Woodlot Associations. 2014. Doig River First Nation Tests Alley Cropping in the Peace. 2pp. https://woodlot.bc.ca/atlas/wp-content/uploads/sites/2/2014/01/Doig-River-FN-Alleycropping.pdf (Accessed January 25, 2020)

[182] Government of Manitoba 2017. Forest Practices Guide. https://www.gov.mb.ca/sd/forestry/pdf/practices/sup_final_june2017.pdf (Accessed January 25, 2020)

[183] 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.

[184] Groupe Anderson. Chesterville, Québec, https://grpanderson.com/en/biomass-press/bale-processor/biobaler/ (Accessed January 25, 2020)

Pellerin, few of these units have been sold in North America, mainly due to a lack of significant willow energy plantations. The unit has received greater interest from Europe.

An Anderson WB-55 Biobaler, a Claas Jaguar 870 forage harvester fitted with a wood harvesting header and a JF192 Z10 silage harvester, adapted for single-row wood harvesting, were tested and demonstrated in 2016 at the willow phytoremediation plantation at Keoma, Alberta.

Riparian planted willow buffers in Prince Edward Island are harvested on a 3-year rotation using a modified sugar cane harvester belonging to Agriculture and Agri-Food Canada. Only willows outside the 15m setback zone are harvested. The chips are being investigated as a soil additive in potato fields upslope from the riparian zone as a way of immobilizing nitrogen from the agriculture field which may otherwise leach into the riparian zone.

b) Utilization of Poplars, Willows and Other Fast-Growing Trees for Wood Products

Trembling aspen is the main poplar used industrially in Canada and grows in association with balsam poplar and adapted softwoods (spruce, pine, fir) in Canada's boreal forest. Poplar wood is used mainly for pulp or oriented strandboard (OSB). In Saskatchewan, the Annual Allowable Cut (AAC) of hardwoods consists of trembling aspen (83%), balsam poplar (11%) and paper birch (6%).

Partnerships between Agriculture and Agri-Food Canada, forestry companies, the Canadian Forest Service and universities resulted in pilot projects/programs, in which hybrid poplars of adapted clones were grown or tested for productivity, while other test plantations incorporated poplar clones from other sources, such as the United States, in small or large-scale clonal comparisons.

Past hybrid poplar tree-planting programs by forest industries produced plantations throughout Canada – notably by Kruger Forest Products (formerly MacMillan-Bloedel) in BC, Alberta-Pacific (Al-Pac) Forest Products in Alberta and Domtar in Québec. The Al-Pac poplar plantations in Alberta are being harvested for use in the company's pulp mill. Similarly, Domtar, at its Windsor Integrated Paper Mill in Québec, will use the wood from its 8,000 hectares of plantations for its pulp feedstock.

c) Utilization of Poplars, Willows and Other Fast-Growing Trees for Bioenergy

The major source of poplar/willow wood for bioenergy is in the form of harvest by-products from the utilization of native aspen from Canada's boreal forests. Canada's National Forest Database reported that 600 thousand m^3 of hardwood was used nationally in 2017 for fuelwood and firewood[185]. Many wood-processing companies use sawdust, bark and branches to produce power for their mills through co-generation facilities[186].

Selected clones of hybrid poplar and willow can be grown in stands that grow quickly and can be used as dedicated biomass sources for bioenergy. Willow clones are especially suitable for bioenergy because they grow quickly and can be repeatedly coppice-harvested on 3-4 year rotations. This includes, especially hybrids and selections of *Salix viminalis*, *S. miyabeana*, *S. purpurea*, *S. eriocephala*, *S. discolor* and *S. dasyclados* from the State University of New York at Syracuse, New York, and from Uppsala,

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[185] Canadian Council of Forest Ministers. National Forestry Database. http://nfdp.ccfm.org/en/index.php (accessed February 24, 2020).

[186] Bourgoin, Anthony – pers. comm.

Sweden. Many of these clones have been tested throughout Canada and are well-adapted to eastern and central Canada (i.e. the Atlantic Provinces and southern Québec and Ontario) as well as the Pacific coast in BC. A separate program of clonal testing was necessary for the Prairie Provinces, however, to choose material that would survive the severe winters.

6. Environmental and Ecosystem Services

Poplars and willows continue to be used for environmental applications. These include phytoremediation of contaminated soils, disposal of municipal wastewater and biosolids, shelterbelt protection, riparian protection and streambank stabilization.

a) Phytoremediation Projects and Initiatives

Two large-scale willow phytoremediation plantations have been established in Alberta. The first one, at the time of planting in 2014-2016, was the largest contiguous willow plantation in North America (400 hectares at Keoma, Alberta) used over 6.7 million cuttings. Bionera Inc. of Campbell River, BC, a subsidiary of PRT Growing Services[187], was involved in planting of the project, which was managed by Sylvis Environmental[188]. The objective of the plantation was to provide a site in which municipal biosolids from the City of Calgary could be safely and effectively disposed[189]. The clones used in the plantings were a series of Swedish clones of *Salix viminalis* and *S. dasyclados*, as well as clones selected or developed by the State University of New York (SUNY) at Syracuse. The clonal cuttings were provided, Agro-Énergie of St-Roch de l'Achigan, Québec, Double A Vineyards of Fredonia, New York, USA, and by Bionera. The management of the plantation includes periodic coppice harvesting, with the harvested material going to a Calgary composter[190]. Some of the willow shoots were used by the Calgary Zoo for feeding giraffes[191]. At this site, some of the willow clones have produced up to 15 oven dry tonnes/ha annually.

In 2019, Sylvis and Bionera began establishing an even larger 500 ha willow plantation at Forestburg, Alberta, in a coal mine reclamation project, called "BioSalix", with Westmoreland Mining Company. It will use over 7.2 million cuttings. The "BioSalix" [192] project also involves other partners, EPCOR Water Services Inc. and the Canadian Forest Service. In it, municipal waste solids from the City of Edmonton provide nutrients, while the biomass will be used as a bioenergy crop. The project is supported by

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[187] Bionera Resources. Campbell River, BC. https://www.bionera.com/ (Accessed January 25, 2020); Labelle, Martin Pers. Comm.
[188] SYLVIS Environmental Services. Edmonton, Alberta. https://www.sylvis.com/our-company (Accessed January 25, 2020)
[189] Alberta Rural Organic Waste Research Network. Grande Prairie, Alberta. https://www.arowrn.ca/blog/arowrn-keoma-demonstration-site-field-tour-2016/ (Accessed January 25, 2020)
[190] Krygier, Richard – pers. comm.
[191] Krygier, Richard – pers. comm.
[192] Emissions Reduction Alberta. BIOSALIX: Mine Reclamation and Biomass Production https://www.eralberta.ca/projects/details/biosalix-mine-reclamation-and-biomass-production/ (Accessed January 25, 2020)

funding from the Government of Canada's Clean Growth Program[193], and two programs by the Government of Alberta - Alberta Innovates and Emission Reductions Alberta.

In the two Alberta phytoremediation projects, nine different willow clones have been used and are being evaluated. Planting of the willows until now has been by means of the Egedal Energy Planter, developed in Denmark[194]. At least some of the future plantings will be by means of short (10 cm) billets horizontally planted in the rows by the HSAB Billet Planter. Past trials have shown this to be a reliable means of willow establishment which reduces the amount of plant material needed to establish the plantation[195].

In BC, several phytoremediation poplar plantings at Vernon and Armstrong continue to be tended and monitored by Passive Remediation Systems (PRSI)[196]. At Armstrong, some of the trees originally planted have been harvested and are re-sprouting from the roots, while additional trees were planted in 2017. Additionally, PRSI has initiated a new project at a new landfill site near Kitimat, BC, but a question currently under discussion is whether hybrid poplar can be used, due to a concern that it may genetically contaminate the nearby native forest[197].

Waste Management Canada[198] has incorporated poplar plantations into two landfill sites in Ontario. At the Twin Creeks landfill, north of Watford, Ontario, WMC engaged the engineering firm CH2M Hill, which designed a poplar plantation for the safe disposal of landfill leachate[199]. The design was based on the successful poplar plantations established for municipal wastewater treatment at Woodburn, Oregon, USA. The St. Clair Conservation Authority planted the poplars according to the project specifications, using four poplar clones, of which two (NM-6 and DN-154) were judged to be too disease-prone for further use, while DN-2 and DN-74 performed well. The St. Clair Conservation Authority continues to replant and maintain poplars at the site[200].

At the West Carleton Landfill, WMC established 6.2 hectares of hybrid poplar and expanded the plantation by 2.0 hectares in 2014 with proposals to increase the tree plantations by several more hectares with a combination of poplar and willow[201]. According to Steve Shaw, the Forester of the St. Clair Conservation Authority, the success of phytoremediation projects with poplars (or willows) is highly

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[193] Government of Canada. Clean Growth Program. https://www.nrcan.gc.ca/climate-change/canadas-green-future/clean-growth-programs/20254 (Accessed January 25, 2020)
[194] Bionera Resources. Campbell River, BC. https://www.bionera.com/how-we-can-help (Accessed January 25, 2020)
[195] Krygier, Richard – pers. comm.
[196] Derbowka, Dave – pers. comm.
[197] Derbowka, Dave – pers. comm.
[198] Waste Management Canada. https://www.wm.com/ca/en/mybusiness (Accessed January 25, 2020)
[199] Waste Management Canada. Twin Creeks Landfill. (Watford, Ontario). http://twincreekslandfill.wm.com/index.jsp (Accessed January 25, 2020)
[200] Shaw, Steve – pers. comm.
[201] Waste Management Canada. 2014. Final D&O Report Volume 1 - West Carleton EC Landfill Expansion. 229pp. http://wcec.wm.com/documents/our-vision/01%20-%20Final%20D&O%20Report%20Volume%201%20-%20West%20Carleton%20EC%20Landfill%20Expansion.pdf (Accessed January 25, 2020)

dependent on the site (soil, climate, site history, etc.). Those factors must be taken into account when planning the clones, spacing, irrigation, weed control and other maintenance[202].

Willows of seven different species were planted in 2008 as a common garden field test at the Salmon Harbour coal mine near Minto, New Brunswick, and are currently being monitored and assessed for performance – for growth as well as survival and disease incidence[203].

b) Riparian and Streambank Protection

Protection of watercourses and riparian areas is supported by provincial jurisdictions throughout the country as well as by the Government of Canada. In Ontario, the Upper Thames River Conservation Authority and other regional conservation authorities use local native sandbar willow cuttings in bioengineering projects to stabilize eroded streambanks, but do not plant non-native willows or poplars into these areas.

The Province of Ontario[204] and conservation authorities and other organizations support such activities. They have used willows for this purpose throughout the agricultural area of Ontario for many years.[205] Nationally, the Canadian Wildlife Federation[206] promotes the use of native shrub willows for bioengineered protection of degraded streambanks.

In Québec, the Eastern Townships Forest Research Trust with funding from the Federal Government Agriculture Greenhouse Gas Program is studying the factors affecting carbon and excess nutrient capture in hybrid poplar riparian buffers and other agroforestry systems[207]. In another Québec study researchers quantified different ecosystem services (C, N and P storage, wood or biomass production, energy production potential, and indirect conservation opportunities) that could be provided by relatively narrow hybrid poplar riparian buffers implemented along deforested farm streams of watersheds with contrasted agricultural land use[208].

In Prince Edward Island, the East Prince Agri-Environment Association is studying the beneficial environmental effects of planting willow trees along riverbanks.[209] This island wide project has willow riparian buffers planted on 12 sites. Buffers range from 0.5 to 1.0 hectare in size. The five-year project, funded by Agriculture and Agri-Food Canada's Agricultural Greenhouse Gas Program, started in 2017.

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[202] Shaw, Steve - pers. comm.
[203] Mosseler, A., and Major, J. E. 2017. Phytoremediation efficacy of Salix discolor and S. eriocephela on adjacent acidic clay and shale overburden on a former mine site: growth, soil, and foliage traits. Forests, Trees and Livelihoods 8 (12).
[204] Government of Ontario. Land Owner Resource Centre. Restoring shorelines with willows. 4pp. http://www.lrconline.com/Extension_Notes_English/pdf/willows.pdf (Accessed January 25, 2020)
[205] Heaton, M.G., Grillmayer, R., Imhof, J.G. 2002. Ontario's Stream Rehabilitation Manual. https://www.ontariostreams.on.ca/PDF/Ontario%20Streams%20Rehabilitation%20Manual.pdf (Accessed January 25, 2020)
[206] Canadian Wildlife Federation. Plant Easy-to-grow Willows. http://cwf-fcf.org/en/resources/DIY/habitat-projects/map-your-backyard/plant-easy-to-grow-willows.html (Accessed January 25, 2020)
[207] Truax, Benoit – Pers. Comm.
[208] Fortier, J., Truax, B., Gagnon, D., and F. Lambert. 2016. Potential for Hybrid Poplar Riparian Buffers to Provide Ecosystem Services in Three Watersheds with Contrasting Agricultural Land Use. *Forests, Trees and Livelihoods* 7 (2). https://doi.org/10.3390/f7020037 (Accessed February 27, 2020)
[209] McKenna, Andrea – Pers. Comm.

Previous Agriculture and Agri-Food Canada research has shown that willows are an excellent choice for riparian buffers. The project goals are to demonstrate the effectiveness of willow riparian buffers to store carbon, thus mitigating greenhouse gases while protecting streams and rivers from nutrient loading. These willow buffers consist of four rows of *Salix viminalis* '5027' planted between the agricultural field and water body. Willow cuttings are spring planted in parallel single rows at a spacing of 0.5 m in-row and 2.5 m between-row. To maximize nutrient uptake the trees are harvested on a three-year rotation using a modified sugar beet harvester. The wood chips generated are being used to determine if the addition of willow woodchips following potato harvest reduces soil nitrate concentrations and nitrate leaching by immobilizing free nitrogen.[210]

c) Shelterbelts

Widespread planting of adapted poplar and willow clones for the protection of farmyards in Canada's Prairie Provinces (Alberta, Saskatchewan and Manitoba) continued for many years prior to the 2013 closure of the Government of Canada's Agroforestry Development Centre at Indian Head, Saskatchewan. In the 50-year period from 1963 to 2013, 16 million hybrid poplars of various clones and 18 million willows (primarily clones of *S. acutifolia* and *S. alba* var*. sericea*) were planted and most of these trees are presumed to be still in place.

Demand by prairie landowners for poplars and willows for shelterbelts has decreased, possibly because of the increased cost of tree material or the greater difficulty of obtaining trees since the discontinuation of the federal program. Another factor may be the decline in the number of farmyards on the agricultural landscape as farms have become significantly larger in recent decades[211]. Large farms combined with high capacity, precision-guided tractors and combines have also caused the clearing of field shelterbelts as well as native aspen and willow stands, such as those bordering on wetlands and depressions.

Poplar shelterbelts are, however, frequently planted around suburban acreages outside of prairie cities, where new homes are built on unprotected prairies and developers or new homeowners desire rapid shelter and greenery around their properties. For such shelterbelts, male clones are preferred since female clones, when mature, shed voluminous cottony seeds annually, which are annoying and inconvenient for a short period in the summer. For this reason, the preferred clones are Okanese, AC Sundancer and Prairie Sky.

Willows have been planted for roadside shelterbelts (living snow fences) near La Pocatière, Quebec[212], where strong northerly winds, combined with heavy snow loads south of the St. Lawrence River, frequently block or create blizzard conditions along the highways and rural roads. These plantings reflect work done with willow development and utilization south of the border at Syracuse, New York[213]. Roadside shelterbelts were also established along the Trans-Canada Highway in Manitoba in the 1990s incorporating the hybrid poplar clones Prairie Sky and Assiniboine. These poplars have declined in recent

[210] Murray, Brian J. – Pers. Comm.
[211] English, Blair – pers. comm.
[212] Vézina, André - pers. comm.
[213] State University of New York. Willow Living Snow Fences. https://www.esf.edu/willow/lsf/ (Accessed January 25, 2020)

years due mainly to weed competition and drought[214]. Living snow fences have been used elsewhere in Canada, such as along the heavily travelled 401 Highway between Toronto and Windsor, but those shelterbelts typically consist of conifers such as Norway spruce rather than poplars or willows and also incorporate slower-growing hardwoods.

Poplars and willows are generally not used in field shelterbelts because of the concern that they are shorter lived than other slower growing species and, where tile drainage is practiced, there is a concern by landowners about poplar roots clogging the drains. However, a multi-row field shelterbelt of Scots pine (for greater longevity) and poplar (for rapid early protection) was reported from Manitoba[215] and, in southern BC, a successful three-row poplar shelterbelt was reported[216].

In the St. Clair and the Grand River Conservation Authority regions of southwestern Ontario, poplars are avoided in shelterbelts because much of the soil is clay and the fields are tile-drained. Landowners fear that poplar roots will invade the drains[217] [218].

d) Carbon Sink

Tree dry weight (cellulose, hemi-cellulose, lignin, etc.) consists of nearly 50% carbon and so the use of fast-growing poplar and willow has received attention as a way to accumulate carbon – perhaps, like bioenergy plantations, the planting of popalrs and willows is a means to contribute to the carbon economy and to reduce Canada's net greenhouse gas (GHG) emissions.

Prime Minister Justin Trudeau highlighted the value of tree-planting for sequestering carbon in a September, 2019, meeting with activist Greta Thunberg, when he promised that Canada would plant 2 billion trees by 2030[219]. Details of a program(s) to make this happen have not been finalized, but it is supposed that there will soon be federal government funding/support for tree planting across the country.

There have been studies and assessments to quantify and evaluate the carbon offset of poplar or willow plantings[220]. Whether or not programs or markets develop that compensate landowners for the carbon in their plantations, it is clear that the amount of carbon fixed can be substantial. As a long-term practice, however, there will be the important question as to what happens to the carbon in the trees at

[214] English, Blair - pers. comm.
[215] Canart, Ryan – pers. comm.
[216] Derbowka, Dave - pers. comm.
[217] Shaw, Steve - pers. comm.
[218] Grand River Forestry Fact Sheet. Trees & Field Drainage Tiles. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=26&ved=2ahUKEwjGxL2v59boAhUJqZ4KHZ4oA2YQFjAZegQIAxAB&url=https%3A%2F%2Fwww.grandriver.ca%2Fen%2Four-watershed%2Fresources%2FDocuments%2FTree_fact_sheets%2Trees_factsheets_drainage.pdf&usg=AOvVaw2-7aJ-UJ7mpuLm4wzo8noq (Accessed April 6, 2020)
[219] Kuitenbrouwer, Peter, 2019. Planting two billion trees in Canada will be a tall order – Op-ed article: Special to the Globe and Mail. Publ. Nov. 29, 2019.
[220] Anderson, J.A., Long, A., and Luckert M.K. 2015. A financial analysis of establishing poplar plantations for carbon offsets using Alberta and British Columbia's afforestation protocols. Canadian Journal of Forest Research. 45, (2): 207-216.

the end of their rotation (harvest for pulp, bioenergy, biochar, etc.). As for other carbon-reduction ideas, full Life Cycle Analyses are needed for tree-planting schemes.

The Federal Agriculture and Agri-Food Canada department have funded projects that will create technologies, practices and processes that can be adopted by farmers to mitigate GHG emissions[221]. Five of these projects focus on agroforestry practices that utilize poplar and willow in the system.

e) Other Environmental Applications

Willows are an important source of early pollen for native bees that are effective in pollinating managed fields of lowbush blueberries (*Vaccinium angustifolium*) in the Canadian Atlantic provinces (New Brunswick, Prince Edward Island, Newfoundland and Labrador). Lowbush blueberry is a native species that requires insect pollination for fruit set. Plantings of selected early-flowering willows have been incorporated into commercial blueberry harvesting operations to increase the abundance of native pollinators[222].

Some wood from hybrid poplar plantations near Armstrong, BC, is currently being used for small amounts of biochar[223]. In the opinion of Dave Derbowka of Passive Remediation Systems, there is scope for the development of major markets and applications of biochar in the future.

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[221] Agricultural Greenhouse Gases Program http://www.agr.gc.ca/eng/agricultural-programs-and-services/agricultural-greenhouse-gases-program/approved-projects/?id=1508423883267 (Accessed Feb. 27, 2020)

[222] Government of New Brunswick. Pollination of Wild Blueberries https://www2.gnb.ca/content/gnb/en/departments/10/agriculture/content/crops/wild_blueberries/pollination.html (Accessed February 25, 2020)

[223] Derbowka, Dave – pers. comm.

III. General Information

1. Administration and Operation of the Poplar and Willow Council of Canada

a) Composition and Governance of the Council

The Poplar and Willow Council of Canada (PWCC) has an elected Board of Directors which provides overall direction and an Executive Committee that is responsible for coordinating day-to-day activities. Working Groups and committees are established to address specific topics or issues. The Poplar and Willow Council Secretariat is based in Edmonton, Alberta. The Council is a federally incorporated not-for-profit organization. The current address for the Council is:

Poplar and Willow Council of Canada,
c/o Canadian Forest Service,
5320 - 122nd Street,
Edmonton, Alberta, Canada T6H 3S5

Phone: 1- 825-510-1179
Fax: 1- 825-510-1342
Email: poplar@poplar.ca
Web: www.poplar.ca

The PWCC secretariat coordinates member services, maintains a library with poplar and willow references, responds to member and public requests for technical information and administers Poplar and Willow Council communication, finances and administration. The Council employs a part-time Executive Assistant (Deborah Brenton) and part-time Technical Director (Jim Richardson).

The membership of the Council represents a cross-section of individuals and corporations who are interested in the development and utilization of poplar and willow resources in Canada. The Council offers both individual and corporate memberships. Membership is open to all those who support the wise use and management of the poplar resource for all Canadians. Corporate members can designate a number of employees as affiliate members. As of the August 2019 Annual General Meeting Council membership was five corporate members with 19 affiliates, 20 individual members and one associate member.

The PWCC has three distinct working groups addressing specific issues and challenges with poplar and willow management. The current working groups are genetics and breeding, pesticides and environmental service and bioenergy. The Genetics and Breeding Working Group helps coordinate poplar genetics and breeding work across the country. It maintains the Council's poplar and willow clone directory. The committee also developed a series of ten factsheets describing the main hybrid poplar used clones used in western Canada. The Pesticide Working Group supports work 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 for approval. The Environmental Services and Bioenergy Working Group aims to improve the 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.

Board of Directors and Executive Committee of Poplar and Willow Council of Canada (January 2020)

Name	**Role**	**Organization**	**Province**	**Executive Committee**
Raju Soolanayakanahally	Director, Chair	Agriculture and Agri-Food Canada	Saskatchewan	Yes
Barb Thomas	Director, Past Chair	University of Alberta	Alberta	Yes
Bill Schroeder	Director, Vice Chair - West	GreenTree Agroforestry Solutions	Saskatchewan	Yes
Annie DesRochers	Director, Vice Chair - East	Université du Québec en Abitibi-Temiscamingue	Québec	Yes
John Doornbos	Treasurer	No Affiliation	Alberta	Yes
Pierre Perinet	Director, Genetics and Breeding Working Group Chair	No Affiliation	Québec	
Richard Krygier	Director, Pesticide Working Group Chair	Canadian Forest Service	Alberta	
Martin Labelle	Director, Environmental Services and Bioenergy Working Group Chair	Bionera	British Columbia	
Nathalie Isabel	Director at Large	Canadian Forest Service	Québec	
Shathi Akhter	Director at Large	Agriculture and Agri-Food Canada	Saskatchewan	
Andrej Pilipovic	Director at Large	Institute of Lowland Forestry and Environment	Serbia	
Jim Richardson	Director at Large	No Affiliation	Ontario	Yes
Deb Brenton*	Executive Assistant	Poplar and Willow Council	Alberta	Yes*

*Ex-Officio

b) Poplar and Willow Council of Canada Activities

The Council organizes an Annual General Meeting which includes technical and field sessions. The meetings provide opportunity to network with other professionals and gain information on current poplar and willow trends. Annual meetings are held in different locations offering exposure to poplar and willow activities across the country.

The 2016 meeting was held in Regina, Saskatchewan from July 19th to 20th. The two-day meeting was hosted by Agriculture and Agri-Food Canada (AAFC). There were 12 participants from six Canadian Provinces. Among the participants were the 2016 winners of the PWCC-University of British Columbia Student Travel Awards. The two day meeting was a combination of technical presentations and a field tour.

In 2016, the PWCC 'Poplar Gold Leaf' award was established. This award was presented to Bill Schroeder of Agriculture and Agri-Food Canada in 2016 and in 2019 to Pierre Périnet of the Ministère des Forêts, de la Faune et des Parcs of Québec. Both were recognized for lifetime contributions to poplar and willow breeding in Canada.

The 2017 meeting was held in Edmonton Alberta in conjunction with the 11th North American Forest Ecology Workshop. The Council held its annual business meeting during the workshop to receive administrative, financial and technical reports, review progress of Council activities. The meeting included a field trip to view poplar genetics and management on the Forest Management Agreement area of Alberta-Pacific Forest Industries Inc. (Al-Pac) at Boyle, Alberta.

The 2018 meeting was held in Rhinelander, Wisconsin, USA, in conjunction with the International Short Rotation Woody Crops Conference. The PWCC conducted its annual business meeting, where reports of activities for the past year were received and discussed, financial reports and budgets were reviewed and approved. At this meeting membership of the Board of Directors was reviewed and updated, and future activities of the Council discussed. Following the annual meeting participants participated in a three-day field tour of phytoremediation trials with poplars and willows in eastern Wisconsin.

The 2019 annual meeting was held in conjunction with the Canadian Forest Genetics Association Conference in Quebec City. Reports for the past year from the Chair, Technical Director, Executive Assistant and the Pesticide Working Group, were received and adopted and the financial report and 2019-20 budget accepted. Present Board members were approved to continue in office for the coming year.

The Poplar and Willow Council of Canada newsletter was discontinued in 2017 with the last issue fall, 2016. Submissions for the newsletter had declined and a decision made to focus on keeping the website up to date with relevant reports, news items and upcoming events.

The Poplar and Willow Council website can be found at www.poplar.ca.[224] Here members and visitors can find information on membership, council governance, database of poplar and willow clones in Canada, grower's corner, publications, statistics, news and upcoming events. Also available are meeting notices, photo gallery, special publications and reports and links to relevant poplar and willow websites

[224] Poplar and Willow Council of Canada website: http://www.poplar.ca

nationally and internationally. The PWCC website provides an avenue for submission of poplar and willow enquiries. Technical questions are answered by the technical director or a PWCC member.

A major initiative completed in 2019 was the update and revision of the interactive, searchable directory of poplar and willow clones in Canada. The database currently includes a total of 26,419 records, organized in Microsoft Access. The directory is available for searching and viewing online at http://www.poplar.ca/clone-directory. Downloading of the database is available to PWCC members only.

c) Difficulties and Lessons Learned

As with most volunteer organizations, maintaining or growing membership is a struggle. The PWCC is no different. As of 2019, membership includes five corporate (including 19 affiliates), 20 individual and one associate member. This is down from eight corporate members with 35 affiliates, 28 individual and three associate members in 2016. Maintaining Council relevance to the members is a constant challenge for a small organization. Encouraging student members by offering reduced membership fees and travel assistance to attend meetings and conference have been tried, however was only marginally successful. Communication with members is critical to the health of any organization. To this end E-newsflash was implemented as the primary means of communicating with members and alerting them to new information on the website.

Expanding the Council mandate to complement the reform of IPC including other fast-growing tree species within the scope of the Council will be difficult. Canada does not have the diversity of fast-growing species like countries with more temperate or tropical climates. Hybrid larch and alder are possible additions but these are not priority species in Canada.

The PWCC has considered joining other North American poplar and willow groups. This opportunity has been explored to the extent joint meetings between the PWCC and United States poplar and willow groups have occurred. Other options such as joining larger organizations as a sub group or committee could reduce the independence and autonomy of the PWCC. The Council continues to explore these options striving for a sustainable organization that provides value and relevancy to its membership, such as building a link with the Reseau de Ligniculture et Reboisement au Québec.

2. Relevant Literature

Research in poplar and willow (and red alder in BC) continues despite changes in programming or uptake in the various provinces. Federal government researchers in Natural Resources Canada (Canadian Forest Service) and Agriculture and Agri-Food Canada as well as university-based and other researchers across the country continue to study poplar and willow genetics, basic biology, ecological function, uses for bioenergy and phytoremediation, etc. Developments of planting designs, planting methods, agronomy and harvesting and end use technologies are also continuing. A total of 421 papers and technical reports are listed below that were published by Canadian researchers and practitioners in the period 2016-2019.

Abassi, M., Lamhamedi, M. S., Hachani, C., and Z. Bejaoui. 2018. Morpho-physiological evaluation of three *Salix* clones from semi-arid zones subjected to excess zinc under hydroponic conditions. *Canadian Journal of Forest Research* 48 (5): 599-609.

Abassi, M., Lamhamedi, M. S., Hachani, C., and Z. Bejaoui. 2019. Interspecific variability and morpho-physiological responses to salinity of *Salix* main Mediterranean species. *Canadian Journal of Forest Research* 49 (6): 606-615.

Adonsou, K. E., DesRochers, A., and F. Tremblay. 2016. Physiological integration of connected balsam poplar ramets. *Tree Physiology* 36 (7): 797-806.

Adonsou, K. E., DesRochers, A., Tremblay, F., Thomas, B. R., and N. Isabel. 2016. The clonal root system of balsam poplar in upland sites of Quebec and Alberta. *Ecology and Evolution* 6 (19): 6846-6854.

Adonsou, K. E., Drobyshev, I., DesRochers, A., and F. Tremblay. 2016. Root connections affect radial growth of balsam poplar trees. *Trees - Structure and Function* 30 (5): 1775-1783.

Akobi, C., Yeo, H., Hafez, H., and G. Nakhla. 2016. Single-stage and two-stage anaerobic digestion of extruded lignocellulosic biomass. *Applied Energy* 184: 548-559.

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Amichev, B. Y., Bentham, M. J., Kulshreshtha, S. N., Laroque, C. P., Piwowar, J. M., and K. C. J. Van Rees. 2017. Carbon sequestration and growth of six common tree and shrub shelterbelts in Saskatchewan, Canada. *Canadian Journal of Soil Science* 97 (3): 368-381.

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Anderson, J., Prescott, C. E., and S. J. Grayston. 2019. Organic matter accumulation in reclaimed soils under spruce, poplar and grass in the Alberta Oil Sands. *New Forests* 50 (2): 307-322.

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3. Relations with Other Countries

The Poplar and Willow Council represents Canada on the International Poplar Commission which brings together 39 member poplar councils and commissions from around the world. Five members of the PWCC attended the 25th Session of the International Poplar Commission in Berlin, Germany in 2016. At the meeting Barb Thomas, past chair of the Poplar and Willow Council of Canada, was re-elected to the IPC Executive Committee for a 4-year term.

The Council has strong connections to poplar and willow colleagues in the United States including the Short Rotation Woody Crops Operations Working Group and Poplar Council of the United States. Informally poplar and willow academics and scientists maintain research collaborations with colleagues at universities and research institutes worldwide.

IV. SUMMARY STATISTICS 2016-2019

Table 1: Total area of poplars, willows and red alder 2017 and area planted from 2016 to 2019

Land Use Category	Total Area 2019 (ha)	Total Area By Forest Function (%)				Area Planted 2016-2019 (ha)
		Production		Protection (%)	Other (%)	
		Industrial Roundwood (%)	Fuelwood Biomass (%)			
Naturally Regenerating Forest						
Poplars	37,592,950	2		15	83	
Willows	59,281			16	84	
Mix of Poplar and Willows						
Alder	187,260	1		15	84	
Planted Forest						
Poplars	9,000	100				3,000
Willows						
Mix of Poplar and Willows						
Alder						
Other Land With Tree Cover						
Agroforestry and Trees Outside Forests						
Poplars	1,464,860			0.9	99.1	200
Willows	28,384				100	200
Mix of Poplar and Willows	16,000			100		200
Alder						
Trees in Urban Settings						
Poplars						
Willows						
Mix of Poplar and Willows						
Alder						
Grand Total	39,357,735					3,600

Poplar area for "Naturally Regenerating Forest" and "Trees Outside Forests" is from the National Forest Inventory https://nfi.nfis.org/en/data_and_tools)."Trees Outside Forests" area is comprised of the poplar area in the "Prairies" and "Mixedwood Plains", which are primarily agricultural areas. This includes a substantial area of aspen and willow in natural stands on the prairies and willows in riparian zones throughout Canada. It also includes an estimated 16,000 hectares of poplar and/or willows planted in agricultural zones as plantations, shelterbelts, phytoremediation or other purposes.

The total poplar area in the NFI was given as 39,057,810 hectares. The percent for industrial roundwood is based on the area harvested, (National Forestry Database - http://nfdp.ccfm.org/en/data/harvest.php).

Red alder is used to a significant extent in BC (average 161 thousand m^3/year) and is the most common deciduous tree in the Pacific Maritime Ecozone.

The 187,260 hectares reported in the NFI as "Other Hardwoods" and "Unspecified Hardwoods" was therefore assumed to be red alder.

Most poplar plantations in forests are assumed to be for industrial purposes.

Willows in "Naturally Regenerating Forests"and "Trees Outside Forests" were considered to be of the same area as in the most recent report (Doornbos et al. 2016). Most of these willows are naturally occurring willows that protect riparian zones.

Table 2: Wood removals

Land Use Category	Wood Removals 2017 (m^3) (in 1000's)*				
	Total Removals	For Industrial Roundwood			For Fuelwood/Wood Chips
		Veneer/ Plywood**	Pulpwood	Sawnwood	
Naturally Regenerating Forest					
Poplars	20,250	12,515	7,338	0	398
Willows					
Mix of Poplar and Willows					
Alder					
Planted Forest					
Poplars					
Willows					
Mix of Poplar and Willows					
Alder					
Other Land With Tree Cover					
Poplars					
Willows					
Mix of Poplar and Willows					
Alder					
Grand Total	20,250	12,515	7,338	0	398
2014 Grand Total (previous report)***	28,246	10,848	12,411	1,779	3,208

* Reported figures for Wood Removals (2017) were taken from the National Forest Database (NFD) of the Canadian Council of Forest Ministers (http://nfdp.ccfm.org/en/index.php). They were aggregated into Mixed Hardwood (including poplars, willows and other hardwood species). Data available from different provinces specified the poplar component of the hardwood harvest (Nova Scotia - 9%; New Brunswick - 19%; Quebec - 38%; Ontario - 74%; Saskatchewan - 94%; Alberta - 96.4%; British Columbia - 86%)

** The National Forest Database reports harvest (roundwood) as: Fuelwood and firewood; Logs and bolts; Other industrial roundwood; Pulpwood. The figures for logs and bolts and other industrial were combined in the "veneer/plywood" category. It is not known how much of this should be categorized as "sawnwood"

*** The difference in hardwood harvest between 2017 and 2014 is mainly due to the fact that the 2014 numbers are for all hardwoods, while the 2017 numbers estimate poplar harvest, based on the percentages given above. There were significant differences ... in Alberta (1,908 thousand m^3 - 1,048 in Logs and bolts and 860 thousand m^3 in Pulpwood) and in Québec (726 thousand m^3). The apparent increase in "Veneer/plywood" can be attributed to the fact that we were unable to separate out the "sawnwood" component, and that the Québec data reported in 2017 apparently aggregated Fuelwood and firewood, Logs and bolts, and Pulpwood into the Logs and bolts category (8,453 thousand m^3 in 2017 versus 3,738 thousand m^3 in 2014).

Table 3: Forest Products in Roundwood Equivalents

Land Use Category	Forest Products in Roundwood Equivalents (1000 m^3 r)							
	Fuel wood	Chips	Industrial Roundwood (log, pulpwood)	Wood Pulp (Mech. or chem.)	Particle board, Fibre board (MDF, hard board)	Veneer Sheets	Plywood	Sawn wood
Naturally Regenerating Forest								
Poplars	398			7,338	12,515			
Willows								
Mix of Poplar & Willows								
Alder								170
Planted Forest								
Poplars								
Willows								
Mix of Poplar & Willows								
Alder								
Agroforestry								
Poplars								
Willows								
Mix of Poplar & Willows								
Alder								
Grand Total	398	0	0	7,338	12,515	0	0	170

Table 4 Prevailing trends*

	Increase	Decrease	Remain as it is	No Comment
1a. The conversion of **naturally regenerating** forests of poplar to other land uses will ...			X	
1b. The conversion of **naturally regenerating** forests of willow to other land uses will ...			X	
1c. The conversion of **naturally regenerating** forests of other fast growing species to other land uses will ...			X	
2a. The conversion of **planted** forests of poplar to other land uses will ...			X	
2b. The conversion of **planted** forests of willow to other land uses will ...				X
2c. The conversion of **planted** forests of other fast growing species to other land uses will ...				X
3a. The area of poplars for bioenergy plantations will ...	X			
3b. The area of willows for bioenergy plantations will ...			X	
3c. The area of other fast growing trees for bioenergy plantations will ...			X	
4a. Government investments in poplars will ...		X		
4b. Government investments in willows will ...	X			
4c. Government investments in other fast growing trees will ...		X		
5a. Private sector investments in poplars will ...			X	
5b. Private sector investments in willows will ...			X	
5c. Private sector investments in other fast growing trees will ...			X	

Table 4 Prevailing trends cont'd

	Increase	Decrease	Remain as it is	No Comment
6a. The significance of poplars for **productive** purposes will ...	X			
6b. The significance of willows for **productive** purposes will ...			X	
6c. The significance of other fast-growing species for **productive** purposes will ...	X			
7a. The significance of poplars for **environmental protection** purposes will …	X			
7b. The significance of willows for **environmental protection** purposes will ...	X			
7c. The significance of other fast-growing species for **environmental protection** purposes will ...			X	
8a. The rejection by environmental groups of poplars will...			X	
8b. The rejection by environmental groups of willows will...			X	
8c. The rejection by environmental groups of other fast growing trees will...			X	
9a. The **acceptance** by the general public of poplars as important natural resources			X	
9b. The **acceptance** by the general public of willows as important natural resources will...	X			
9c. The **acceptance** by the general public of other fast growing trees as important natural resources will...	X			

*Based on a telephone survey of federal and provincial government representatives, and poplar, willow and other fast growing hardwood breeders, growers and users in Canada

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