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

CANADIAN REPORT TO THE 27TH SESSION OF THE INTERNATIONAL COMMISSION ON POPLARS AND OTHER FAST-GROWING TREES SUSTAINING PEOPLE AND THE ENVIRONMENT (IPC)

BORDEAUX, FRANCE
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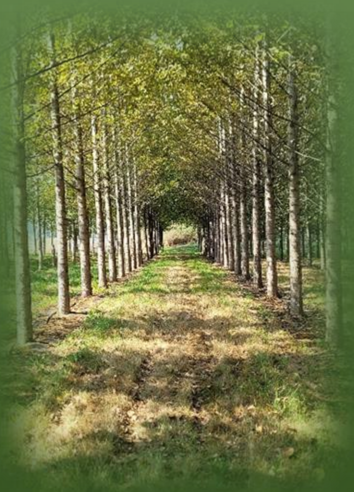

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Canadian Report to the 27th Session of the International Commission on Poplars and other Fast-Growing Trees Sustaining People and the Environment (IPC)
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FOREWORD

The International Commission on Poplars and Other Fast-Growing Trees Sustaining People and the Environment (IPC) of the Food and Agriculture Organization (FAO) stands committed to bolstering rural livelihoods, fortifying food security, and fostering sustainable land use. Our mission hinges on championing the genetic conservation and utilization of poplars, willows, and other fast-growing trees, recognizing their pivotal role in enhancing ecosystem services such as carbon sequestration, biodiversity enrichment, and soil and water conservation.

Recent strides in research, deployment, and technology transfer concerning *Populus*, *Salix*, *Alnus*, and *Acer* species, both in Canada and beyond, underscore a burgeoning demand for plywood and pellet production, the phytoremediation of marginal lands, dedicated bioenergy crops, and biofuel conversion. As this demand surges in the global market, there arises an imperative for widespread cultivation of improved climate resilient cultivars, necessitating collaboration among landowners, governmental bodies, and stakeholders at large.

I am very pleased that the 27th session of the IPC, themed "*Poplars and other fast-growing trees for climate change mitigation and adaptation: pathways to climate resilience and carbon-neutral societies*," scheduled to convene in Bordeaux, France, in October 2024.

I am hopeful that Canada's National Report, spearheaded by the Canadian Forest Service (CFS) and the Poplar and Willow Council of Canada (PWCC), will yield invaluable insights, and prove instrumental to practitioners worldwide.

In closing, I wish to express heartfelt gratitude to Natural Resources Canada - Canadian Forest Service, whose unwavering support has made the production of this report possible. With best wishes for the success of this pivotal global meeting on fast-growing trees, poised to address our shared challenges.

Sincerely,
Raju Soolanayakanahally
Chair, Poplar and Willow Council of Canada

Contents

I Policy and Legal Framework

1. Introduction

Jurisdiction over forestry and agriculture in Canada rests mainly with Canada's ten provinces and three northern territories (Yukon Territory, Northwest Territories and Nunavut). Nunavut is large in area but has little forest land and no commercial forestry and is not discussed further in this report. The provinces have constitutional authority for most laws, policies and regulations affecting natural resources such as forests. The provinces determine land use priorities, grant logging licenses and set harvest levels. Most of these responsibilities have also been devolved by the federal government to the northern territories. The Government of Canada is responsible for national and international issues like migratory birds, fish, and fisheries and for environment and trade agreements.

This section on the policies and laws that affect the status and use of poplars, willows and other fast-growing species focuses on those areas throughout Canada classified as forests (387.6 million ha) and agricultural land (62.2 million ha). Canada's forests are about 82% softwoods while trembling aspen (*Populus tremuloides*) is the main hardwood. Of Canada's total forest area, just under 0.2% (710 thousand hectares) was harvested in 2020, the most recent year for which national harvest data is available.[1]

Area of hardwood species in Canada's forests.[2]

Hardwood Species	Area (1000s of ha.)	Percent of hardwood forest area
Poplar (*P. tremuloides* & *P. balsamifera*)	39,351	60%
Birch	13,504	20%
Maple	9,543	14%
Other hardwoods	3,476	6%
Total	65,874	100%

Most forest land is government-owned and is called "Crown land." The provinces (75.8%) and territories (12.8%) own a total of 88.6% of Canada's forest.[3,4] Provincial and territorial Crown land forests account

[1] Government of Canada, Natural Resources Canada (2022) "The State of Canada's Forests Annual Report 2022." ISSN 1196-1589.
[2] Canadian Council of Forest Ministers, National Forest Inventory – "Table 14. Area (1000 ha) of forest land by species and age class in Canada." https://nfi.nfis.org (Accessed February 2, 2024).
[3] Canadian Council of Forest Ministers, National Forest Inventory – "Table 12. Area of forest land by ownership in Canada ... V.2, November 2022" https://nfi.nfis.org (Accessed January 28, 2024).
[4] Federally managed forest land, 1.7% of the national total, includes national parks, national defence and other purposes. Less than 1% of the wood harvested nationally is from federal land.

for 85% of the wood harvested annually, with private lands making up the remaining harvest (14.9%).[5] Forest companies lease defined areas of these Crown land forests. The provinces and territories develop wood supply agreements and forest management plans with forest companies, who must abide by them in their operations. Forest management plans commit the companies to sustainably managing the forests according to provincial or territorial laws, regulations and policies. The companies pay royalties to the responsible government for the use of the land and the wood that they harvest from it. The maximum amount of wood that they can harvest is specified in the management plan as the Annual Allowable Cut (AAC).

Canada's agricultural land is almost entirely privately owned by 190,000 farms.[6] Much of this land is at least partially treed in forests, woodlots, riparian zones, agroforestry, sandy or swampy areas, etc. Agricultural landowners, provided they abide by provincial and federal agricultural and environmental laws and regulations, such as those that protect waterways, control pesticide use, etc., can make their own decisions about the planting, harvesting and management of trees on their land. Some agriculture producers lease non-forested or partially forested Crown land for grazing cattle.

In Crown land forests, the degree to which poplars are harvested or managed depends on the companies' business plans, their manufacturing processes, and the approved forest management plans. Owners of private forest land, provided they abide by provincial and federal laws, such as those that protect waterways, can make their own decisions about the planting, harvesting and management of trees on their land.

Many forest companies also voluntarily have their forest management practices certified by the Canadian Standards Association (CSA), Forest Stewardship Council (FSC) and/or the Sustainable Forestry Initiative (SFI). These internationally recognized standards may go beyond those agreed to with the respective provinces in the forest management agreements.[7]

The planting of introduced poplars or willows and hybridized or selected clonal material on Crown land is not generally approved. Nevertheless, according to Rivera et al (2016), "Six out of ten Canadian provinces do not have specific legislation to control the use of exotic tree species for reforestation within their borders."[8] Provincial and territorial governments regard their Crown land forests as natural preserves in which, although the forests can be harvested, it must be done in a sustainable manner and their natural ecology should be preserved as much as possible. Anderson et al (2015) suggested that

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[5] Canadian Council of Forest Ministers, National Forest Database – Harvest Table 5.1 Net merchantable volume of roundwood harvested by ownership, category and species group. http://nfdp.ccfm.org/en/data/harvest.php (Accessed January 28, 2024).
[6] Government of Canada, Agriculture and Agri-Food Canada (2024) Overview of Canada's agriculture and agri-food sector. https://agriculture.canada.ca/en/sector/overview (Accessed January 28, 2024).
[7] Government of Canada, Natural Resources Canada (2022) The State of Canada's Forests Annual Report 2022. ISSN 1196-1589.
[8] Rivera, B., M. Barrette, and N. Thiffault (2016) "Issues and perspectives on the use of exotic species in the sustainable management of Canadian forests." Reforesta **1**: 261-280.

restrictions of exotic species on Crown land are excessive and recommended following the trends in Australia and the United States toward the use of more productive and faster growing species.[9]

On private land, there are no regulations restricting the use of selected clonal varieties of poplar or willow. However, poplar or willow plantations, as with all agricultural production, must comply with federal and provincial regulations such as protection of wetlands or the use of herbicides and pesticides. Weed control in plantation establishment is often a major concern and there are few registered chemical control options so that plantation managers must rely mostly on mechanical methods.

The most harvested poplar species 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.[10] It often grows in association with balsam poplar (*Populus balsamifera*). Both species occur naturally across Canada, 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 regenerate naturally through regrowth from root suckers and do not need to be replanted after harvest.

The volume of poplar harvested varies by province/territory. It is directly dependant on the proportion of the natural forest in each province that includes poplar in its composition and the existence of industries to utilize it.

[9] Anderson, J.A., M.K. Luckert and H. N. Campbell (2015) "Potential policy reforms for a 'more exotic' Canadian forest sector: Comparing Canada's plantation policies with those in Australia, New Zealand and the United States." The Forestry Chronicle **91** (5): 560-572.

[10] Canadian Council of Forest Ministers, National Forest Inventory. https://nfi.nfis.org/en/data_and_tools (Accessed January 28, 2024).

Harvested softwood/hardwood/poplar in 2020 by province/territory (1000s of m^3).[11]

Province/Territory	Softwoods	Hardwoods	Poplar (see Part 4 – Summary Statistics – Table 2)
British Columbia	54,306	236	203
Alberta	19,108	10,545	10,166
Saskatchewan	1,588	2,471	2,322
Manitoba	773	479	398
Ontario	10,302	3,190	2,361
Québec	20,374	5,552	2,110
New Brunswick	6,208	3,133	595
Nova Scotia	2,168	335	30
Prince Edward Island	82	278	53
Newfoundland/Labrador	1,223	77	74
Yukon Territory	2	0	0
Northwest Territories	35	2	2
TOTAL	116,160	26,293	18,314

Willow species are not considered to be commercial forest hardwood species. The area covered by willows on Crown land or private land and the degree to which they are harvested cannot be determined from the National Forest Inventory or the National Forest Database, but the harvest of willow is likely negligible. Willows that occur naturally in wetlands may be protected by laws that protect riparian zones and are not harvested in such areas.

Crown land leases are either for wood management and harvesting or for agricultural livestock grazing, but usually not both. Most provinces do not have policies or regulations that allow both livestock producers and forest industries to use the same Crown land to their mutual benefit. Studies have shown that silvopasture and agroforestry can be sustainable systems in which the value of the forest for wood and livestock production is optimized. In practice, however, the companies or individuals interested in harvesting wood are different from those producing livestock and mutually beneficial management plans are difficult to formulate. Functional silvopasture systems, therefore, are more likely to occur on private lands, in which the landowner has interest in both the livestock and the wood production.

Poplar or willow hybrids or selections are generally grown on privately owned agricultural land rather than on forested Crown land. The production and harvest of these trees for industrial products (wood, bioenergy, or other commercial purposes) is generally not affected by federal or provincial regulations but can be encouraged or supported by programming that addresses climate change, environmental protection, bioenergy, economic innovation, etc.

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[11] Canadian Council of Forest Ministers, National Forest Database – Harvest Table 5.1 Net merchantable volume of roundwood harvested by jurisdiction and species group. http://nfdp.ccfm.org/en/data/harvest.php (Accessed January 28, 2024).

When poplar and willow are grown for phytoremediation – landfills, water treatment, mine spoils or industrial sites – there are usually additional regulations or restrictions, especially for the safe management of water or soil that may contain substances considered hazardous to human health or to the environment. Because phytoremediation has been a topic of significant research in recent years, the design of phytoremediation systems and the development of accepted engineering standards are likely to improve in coming years so that government policies or regulations can be amended to allow for effective use of poplars and willows for this purpose.

2. Canadian National Policies and Laws

The Government of Canada conducts forestry-based research through Natural Resources Canada's Canadian Forest Service (NRCan - CFS) and agriculture-based research is conducted through Agriculture and Agri-Food Canada (AAFC). Both departments emphasize environmental sustainability in their research programs and collaborate with researchers in Environment and Climate Change Canada (ECCC). Much collaborative research is done by scientists in these three federal departments.

The Government of Canada works in partnership with provinces and territories in forestry, agriculture and the environment. In 2017, the Canadian Council of Forest Ministers (CCFM) published "A Forest Bioeconomy Framework for Canada" in which it stated, "Potential forest biomass comes from a variety of sources such as sustainable wood supply and biomass plantations (e.g., fast-growing willow species) ... Private woodlot owners can offer flexibility and innovative approaches to supplying fibre as well as offering long term supply contracts." [12]

The "Federal Sustainable Development Act",[13] 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."[14]

[12] Canadian Council of Forest Ministers (2017) "A Forest Bioeconomy Framework for Canada." ISBN: 978-0-660-09391-8 30pp. https://cfs.nrcan.gc.ca/publications?id=39162 (Accessed February 12, 2024).
[13] 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/ (Accessed February 2, 2024).
[14] 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 (Accessed February 2, 2024).

The Government of Canada provides funding for tree planting under the 10-year (2020-2030) Two Billion Trees (2BT) program as "part of our commitment to nature-based climate solutions."[15] This is also a part of Canada's Paris Agreement greenhouse gases emissions reduction target.[16] The 2BT program funding is for provinces, territories, third-party organizations, and Indigenous organizations and includes trees planted on public or private lands. The program supports projects in remote, rural, suburban, and urban areas and this includes afforestation projects. This program is now being accessed for poplar and willow planting projects for phytoremediation or other purposes. In 2021 and 2022, the 2BT program supported the planting of around 6.4 million willows and 1.4 million poplars. Data for 2023 tree plantings is not yet available.[17]

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.[18,19] Forests Ontario, which has a "50 Million Tree Program" to provide trees for the same purposes, recently signed an agreement with the federal 2BT program to increase its support to help Ontario landowners plant poplars, willows and other species on their farms and other landholdings for shelter, afforestation, riparian protection and other uses.[20]

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,[21] Agriculture and Agri-Food Canada,[22] or other federal departments – the Government of Canada encourages the planting, harvesting and utilization of poplars and willows. Agroforestry research is also supported by Agriculture and Agri-Food Canada's 10-year Living

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[15] Government of Canada. Two billion trees program. https://www.canada.ca/en/campaign/2-billion-trees/2-billion-trees-program.html (Accessed February 2, 2024).
[16] Government of Canada (2022) "Canada's 8th National Communication and 5th Biennial Report." https://www.canada.ca/en/campaign/2-billion-trees/2-billion-trees-program.html (Accessed February 14, 2024)
[17] 2 Billion Trees program – Pers. Comm.
[18] 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 February 14, 2024).
[19] 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 (Accessed February 14, 2024).
[20] Forests Ontario. 50 Million Tree Program https://www.forestsontario.ca/planting/programs/50-million-tree-program (accessed February 2, 2024).
[21] Government of Canada, Natural Resources Canada (2024) Funding, grants and incentives https://www.nrcan.gc.ca/funding-grants-incentives/4943 (Accessed February 14, 2024).
[22] Government of Canada, Agriculture and Agri-Food Canada. Agricultural Climate Solutions https://agriculture.canada.ca/en/environment/climate-change/climate-solutions (Accessed February 14, 2024)

Laboratories Program.[23] In addition, the Genomic Adaptation and Resilience to Climate Change (GenARCC) project, a collaborative inter-departmental effort, is aimed at harnessing the power of genomics to safeguard the future of these critical ecosystems.[24]

Although jurisdiction for forestry and agriculture rests mainly with the various provinces, the Government of Canada, by making international agreements, creating national legislation and programs, 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 trees.

3. British Columbia

British Columbia (BC) is the most heavily forested province in Canada. Of the 116 million m^3 of softwood harvested from Canadian forests in 2020, 54 million m^3 (47%) came from BC.[25] Crown land forests accounted for 84% of BC's 2020 harvest. However, hardwoods comprised only 0.4% of BC's 2020 harvest. About 86% of the hardwood harvested is poplar (aspen and cottonwood)[26] with the remainder being alder, birch, and maple. From 2015 to 2019, red alder (*Alnus rubra*), a fast-growing species in BC's coastal regions, made up over 9% of the hardwood harvest.[27] Bigleaf maple (*Acer macrophyllum*) may be considered as a potential fast-growing species in Canada and the western United States. It grows in BC's coastal region and has commercial value. Although it regenerates from cut stumps, planted seedlings are recommended for producing quality lumber.[28]

BC's 2002 Forest and Range Practices Act (Chapter 69)[29] governs the use of provincially owned Crown land and sets criteria for Forest Stewardship Plans and Woodlot Licence Plans. Although BC allows for

[23] Government of Canada, Agriculture and Agri-Food Canada. 2024. https://agriculture.canada.ca/en/environment/climate-change/agricultural-climate-solutions/agricultural-climate-solutions-living-labs (Accessed February 14, 2024).

[24] Government of Canada, Environment and Climate Change Canada https://www.canada.ca/en/environment-climate-change/services/climate-change/adapting/genomic-adaptation-resilience-climate-change.html (Accessed March 11, 2024).

[25] Canadian Council of Forest Ministers, National Forest Database – Harvest Table 5.1 Net merchantable volume of roundwood harvested by jurisdiction and species group. http://nfdp.ccfm.org/en/data/harvest.php (Accessed January 28, 2024).

[26] 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 14, 2024).

[27] Fong, Edward – Pers. Comm.

[28] Oregon State University, Oregon Wood Innovation Center. https://owic.oregonstate.edu/bigleaf-maple-acer-macrophyllum (Accessed February 22, 2024).

[29] 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 14, 2024).

selected poplars to be planted on Crown land for research or demonstration purposes, clonal poplar plantings are limited to a maximum of 10 hectares.[30]

The Government of British Columbia provides agroforestry information through the Ministry of Agriculture[31] and other information is provided bythe Federation of British Columbia Woodlot Associations.[32] There are regulatory considerations for planting poplars or willows on land classified as agricultural since the BC Assessment Authority specifies that, "fast-growing cottonwood/poplar/aspen and willow cultivated in planting will qualify (as crops) as long as they mature within 12 years."[33] Shelterbelts are not affected by this as they are considered to be agriculture infrastructure plantings.

4. Alberta

Alberta's harvest in 2020 was 29.7 million m^3, of which 36% was hardwood.[34] The hardwood was 81% trembling aspen and 15% balsam poplar.[35] Over 75% of the poplar harvested comes from provincial Crown land.[36]

On Crown land, Forest Management Agreements (FMAs) between the Province of Alberta and forest companies prohibit the planting of non-native species such as hybrid poplar or non-native willows. Clonal material of locally collected native species, including balsam poplar and trembling aspen, may be planted on Crown land in order that tree improvement may occur within the local populations.[37] The FMAs also specify the buffer widths for various riparian areas (rivers, streams, wetlands, and lakes). This limits the degree to which species associated with riparian zones, such as willows, can be harvested.

Because Alberta has a great amount of commercial aspen forest in the boreal forest's southern fringe, and in the foothills of the Rocky Mountains, both areas merging with natural grazing lands for commercial beef production, the province has developed several publications to facilitate silvopastoral sharing of Crown land between beef producers and forest companies. The 2006 "Grazing and Timber

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[30] Zabek, Lisa – Pers. Comm.
[31] Government of British Columbia. https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/agricultural-land-and-environment/agroforestry (Accessed February 14, 2024).
[32] Federation of BC Woodlot Associations. https://woodlot.bc.ca/ (Accessed February 22, 2024).
[33] 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 22, 2024).
[34] Canadian Council of Forest Ministers. National Forestry Database. http://nfdp.ccfm.org/en/index.php (Accessed February 14, 2024).
[35] Government of Alberta (2023) "Alberta's forest economy 2023: A handbook of public economic and socioeconomic accounts." https://open.alberta.ca/dataset/bcec0091-cac0-4257-a8fd-bee57b8a0e6a/resource/1b596266-003c-4ca9-b835-c24bec464613/download/fp-albertas-forest-economy-2023.pdf (Accessed February 22, 2024).
[36] Canadian Council of Forest Ministers. National Forestry Database. http://nfdp.ccfm.org/en/index.php (Accessed February 14, 2024).
[37] 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 (Accessed February 14, 2024).

Integration Manual"[38] encourages co-management of certain areas with the development of a "Grazing Timber Agreement" based upon pre-agreement inventories of woody and herbaceous vegetation and on-going monitoring of these resources and on-going communications between the stakeholders.

Alberta-Pacific Forest Products of Boyle, Alberta, with a pulp mill using poplar, is among the forest industries in Canada that are certified by the Forest Stewardship Council (FSC).[39] FSC criteria are stringent with respect to environmental management of forests and address many aspects of environmental stewardship and sustainability.

The Government of Alberta program, Alberta Innovates,[40] provides funding for projects that seek to diversify the province's economy or reduce its net greenhouse gas emissions. Reduction of the use of coal for energy within the province may encourage the use of poplars and willows for bioenergy, while at the same time, revegetating and reclaiming coal mine sites[41] (see Section II.6.a. Phytoremediation Projects and Initiatives).

5. Saskatchewan

Harvested hardwood in Saskatchewan was 2.5 million m^3 in 2020, 61% of the total wood harvested in the province.[42] Trembling aspen and balsam poplar account for 83% and 11%, respectively, of the hardwood harvested. Over 85% of the hardwood harvested in Saskatchewan comes from Crown land, the majority being used by four large processors (two OSB mills and two pulp mills).[43] Additionally, three sawmills use softwoods to produce lumber.

Management of forests on Saskatchewan Crown land is regulated through the Forest Resources Management Act, Forest Resources Management Regulations, and the Saskatchewan Environmental Code.[44] Forest companies sign 20-year Forest Management Agreements with the Government of Saskatchewan. Among other things, 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 and propagation of exotic plants on provincial forest

[38] Government of Alberta (2006) "Grazing timber integration manual." https://open.alberta.ca/publications/3594022 (Accessed February 23, 2024).
[39] Forest Stewardship Council (FSC). https://ca.fsc.org/en-ca (Accessed February 14, 2024).
[40] Government of Alberta. Alberta Innovates. https://albertainnovates.ca (Accessed February 11, 2024).
[41] Government of Alberta (2019) "Alberta coal mine reclamation project to provide green energy source." https://albertainnovates.ca/news/alberta-coal-mine-reclamation-project-to-provide-green-energy-source (Accessed February 14, 2024).
[42] Canadian Council of Forest Ministers. National Forestry Database. http://nfdp.ccfm.org/en/data/harvest.php (Accessed February 7, 2024).
[43] Province of Saskatchewan. https://gisappl.saskatchewan.ca/Map_Gallery/Administrative/pdf/Timber_Supply_Map.pdf (Accessed February 11, 2024).
[44] Government of Saskatchewan. https://publications.saskatchewan.ca/#/home (Accessed February 11, 2024).

land."[45] 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. 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. Although Agriculture and Agri-Food Canada's (AAFC) Agroforestry Development Centre at Indian Head, Saskatchewan and the Saskatchewan Forestry Centre at Prince Albert are now closed, many poplar test plantings or demonstration plantings that were established still survive. The University of Saskatchewan's Centre for Northern Agroforestry and Afforestation conducted trials and research in various Saskatchewan sites resulting in graduate student theses and peer-reviewed papers, some of which are to be found in Section III-2 Literature.

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. Genetic collections of balsam poplar, hybrid poplar and hybrid and native willow continue to be cared for at the Agriculture and Agri-Food Canada Research Farm at Indian Head, Saskatchewan.

6. Manitoba

Manitoba's 2020-2021 reported wood harvest (1,252 thousand m^3) was entirely from Crown land.[46] The hardwood component of that (479 thousand m^3) was mainly trembling aspen while the remainder was balsam poplar and white birch. Forest companies operate in Crown forests under provincially approved Forest Management Plans.

Watershed-based conservation districts, represented provincially by the Manitoba Association of Watersheds,[47] conduct tree-planting programs in agricultural Manitoba. The province currently provides funding to these watershed districts. Support for tree-planting comes from several sources, of which the federal 2 Billion Trees program is an important one,[48] under an agreement between the Province of Manitoba and Natural Resources Canada.[49] Tree seedlings and rooted cuttings are supplied from a number of private nurseries, with the program covering the cost of trees and providing payments to the landowner for maintenance costs.[50] Some of the poplar material used in the program is provided by the Lincoln-Oakes Conservation Nursery in Bismarck, North Dakota.

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[45] Government of Saskatchewan. F-19.1 Reg 1 - The Forest Resources Management Regulations https://publications.saskatchewan.ca/#/products/1124 (Accessed February 11, 2024).
[46] Canadian Council of Forest Ministers. National Forestry Database. http://nfdp.ccfm.org/en/data/harvest.php (Accessed February 7, 2024).
[47] Manitoba Association of Watersheds. https://manitobawatersheds.org/ (Accessed February 12, 2024).
[48] Assiniboine West Watershed District (2023) "Back to our roots: Tree planting programs alive and strong in AWWD." Page 16 in: "The Current" Manitoba Association of Watersheds Newsletter. http://lesterfiles.com/pubs/MAW/the-current/2023/#p=16 (Accessed February 12, 2024).
[49] Province of Manitoba (2023) https://www.gov.mb.ca/nrnd/forest/2-billion-trees/index.html (Accessed February 12, 2024).
[50] Canart, Ryan – Pers. Comm.

Current large-scale precision farming with field machinery traveling in straight lines has resulted in the clearing of small copses of aspen and willows surrounding wetlands.

7. Ontario

Poplar (trembling aspen and balsam poplar) constitutes approximately 80% of the hardwood harvested in Ontario in 2020 and 22% of the total wood harvested.[51] The other main hardwood species is white birch (7% of the hardwood harvested). Private land wood harvest in 2020 was not reported in the National Forest Database.[52]

Wood is harvested from Crown land by forest companies according to Sustainable Forest Licences with the Province of Ontario, by which the companies agree to manage and harvest the forest land according to management plans, including replanting or maintenance of harvested lands.

Many trees are planted, maintained, or harvested on private land in the predominantly agricultural Mixedwood Plains. Landowners can receive support through Forests Ontario under its 50 Million Tree Program, now funded by the federal 2 Billion Trees program.[53]

Part of this funding supports the tree-planting programs of Conservation Ontario's 36 conservation authorities (CAs).[54] For example, the Grand River CA plants about 150 thousand trees per year, of which about 20% are poplars or willows.[55] Tree-planting, both on private and publicly owned land, is an important component of the conservation services undertaken by these CAs. Through the CAs, 1,710 landowners planted 1.3 million trees in 2020. Like other CAs, the Grand River CA's tree-planting program receives financial support from the 2 Billion Trees program[56] through Forests Ontario.[57] CAs annually get just over 50% of their basic funding from municipal taxes, while 35% is self-generated from the parks that they operate and the remainder comes from the provincial and federal governments.[58] The CAs also have responsibility for regulating development activities that affect riparian areas and follow federal, provincial and municipal laws and policies.

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[51] Government of Ontario. Analysis of Regional Wood Supply. https://data.ontario.ca/dataset/analysis-of-regional-wood-supply (Accessed February 6, 2024).
[52] Canadian Council of Forest Ministers. National Forestry Database. http://nfdp.ccfm.org/en/index.php (Accessed February 6, 2024).
[53] Forests Ontario (2021) "2020-2021 Annual Report." https://forestsontario.ca/en/resource/annual-reports (Accessed February 6, 2024).
[54] Conservation Ontario. https://conservationontario.ca (Accessed February 6, 2024)
[55] Grand River Conservation Authority (2024) "Tree planting." https://www.grandriver.ca/en/our-watershed/Tree-planting.aspx#gsc.tab=0 (Accessed February 14, 2024).
[56] Grand River Conservation Authority (2024) "Agenda - Annual General Meeting. Friday, February 23, 2024." https://calendar.grandriver.ca/directors/Detail/2024-02-23-GRCA-General-Membership-Meeting-Annual-General-Mee/Agenda%20Package%20-%20GRCA%20Annual%20General%20Meeting_Feb23_2024.pdf (Accessed February 16, 2024).
[57] Munn, Nathan – Pers. Comm.
[58] Conservation Ontario. https://conservationontario.ca (Accessed February 6, 2024).

8. Québec

Of the 26 million m^3 harvested in Québec in 2020, 21% was hardwood.[59] Most of this was trembling aspen, with the other hardwood species being mainly maple and birch species. 29% of Québec's wood harvest in 2020 was from private land.[60] Private land occurs mainly in the southerly Mixedwood Plains Ecozone and Atlantic Maritime Ecozone, which contain a greater percentage of valuable hardwood, like maple and oak, than the more northerly Crown lands.

Québec's Sustainable Forest Development Act governs the harvest and use of wood and management of forests in the province.[61] 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 agree to General Forest Management Plans (GFMPs) which incorporate the RSFM regulations.[62] Domtar and other forest companies have additional forest certifications – primarily through the Forest Stewardship Council (FSC) and the Sustainable Forest Initiative (SFI).

Government of Québec scientists initiated a hybrid poplar breeding and selection program in 1969, with testing of clonal material at different sites throughout Québec.[63,64] A 2008 Green Paper 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 ecosystem management areas.[65]

Some of the poplar plantations by various companies in Québec have been on Crown land[66] but most of them 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.

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[59] Canadian Council of Forest Ministers. National Forestry Database. http://nfdp.ccfm.org/en/index.php (Accessed February 16, 2024).
[60] Canadian Council of Forest Ministers. National Forestry Database. http://nfdp.ccfm.org/en/index.php (Accessed February 16, 2024).
[61] Government of Québec (2023) "Sustainable Forest Development Act – Updated to December 1, 2023." http://legisquebec.gouv.qc.ca/en/ShowDoc/cs/A-18.1 (Accessed February 17, 2024).
[62] Government of Québec. Guide to the application of the regulation on the sustainable development of forests in the state domain. https://mffp.gouv.qc.ca/RADF/guide/presentation-du-guide-dapplication/ (Accessed February 17, 2024).
[63] Périnet, P (2007) "Le programme d'amélioration génétique du peuplier au Québec." In P. Périnet, M. Perron and P. Bélanger (eds.). La populiculture : un projet collectif, du clone à l'usine. Guide des visites de terrain. Réunion annuelle 2007 du Conseil du peuplier du Canada. pp. 11–12.
[64] Périnet, P., H. Gagnon and S. Morin (2008) "Liste des clones recommandés de peuplier hybride par sous-région écologique au Québec (révision février 2008)." Direction de la recherche forestière, MRN, Québec.
[65] Government of Québec (2008) "Forests: Building a future for Québec." ISBN 978-2-550-52051-1 74pp.
[66] Doornbos, J., J. Richardson and C. van Oosten (2016) "Activities related to poplar and willow utilization in Canada 2012-2015." p19.

Trees and shrubs planted on private land for riparian buffers and other agri-environmental purposes are supported with a 70% to 85% cost share of eligible projects by the Québec Government's Program Prime-Vert.[67] This includes all establishment costs, including the cost of seedlings, soil preparation, the laying of black plastic weed barrier and planting – normally all provided by private companies or contractors.[68]

9. New Brunswick

Forestry land in New Brunswick consists of Crown land, privately owned industrial forest lands and private woodlots. Hardwoods constituted 34% of New Brunswick's total harvest in 2020 and consisted mainly of maple and birch. Trembling aspen (*Populus tremuloides*) and largetooth aspen (*Populus grandidentata*) accounted for only 19% of the hardwoods harvested.[69]

Crown land forests accounted for 60% of the volume[70] that was harvested by companies under Forest Management Agreements.[71] Under the province's Forest Act, planting of non-native trees, such as hybrid poplar is prohibited on provincially owned Crown lands.

Private woodlots, occupying 1.9 million hectares, account for 30% of the province's forests. Through the Private Woodlot Silviculture Program, the provincial government provides 90% funding for silviculture treatments (site preparation, planting, weed management and thinning). Woodlot owners must comply with all applicable legislation, including laws dealing with water bodies, forest fires and pesticide applications. In addition, eligible projects must follow accepted Beneficial Management Practices and take into consideration, adaptation to climate change.[72]

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.

[67] Government of Quebec. Programme Prime-Vert. https://www.mapaq.gouv.qc.ca/SiteCollectionDocuments/Formulaires/Programme-Prime-Vert-2023-2026.pdf (Accessed February 16, 2024).
[68] Vézina, André – Pers. Comm.
[69] Canadian Council of Forest Ministers. National Forestry Database. http://nfdp.ccfm.org/en/index.php (Accessed February 6, 2024).
[70] Canadian Council of Forest Ministers. National Forestry Database. http://nfdp.ccfm.org/en/index.php (Accessed February 6, 2024).
[71] 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 (Accessed February 11, 2024).
[72] Government of New Brunswick (2019) "New Brunswick Private Woodlot Silviculture Program 2023-2024." https://senb.ca/images/2023-24_Private_Woodlot_Silviculture_Manual_EN.pdf (Accessed February 22, 2024).

10. Prince Edward Island

In 2020, 97% of the wood harvested in Prince Edward Island came from private land.[73] Forests occupy just under half of the island's total area of 568,600 hectares and 85% of this is privately owned.[74] The hardwood harvest constituted 84% of the total wood harvest in 2020, with the majority of that being red maple (*Acer rubrum*).[75] Poplar is only 16% of the PEI's hardwood harvest.

The Government of PEI encourages the use of biomass for energy, but woody biomass from willow and/or poplar is not yet a major practice. Legislated 15 meters (m) riparian buffer widths apply to agricultural and forest lands alike. Although experimental willow buffers have been planted to protect riparian zones, only those that are more than 15 m from the water's edge can be harvested for biomass.[76]

11. Nova Scotia

Private land forestry is dominant in Nova Scotia (75% of total wood harvested in 2020). Hardwoods account for 13% (335 thousand m^3) of the total provincial harvest (2.5 million 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.[77]

Riparian buffer zones in Nova Scotia, in which wood harvesting is not permitted, are fixed at 20 m by the Wildlife Habitat and Watercourse Protection Regulations on both Crown land and privately owned forest land.[78] This limits the degree to which species associated with riparian zones are available for harvest (i.e., willows or balsam poplar).

Plantations on both private and Crown land consist of native softwoods (spruce or pine). Nova Scotia has followed Québec's lead in adopting a "Triad" system of forest management which categorizes three

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[73] Canadian Council of Forest Ministers. National Forest Database – Harvest Table 5.1 Net merchantable volume harvested by tenure (http://nfdp.ccfm.org/en/data/harvest.php (Accessed January 28, 2024).
[74] Government of Prince Edward Island (2020) "State of the Forest Report 2020." https://www.princeedwardisland.ca/sites/default/files/publications/state_of_the_forest_2020.pdf (Accessed February 6, 2024).
[75] Government of Prince Edward Island (2020) "State of the Forest Report 2020." https://www.princeedwardisland.ca/sites/default/files/publications/state_of_the_forest_2020.pdf (Accessed February 6, 2024).
[76] Government of Prince Edward Island (2020) "State of the Forest Report 2020." https://www.princeedwardisland.ca/sites/default/files/publications/state_of_the_forest_2020.pdf (Accessed February 6, 2024).
[77] Townsend, Peter (2004) "Nova Scotia Forest Inventory Based on Permanent Sample Plots Measured between 1999 and 2003 Report FOR 2004 – 3."
[78] 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 February 6, 2024).

forest zones – high-production forest, protection forest, and the ecological matrix.[79] However, hybrid poplar has not been under discussion, as high-production forests in Nova Scotia refer to fast-growing native softwoods.[80]

12. Newfoundland and Labrador

The forest industry in Newfoundland and Labrador is small compared to most of the other provinces with 1.3 million m^3 harvested in 2020, slightly less than 1% of the national total.[81] Of this, only 97,000 m^3 are hardwoods – mostly birch and aspen. Therefore, Newfoundland and Labrador laws and policies regarding poplar and willow were not researched further in this report.

13. Yukon Territory

Although trembling aspen, balsam poplar and native willow species grow naturally in the Yukon Territory of northwestern Canada, no hardwood harvest was recorded in the National Forest Database for 2020, the most recent year in the database. Responsibility for managing the Yukon's forests devolved from the federal government, with the Yukon Forest Management Branch assuming full control in 2003. The Yukon Forest Resources Act specifies the territory's laws and policies regarding forestry. Although poplar and willow species are not commercially harvested, they are important species to various species of wildlife and they occur especially in riparian zones, which are protected areas.[82]

14. Northwest Territories

The National Forest Database gives 36,669 m^3 as the total amount of wood harvested in the Northwest Territories (NWT) in 2020, with only 1,505 m^3 of that being recorded as hardwoods.[83] Hardwoods consist of naturally growing aspen, birch, and balsam poplar but the harvested amounts of each are not specified. Aspen and birch wood is mostly used as fuelwood. Natural stands of poplar and willow occur especially in riparian zones, which are protected areas.[84]

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[79] 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 February 6, 2024).

[80] Government of Nova Scotia (2019) "High-Production Forestry in Nova Scotia." ISBN:978-1-77448-216-2 https://novascotia.ca/ecological-forestry/docs/HPF-phase1-report.pdf (Accessed February 6, 2024).

[81] Canadian Council of Forest Ministers. National Forest Database – Harvest Table 5.1 Net merchantable volume of roundwood harvested by jurisdiction and species group http://nfdp.ccfm.org/en/data/harvest.php (Accessed January 28, 2024).

[82] Yukon Department of Energy, Mines and Resources, Forest Management Branch (2015) "Yukon Forestry Handbook 2015" ISBN:978-1-55362-725-8. 116 p.

[83] Canadian Council of Forest Ministers. National Forest Database – Harvest Table 5.1 Net merchantable volume of roundwood harvested by jurisdiction and species group http://nfdp.ccfm.org/en/data/harvest.php (Accessed January 28, 2024).

[84] Government of Canada, Natural Resources Canada, Canadian Forest Service (1997) "Forests of the Northwest Territories." 16 p https://cfs.nrcan.gc.ca/pubwarehouse/pdfs/20057.pdf (Accessed January 28, 2024).

Nevertheless, the Government of the NWT, in 2010, developed a Biomass Energy Strategy[85] in which it explicitly recognized fast-growing willow or poplar as a possible source of biomass. No report was found that showed an increase in poplar or willow plantations or an increase in harvest of natural stands for this purpose.

15. Summary

Although Canada's ten provinces have jurisdiction over forest management, their Crown land regulations are very similar and have similar provisions for ecosystem-based forest management and for the protection of riparian areas. The harvest of native poplars (mostly aspen and balsam poplar) is considered in setting Annual Allowable Cuts for areas in which aspen is an important source of wood for pulp and oriented strandboard. Within Crown land areas, the planting of hybrid poplars or other exotic species is not done, unless it is for research. Québec and Nova Scotia have adopted a Triad classification in which designated areas are available for intensive wood production. 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, provided 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 land only if they meet provincial forest management criteria in their management plans. Nevertheless, many companies choose to also be certified under the Forest Stewardship Council and/or Sustainable Forests Initiative. Because the companies operate internationally, such internationally recognized certification is beneficial to them.

[85] Government of the Northwest Territories (2010) "NWT Biomass Energy Strategy." http://www.grrb.nt.ca/pdf/forestry/NWT_Biomass_Energy_Strategy.pdf (Accessed January 31, 2024).

II Technical Information

1. Taxonomy, Nomenclature and Registration

a) *Salix*

Salix L. is the largest genus in the family Salicaceae (450 species). The genus *Salix* is represented in all regions of Canada and is one of the most diverse woody genera in the country. In Canada, 30% of the woody species are willows with 76 native species.[86] Willows are mostly shrubs that play an important role in riparian habitats, wetlands and in shrub tundra. Willows contribute socially and economically to human societies.[87] Interest in the environmental applications of *Salix*, notably for shelterbelts, riparian buffers, biomass production and bioremediation has grown in Canada over the past decades.

The taxonomy of *Salix* is complex, mainly because of their dioecious reproduction, simple flowers, common natural hybridization, and large intraspecific phenotypic variation. They are obligate outcrossers and consequently hybridization, introgression, and polyploidy is common. The genus is easy to recognize, however species identification in the field can be challenging. In this regard, identification keys have been helpful. For example, an illustrated key to the *Salicaceae* of Alberta covering both poplar and willow was published in 2019.[88] Earlier, George Argus published a key that describes both introduced and naturally occurring *Salix* species in Saskatchewan.[89] In 2022, research by Murphy et al. provided new insights into the extent of genetic variation that exists within native shrub willow species in Canada. They revealed that the highest genetic variation in the species *Salix famelica* and *Salix eriocephala* occurred within genotypes (69 percent), while 8 percent of the variation existed among clusters and 23 percent between genotypes within clusters.[90]

The use of native Canadian shrub willow for bioenergy and environmental applications is in its infancy. 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.

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[86] 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 7, 2024).

[87] Lauron-Moreau A., F.E. Pitre, G.W. Argus, M. Labrecque and L. Brouillet (2015) Correction: Phylogenetic Relationships of American Willows (*Salix* L., Salicaceae). PLOS ONE 10(9).

[88] An Illustrated Key to the *Salicaceae* of Alberta. https://anpc.ab.ca/wp-content/uploads/2019/04/Salicaceae-2019-04.pdf (Accessed February 7, 2024).

[89] Argus G.W., V. Harms, A. Leighton and M. Vetter (2016) "Conifers and Catkin-Bearing Trees and Shrubs of Saskatchewan." Nature Saskatchewan.

[90] Murphy, E. K., E. P. Cappa, R. Y. Soolanayakanahally, Y. A. El-Kassaby, I. A. P. Parkin, W. R. Schroeder and S. D. Mansfield (2022). "Unweaving the population structure and genetic diversity of Canadian shrub willow." Scientific Reports **12**, 17254.

b) *Alnus*

The genus *Alnus* belongs to the *Betulaceae* family and worldwide there are about 30 species. In Canada, six *Alnus* species occur 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*.[91]

c) *Populus*

The genus *Populus* includes six sections, of which three naturally occur in Canada: balsam poplars [sect. *Tacamahaca* (*P. angustifolia*, *P. balsamifera*, and *P. trichocarpa*)]; cottonwoods [sect. *Aigeiros* (*P. deltoides*)]; and aspens [sect. *Leuce* (*P. grandidentata* and *P. tremuloides*)].

Difficulties in identification of *Populus* taxa is caused by their seasonal heterophylly. Also, 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. Five natural *Populus* hybrids are recognized in Canada: *Populus* ×*brayshawii* Boivin (= *P. angustifolia* × *P. balsamifera*) *Populus* ×*jackii* Sarg (= *P. balsamifera* × *P. deltoides*), *Populus* ×*acuminata* Rydb (= *P. angustifolia* × *P. deltoides* subsp. *monolifera*), *Populus* ×*generosa* Henry (= *P. deltoides* × *P. trichocarpa*) and *Populus* ×*hastata* Dode (= *P. trichocarpa* × *P. balsamifera*).[92]

d) *Acer*

The genus *Acer* belongs to the *Aceraceae* family. Ten species in the *Acer* genus are native to Canada. These include *A. saccharum*, *A. nigrum*, *A. macrophyllum*, *A. rubrum*, *A. saccharinum*, *A. negundo*, *A. spicatum*, *A. pensylvanicum*, *A. glabrum* var. *douglasii* and *A. cirinatum*. *A. saccharum* is Canada's national tree and best known for its production of maple syrup. Forestry use for maple is limited to *A. saccharum* and *A. macrophyllum*.[93] Other species are used ornamentally or for ecological purposes. Due to its growth rate and successional role in the coastal areas of British Columbia, *A. macrophyllum* (bigleaf maple) is considered a fast-growing species there.[94]

e) 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

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[91] Farrar, J.L. (1996) Trees in Canada, Fitzhenry & Whitehead Ltd and Canadian Forest Service
[92] Argus G.W., J.E. Eckenwalderand R.W. Kiger (2010) Salicaceae. In: Flora of North America Editorial Committee, editor. Flora of North America. Oxford and New York: Oxford University Press.
[93] Farrar, J.L. (1996) Trees in Canada, Fitzhenry & Whitehead Ltd and Canadian Forest Service
[94] Yanchuk, Alvin – Pers. Comm.

currently registered under Plant Breeder's Rights (PBR) in Canada is the cultivar 'Preble' (*Salix viminalis* x *S. miyabeana*).[95] 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 tremuloides* selection named 'Prairie Skyrise'.[96] 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 stand, if the stand does not exceed 10 hectares.[97] A new climate-based seed transfer system is being developed for Alberta but is currently not in practice.[98]

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.[99] The directory has been in existence for more than 35 years. The database stores Canadian germplasm data for clones, pollen, seedlot, and progeny. The database is available on the Poplar and Willow Council of Canada website http://www.poplar.ca/clone-directory. The database includes a total of 26,419 records with 25 searchable column headings, which are listed and described below:[100]

- **ID:** A unique number for each entry. This column may allow duplicate "Name" column entries without conflict.
- **Name:** The family population name or a clone number or name.
- **Family:** Population entries display seedlot number. Clone entries display family numbers if known. This column data may associate with other family columns such as "Family comments", Male and Female parent columns, Male and Female Clone, and "Year Bred" columns.
- **Sex:** Four single-character designations: M (Male), F (Female), U (Unknown), or B (Both).
- **Genus/Material Type:** Five two-character designations for the genus or material type.
- **Source Type:** Multi-character categories describing source types including sib types, cuttings, wild, or NA (Not Available/Not Applicable).

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[95] Plant Breeders Rights Variety Description for 'Preble' willow. https://www.inspection.gc.ca/english/plaveg/pbrpov/cropreport/wil/app00009178e.shtml (Accessed February 20, 2024).

[96] 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, 2024).

[97] Government of British Columbia. Chief Forester's Standards for Seed Use https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/tree-seed/legislation-standards/current-standards/consolidated_cf_stds__amended_1apr2022.pdf (Accessed February 7, 2024).

[98] Thomas, Barb – Pers. Comm.

[99] Poplar and Willow Council of Canada - *Populus* and *Salix* Clone Directory for Canada. http://www.poplar.ca/clone-directory (Accessed February 7 2024).

[100] Poplar and Willow Council of Canada Headings and descriptions for the Poplar & Willow Clone Directory Database. http:// http://www.poplar.ca/clone-directory-descriptions (Accessed February 7, 2024).

- **Category:** Multi-character classifications of *Populus* or *Salix* germplasm including sib types, cuttings, wild, native, or NA (Not Available/Not Applicable).
- **Female and Male Parent Columns:** The female or male species name with parentheses used to distinguish between parents in three-species clones.
- **Female and Male Parent Clone Columns:** The female or male clone name or number used to produce the clone. Parentheses are used to distinguish between parents in three-species clones.
- **Year Bred:** The four-digit year when the breeding or collection took place or NA (Not Available/Not Applicable).
- **Year Selected:** The four-digit year when the material was selected or NA (Not Available/Not Applicable).
- **Year Released:** The four-digit year when the material was released for commercial use or NA (Not Available/Not Applicable).
- **Hybrid Designation:** Hybrid names are preceded with the Punycode "×" multiplication character to improve database searching. However, caution is urged since the exact hybrid lineage has not been scientifically verified for some of the earlier data. This column lists an applicable hybrid name that may associate with the listed parental species name entries.

2. Domestication, Breeding and Selection of Genetic Resources

a) *Populus*

There are six species of *Populus* found in Canada.

Aigeiros section

P. deltoides ssp. *deltoides* (Eastern cottonwood) – Southern Ontario and Québec
P. deltoides ssp. *monilifera* (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 southwestern Alberta
P. angustifolia (Narrowleaf cottonwood) – Southeast British Columbia and southwestern Alberta

Populus Breeding and Testing

The Agriculture and Agri-Food Canada (AAFC) poplar breeding program at Indian Head, Saskatchewan, has been ongoing for over 75 years. The current program has been underway since the 1980's with activity increasing since 2000. The breeding program includes over 12,000 genetic lines within 125 controlled pollination families. Seventy-five percent of the lines have been propagated and are planted in replicated field trials in 2006. In 2014, improved inter-specific hybrid selections were planted into a common garden at Indian Head along with intra-specific *P. balsamifera*. New clones have an accepted role for soil conservation, carbon sequestration, farmstead protection, phytoremediation, bioenergy plantations, riparian protection, and fibre production in agricultural regions of western Canada.[101]

Agriculture and Agri-Food Canada *Populus* Breeding Program

Species / hybrids	
P. deltoides	*P. tremuloides*
P. nigra	*P. angustofolia*
P. maximowiczii	*P. tristis*
P. balsamifera	*P. ×petrowskyana*
P. laurifolia	*P. ×'Walker'*
P. trichocarpa	*P. ×'Hill'*
P. simonii	*P. ×'38P38*
Major cultivars released and date of first release	
P. ×'Walker' (1977)	*P. ×'Hill'* (1999)
P. ×'Assiniboine' (1986)	*P. ×'Katepwa'* (2003)
P. ×'Manitou' (1991)	*P. ×'Okanese'* (2009)
P. ×'CanAm' (1994)	*P. ×'Sundancer'* (2012)
Hybrids produced	
P. deltoides × P. balsamifera	*P. × Hill × P. balsamifera*
P. deltoides × P. maximowiczii	*P. × Hill × P. laurifolia*
P. deltoides × P. ×petrowskyana	*P. × Hill × P. octorabdus*
P. deltoides × P. laurifolia	*P. × Hill × P. tristis*
P. deltoides × P. octorabdus	*P. × Hill × P. maximowiczii*
P. deltoides × P. trustis	*P. balsamifera × P. balsamifera*
P. × Walker × P. deltoides	*P. balsamifera × P. deltoides*
P. × Walker × P. balsamifera	*P. balsamifera × P. maximowiczii*
P. × Walker × P. laurifolia	*P. balsamifera × P. laurifolia*
P. × Walker × P. octorabdus	*P. balsamifera × P. octorabdus*
P. × Hill × P. nigra	*P. balsamifera × P. simonii*
P. maximowiczii × P. nigra	*P. 38P38 × P. deltoides*
P. maximowiczii × P. x petrowskyana	*P. 38P38 × P. balsamifera*
P. maximowiczii × P. balsamifera	*P. 38P38 × P. maximowiczii*
P. × Walker × P. simonii	*P. balsamifera × P. trichocarpa*
P. × Walker × P. tristis	*P. trichocarpa × P. balsamifera*
P. × Walker × P. maximowiczii	

[101] Soolanayakanahally, Raju - Pers. Comm.

The short-term goal 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, and riparian protection). The long-term goal is primarily to solidify the genetic resources in *P. deltoides* and *P. balsamifera* that would serve a recurrent breeding effort. The breeding efforts focus on exploitation of within-species population level genetic variation that would best serve the current and future climates of the Canadian prairies and beyond. In addition, the exploratory effort would evaluate new intra-specific F_1 combinations with *P. deltoides* and *P. balsamifera* as well as in their pure species state. The latter focus is on provenance, family, or clone tests. A secondary long-term effort is to conduct exploratory evaluations of additional non-native species (e.g., *P. laurifolia., P. nigra, P. maximowiczii*, and *P. simonii*). The AAFC breeding program process involves nursery scoring for Melampsora, branch habit, leader dominance and vigour; nursery screening for water use efficiency ($\delta^{13}C$) and nutrient use efficiency ($\delta^{15}N$); screening for cold hardiness at year five; and field testing for site adaptability, growth, and form and stock/pest resistance. [102]

Overall, the AAFC breeding program aims to develop the "ideal poplar ideotype" with fast growth rate; adapted to short summers and the risk of growing-season frost; winter hardiness to temperatures as low as –50°C; drought resistance; insect and disease resistance; 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.[103]

Balsam poplar (*P. balsamifera*) is the preferred species for oil sands reclamation planting in northern Alberta. Balsam poplar 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.

Currently, the most active poplar breeding program in Canada is in the province of Québec. The Ministère des Ressources naturelles et des Forêts (MRNF) poplar breeding program has been underway 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. Québec poplar breeders have been focusing on increasing the resistance of hybrids to *Sphaerulina musiva* (Peck) Quaedv., Verkley, and Crous *(*syn. *Septoria musiva* Peck*)* a native ascomycete responsible for leaf spot and canker disease on poplar trees. The native species *Populus deltoides* and *Populus balsamifera* have generally shown more resistance compared to *Populus maximowiczii* and *Populus trichocarpa*. As a result, most hybrids in the Québec breeding program include one of *P. deltoides* or *P. balsamifera* as a parent.

Disease continues to be one of the most important factors affecting hybrid poplar in Québec. This situation necessitates identifying resistant clones as deployment of resistant clones is one of the best ways to cope with these diseases. A Québec study provided preliminary estimates of genetic parameters and familial selection for non-native poplars that showed good potential for genetic gains on growth,

[102] Soolanayakanahally, Raju - Pers. Comm.
[103] Soolanayakanahally, Raju - Pers. Comm.

cold hardiness, trunk quality and *Sphaerulina musiva* susceptibility.[104] Since 2019, efforts have focused breeding of parental populations. This intra-specific breeding has produced new progenies for the following parental lines (*P. deltoides* × *P. deltoides*, *P. maximowiczii* × *P. maximowiczii*, and *P. maximowiczii* × *P. suaveolens*) with *s*eeds from these crosses planted in 2022 and 2023. For the 2020-2023 period, one new M×D clone (*P. maximowiczii* × *P. deltoides*) was deployed for commercial planting in Québec. [105]

In British Columbia, a poplar breeding program was initiated in 1989, with testing of native and hybrid poplars. With the demise of poplar activity in British Columbia, there has been no activity in recent years. A poplar clone bank is maintained at the Puckle Road Seed Orchard, in Saanichton, BC, and has about 300 clones archived. However, this collection is being damaged by poplar borer and *Septoria* leaf rust and dead clones are not being re-propagated.[106]

In Alberta, aspen tree improvement programs have been underway for over twenty years. The Western Boreal Aspen Corporation (WBAC) program is still underway with the objective of developing aspen for deployment with genetic gain in wood production. They have two programs located in western Alberta with both supported by the forest industry including Mercer International, West Fraser and Weyerhaeuser.[107] WBAC has reached the pilot plantation stage with operational planting of superior selections of aspen from wild populations. With the pilot, between 2020 and 2023, 189 thousand improved seedlings were planted by the three industry partners on a total area of 170 hectares. All of the planted aspen are genetically superior clones with over 20 years of testing in replicated randomized trials using source-identified wild selections. All aspen clones are being deployed onto Crown lands.[108]

Populus Ex Situ Conservation

At Agriculture and Agri-Food Canada (AAFC), *ex situ* collections and resulting common garden trials provide opportunities for a variety of studies in population genetics, climatic adaptation, long-term phenology responses of provenances and ecophysiology studies. The primary purpose is to obtain a genetically representative sample of *P. balsamifera*, *P. deltoides* var. *occidentalis* and *P. tremuloides* germplasm over 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 is to sample the geographic range of the species. Within each population, a minimal sample size of 15 distinct trees is collected. This sample size is adequate to capture a high proportion of the genetic variation recognizing that most of the genetic variation resides within populations and characterizes a provenance. In addition, the collections provide foundation stock for basic research and to focus on trait-assisted breeding.

Since the beginning of the Québec program, diverse and multiple populations were tested and conserved in different tests across the province. Since 2020, new parental populations from intraspecific crossing were planted (*P. maximowiczii* and *P. deltoides*) to obtain an advanced generation for future

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[104] Otis-Prud'homme, G., J. Deblois and M. Perron (2023). "Preliminary estimates of genetic parameters and familial selection for non-native poplars show good potential for genetic gains on growth, cold hardiness, trunk quality and *Sphaerulina musiva* susceptibility." Tree Genetics & Genomes **19**(6).
[105] Otis-Prud'homme, Guillaume – Pers. Comm.
[106] Yanchuk, Alvin – Pers. Comm.
[107] Thomas, Barb – Pers. Comm.
[108] Brouard, Jean – Pers. Comm.

crosses. Efforts are also underway to renew other parental populations through cuttings for conservation purposes.[109]

In Alberta, there are currently no collection programs designed with the sole purpose of conservation of any fast-growing species in Alberta (i.e., poplar/aspens or willows). Any breeding programs are required to develop a conservation plan following the standards set out in the Alberta Forest Genetic Resources and Conservation Standards (2016). To date, however, no conservation plans have been implemented for any tree improvement program in Alberta.[110]

In British Columbia, the Ministry of Forests maintains two clone banks of *P. trichocarpa, P. balsamifera,* and some hybrids. These collections are mainly for conservation purposes[111]

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, several 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 programs. The development of genomic resources has also provided cost-effective markers to distinguish genotypes that can help address specific forest management or restoration questions. [112]

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 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. The availability of a *P. balsamifera* sequenced genome made it possible to study candidate genes of interest including phenology, carbon gain, resource use (water and nitrogen), and disease resistance. Using balsam poplar as a model, researchers employed high-throughput sequencing and Gradient Forests (GFs) to identify candidate loci associated with climate adaptations. By relating these loci to environmental gradients, they predicted the magnitude of population response when transplanted to common gardens. Results showed a negative correlation between genetic offset and performance in common gardens, indicating higher maladaptation in populations with larger offsets. Their findings suggested that genetic offsets offer a valuable estimate of population maladaptation to rapid environmental changes and highlight the potential of GFs for identifying candidate SNPs.[113]

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[109] Otis-Prud'homme, Guillaume – Pers. Comm.
[110] Thomas, Barb – Pers. Comm.
[111] Yanchuk, Alvin – Pers. Comm.
[112] Soolanayakanahally, Raju – Pers. Comm.
[113] Fitzpatrick, M. C., V. E. Chhatre, R. Y. Soolanayakanahally and S. R. Keller (2021). "Experimental support for genomic prediction of climate maladaptation using the machine learning approach Gradient Forests." Molecular Ecology Resources **21**(8): 2749-2765.

Using machine learning models, AAFC researchers investigated the genetic basis of natural variation in leaf morphology in poplar species, specifically focusing on *P. balsamifera* genotypes. They employed genome-wide association and deep-learning genomic prediction methods to map the genetic architecture of twelve leaf traits related to size and shape. Using FarmCPU, significant associations were found between leaf traits and single nucleotide polymorphisms (SNPs) located in genes such as the poplar TOR orthologue and activating kinases SnRK3 and SnAK1. Particularly, an intron of TERPENE SYNTHASE5 (*PbTPS5*) showed the most significant association, explaining variance in total leaf area, leaf thickness, and serration density. Deep-learning genomic prediction accurately estimated leaf traits and identified the *PbTPS5*-associated polymorphism as a key predictor of leaf morphology. This study provided a genetic and mathematical foundation for improving poplar performance by optimizing leaf morphology.[114]

Studying gene expression patterns across seven time points representing the full annual flowering cycle in male and female balsam poplar buds and catkins, the University of Toronto (UofT), University of British Columbia (UBC) and Agriculture and Agri-Food Canada (AAFC) researchers found that developmental stage (time) primarily influenced gene expression, with sex differences nested within this framework. This study offered insights into the dynamics of reproductive development and sex-specific gene regulation in balsam poplar.[115]

AAFC collaborated on a study to investigate the impact of chilling duration on the timing of bud flush in *Populus balsamifera* trees that represent a range of latitudes from 43 to 58 degrees north. They conducted controlled environment experiments in which dormant cuttings from 10 different genotypes were exposed to varying lengths of chilling (0 to 10 weeks), followed by monitoring the accumulation of growing degree days (GDD) needed for bud flush. The results showed that chilling duration significantly influenced bud flush timing, with longer periods of chilling leading to fewer GDD required for bud flush. Additionally, there was significant genotypic variation in bud flush timing, and this variation was stratified by latitude. Southern genotypes required more GDD to flush than northern genotypes. The latitudinal cline in bud flush timing was more pronounced under minimal chilling, but as chilling increased, genotypic variation in GDD to bud flush became less distinct. The study highlighted the importance of genotype-by-environment interactions in determining bud flush timing, with chilling requirements playing a critical role in shaping latitudinal clines. Their findings suggest that selection pressure has influenced chilling requirements as an adaptive strategy to avoid premature bud flush in climates with midwinter warming.[116]

UBC and AAFC researchers investigated the susceptibility of balsam poplar to drought-induced embolism and the role of water release from surrounding xylem fibres in balsam poplar. Using X-ray micro-computed tomography, they observed that under moderate drought stress, water-depleted fibres appeared while vessels remained filled with water. Interestingly, despite differences in vessel size and density between genotypes sourced from two latitudes, both showed comparable susceptibility to embolism. Additionally, they found that higher stomatal conductance in northern genotype did not

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[114] Soolanayakanahally et al. (unpublished results).
[115] Cronk, Q., R. Soolanayakanahally and K. Bräutigam (2020). "Gene expression trajectories during male and female reproductive development in balsam poplar (*Populus balsamifera* L.)." Scientific Reports **10**, 8413.
[116] Thibault, E., R. Soolanayakanahally and S. R. Keller (2020). "Latitudinal clines in bud flush phenology reflect genetic variation in chilling requirements in balsam poplar, *Populus balsamifera*." American Journal of Botany **107**(11): 1597-1605.

correlate with greater embolism resistance. The findings suggest that fibres water release may play a crucial role in maintaining vessel function during drought stress in balsam poplar saplings.[117]

Using four hybrid poplars and willows, UBC and AAFC investigated the metabolic response to increasing external phosphate levels and explored differences in anion resorption patterns between hybrid poplar and willow. They found that as phosphate levels increased, there was an accumulation of phosphate in leaves. However, metabolic adjustments primarily involved increased influx of inorganic cations rather than changes in organic acid content. During senescence, the hybrid poplar 'Tristis' exhibited higher sulfate and organic acid resorption, while the hybrid willow 'AAFC-5' showed higher phosphate resorption. Additionally, phosphate accumulation continued after bud-set in poplar hybrids, potentially contributing to low phosphorus resorption efficiency. This suggested that closely related species with similar growth strategies, display a different resorption stargery for phosphorus.[118]

The Université Laval and AAFC researchers investigated the genetic structure and adaptive responses of aspen (*Populus tremuloides*) across its vast range, spanning from Alaska to central Mexico. By genotyping over 1000 individuals and analysing approximately 44,000 SNPs, the researchers identified four major genetic clusters and observed shifts in reproductive strategies and ploidy levels in response to drought. They also identified genomic regions under selection, linked to temperature and precipitation variations. Additionally, experiments on seed germination under elevated temperature and water stress revealed differences between western US and eastern Canadian populations. These findings contribute to understanding the adaptive evolution of aspen and highlight its potential for climate-resilient revegetation efforts amidst its declining western distribution.[119]

Gender Determination

Research at UBC, UofT and AAFC presented possible mechanisms for the developmental control of male and female flowers in poplar. A study published in 2020 provided insights into expression trajectories shaping reproductive development, its potential underlying mechanisms, and sex-specific translation of the genome information into reproductive structures in balsam poplar. They found evidence for five successive waves of alterations to the chromatin landscape which may be important in setting the overall reproductive trajectory, regardless of sex. In addition, each individual developmental stage was characterized by marked sex-differential gene expression. The consistent sexually differentiated gene expression regardless of developmental stage revealed candidates for high-level regulators of sex and include the female-specific poplar *ARR17* homologue.[120]

Researchers at the University of Lethbridge (UofL) studied dioecy in riparian poplars (*P. angustifolia,*

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[117] Chu, C., M. Momayyezi, J. A. Stobbs, R. Y. Soolanayakanahally, A. J. McElrone and T. Knipfer (2023). "Drought-induced fiber water release and xylem embolism susceptibility of intact balsam poplar saplings." Physiologia Plantarum **175**(5), e14040.
[118] Da Ros, L. M., R. U. Y. Soolanayakanahally and S. D. Mansfield (2020). "Discerning the effects of phosphate status on the metabolism of hybrid poplar." Tree Physiology **40**(2): 158-169.
[119] Goessen, R., N. Isabel, C. Wehenkel, N. Pavy, L. Tischenko, L. Touchette, I. Giguère, M.C. Gros-Louis, J.M. Laroche, B. Boyle, R. Soolanayakanahally, K. Mock, J. Hernández-Velasco, S.L. Simental-Rodriguez, J. Bousquet and I.M. Porth. "Coping with environmental constraints: Geographically divergent adaptive evolution and germination plasticity in the transcontinental *Populus tremuloides*." Plants People Planet **4**(6): 638-654
[120] Cronk, Q., R. Soolanayakanahally and K. Bräutigam (2020). "Gene expression trajectories during male and female reproductive development in balsam poplar (*Populus balsamifera* L.)." Scientific Reports **10**, 8413 (2020).

P. ×acuminata and P. deltoides). They found that with decreasing temperature, stomatal density and stomatal conductance decreased, chlorophyll content was consistent whereas nitrogen concentration, photosynthesis, and water use efficiency increased. None of the foliar characteristics varied significantly between the sexes, and there was no sex and temperature interaction for any physiological traits. They concluded that low temperature adaptation has minimal contribution to sex differentiation in cottonwoods.[121]

b) *Alnus*

Alders are divided into two subgenera *Alnus* and *Alnobetula*.[122] One species, *Alnus rubra* is commercially significant as a fast-growing tree species in western British Columbia, where it is the main harvested hardwood species with a rotation age of approximately 30 years.[123]

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 Québec

[121] Zanewich, K. P. and S. B. Rood (2023). "Limited sex differentiation in poplars: similar physiological responses to low temperature of males and females of three cottonwood taxa." Trees-Structure and Function **37**(4): 1217-1223.
[122] Farrar, J.L. Trees in Canada. 1995. Natural Resources Canada, Canadian Forest Service, Ottawa, Co-published by Fitzhenry and Whiteside Limited, Markham, Ontario. 502 p.
[123] Yanchuk, Alvin – Pers. Comm.

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 the sole N_2-fixing tree species along the Pacific coast of British Columbia and is well recognized for its role in the enhancement of fertility of forest soils, particularly after disturbance. This makes alder suitable as a nurse crop species on nitrogen-poor sites and severely disturbed sites (landslides, landings, etc.).[124] A draft report of the genecology and seed transfer for red alder in coastal BC, based on the nine genecology tests site has been prepared. [125]

In British Columbia, there are 14 red alder research trials established around Vancouver Island and the lower mainland. 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 in 2010 with concurrent field trial evaluations in two phases starting in 2007, with the second phase in 2021. The progeny testing program, started in 2011, has over 25,000 trees in 14 tests. The final selection for phase two was completed in 2023 with establishment of the phase 2 seed orchard scheduled for 2030. The breeding population has an effective population size of approximately 80 lines. Screening for western tent caterpillar resistance will be incorporated into the next selection cycle. Researchers are hopeful that the 2nd phase orchard will produce gains around 30% in volume at rotation age 35.[126]

A new clone bank is being grafted at Cowichan Lake using approximately 120 clones selected from about 10,000 trees at four progeny testing sites. Controlled crosses will be made once a complement of better clones are producing flowers. Height growth at age 6 and form are the selection criteria to be used. [127]

c) *Acer*

Bigleaf maple (*Acer macrophyllum*) is second to red alder among native hardwood species in abundance and in commercial importance in British Columbia where rotation age is 40-45 years. Bigleaf maple is a medium-sized, deciduous, broad-leaved tree with a broad, rounded crown, and often a curved stem. Like sugar maple, bigleaf maple has sweet sap that can be made into syrup. Its wood is used for furniture, flooring, interior paneling, and musical instruments. In British Columbia, bigleaf maple occasionally grows in even-aged, pure stands, but most commonly in early and intermediate stages of secondary succession mixed with conifers or hardwoods. It is a pioneer species on floodplains and is present in second-growth stands on upland sites. Bigleaf maple may invade gaps created by windthrow

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[124] Nehring, L., J. M. Kranabetter, G. J. Harper and B. J. Hawkins (2023). "Tree-ring $\delta^{15}N$ as an indicator of nitrogen dynamics in stands with N_2-fixing *Alnus rubra*." Tree Physiology **43**(12):2064-2075

[125] Yanchuk, Alvin – Pers. Comm.

[126] Yanchuk, Alvin – Pers. Comm.

[127] Yanchuk, Alvin – Pers. Comm.

of climax tree species, such as western redcedar on floodplains and colluvial sites. It frequently grows in clumps of three to five, all originating from a single stump. Considering its productivity, easy regeneration, and low risk of being affected by damaging agents, bigleaf maple is considered a suitable species for intensive management on some coastal sites.[128]

Bigleaf maple is locally significant in British Columbia for the manufacture of furniture, musical instruments, interior panelling, and other select uses such as large bowls turned from burls. Natural populations of bigleaf maple trees contain, at low frequency, individuals with stems that have attractive and valuable wavy grain in the wood. In some individuals the grain patterns are unsurpassed, even by walnut, suggesting a potential for use in furniture.[129] The wood of maples typically is cream coloured and unimpregnated by tannins, the component that makes wood weather resistant. Therefore, the wood decomposes quickly after contact with soil or exposure to weather. Bigleaf maple is considered a softer wood, and as such is used to make wooden tools, kitchen utensils, furniture, veneer, panelling, musical instruments, moulding, turnery, pallets, pulpwood, and hardwood plywood, as well as for firewood. Specialty markets exist for figured wood from bigleaf maple.[130]

Acer Breeding and Testing

The British Columbia Ministry of Forests is developing a bigleaf maple screening program. Between 2020 and 2023, about 100 selections were made from approximately 130,000 ten-year-old trees in three test sites. Selections are based on superior height, volume, and form.[131]

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[128] Bigleaf maple. https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/silviculture/tree-species-selection/tree-species-compendium-index/bigleaf-maple (Accessed February 13, 2024).

[129] Zhou, C. and J. Mattson (2021) "Development of Micropropagation in Bigleaf Maple (Acer macrophyllum)." Horticulturae **7**(7).

[130] Peterson, E.M., Peterson, E.B., Comeau, P.G. and Thomas, K.D. (1999) "Bigleaf maple managers' handbook for British Columbia", British Columbia Ministry of Forests.

[131] Yanchuk, Alvin – Pers. Comm.

d) *Salix*

The classification of *Salix* in Canada recognizes five subgenera and is based on morphological characteristics of the genus.

Distribution of *Salix* subgenera in Canada[132]			
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 caudata	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*	All Provinces
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
reticulata	BC YK NT NU QC	*pyrifolia*	All Provinces
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

[132] 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

Salix clones have an accepted role for shelterbelts, nutrient management, carbon sequestration, phytoremediation, bioenergy plantations, riparian protection, and fibre production in Canada. *Salix* selection and breeding have traditionally 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 *Salix* 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 agronomic traits necessary for bioenergy plantations. The first *Salix* breeding programs in Canada were by Alex Mosseler in Dr. Louis Zsuffa's 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* × *miyabeana* hybrids that are still in use today.

Most *Salix* cultivars used commercially in Canada are produced at the Ramo nursery in Québec.[133] Numerous clones have been tested at multiple locations across Canada. These trials are determining optimum clones for different regions of the country. The following *Salix* clones are currently being deployed or tested in Canadian plantings.

***Salix* clones in Canadian trials**			
Clone	**Species**	**Clone**	**Species**
Allegany	*S. purpurea*	Vim 5027	*S. viminalis*
Millbrook	*S. viminalis* × *S. miyabeana*	India	*S. gmelinii*
Olof	*S. viminalis* × *(S. viminalis* × *S. scherwinii)*	Nigra 5005	*S. nigra*
Otisco	*S. viminalis* × *S. miyabeana*	Alba 5044	*S. alba*
Owasco	*S. viminalis* × *S. miyabeana*	Eriocephala S25	*S. eriocephala*
Preble	*S. viminalis* × *S. miyabeana*	Discolor S365	*S. discolor*
SV1	*S. gmelinii (dasyclados)*	Fish Creek	*S. purpurea*
Sx61	*S. viminalis* × *S. miyabeana*	Fabius	*S. viminalis* × *S. miyabeana*
Sx64	*S. viminalis* × *S. miyabeana*	Cherimisina	*S. alba chermisina*
Sx67	*S. viminalis* × *S. miyabeana*	Acute	*S. acutifolia*
Tully	*S. viminalis* × *S. miyabeana*	Heart leaf willow	*S. eriocephala*
Tora	*S. viminalis* × *S. scherwinii*	Sandbar willow	*S. exigua*
White	*S. alba sericea*	Silver leaf	*S. alba var. sericea*
Golden	*S. alba 'Vitellina'*	Peach leaf	*S. amygdaloides*
Laurel	*S. pentandra*	Bebbs' willow	*S. bebbiana*

[133] Blank, Martin – Pers. Comm.

In Alberta, the Canadian Wood Fibre Centre has five *Salix* common garden sites. They are located near the communities of Beaverlodge, Coronation, Keoma, Ohaton and Crossfield. Fourteen *Salix* cultivars are being tested at each of these sites. The cultivars which originate from United States and Swedish breeding programs are below.[134]

***Salix* cultivars evaluated at Alberta sites**			
Clone	**Parentage**	**Clone**	**Parentage**
Fabius	*S. viminalis* × *S. miyabeana*	Viminalis	*S. viminalis*
Millbrook	*S. viminalis* × *S. miyabeana*	Tora	*S. viminalis* × (*S. viminalis* × *S. scherwinii*)
Otisco	*S. viminalis* × *S. miyabeana*	Torhild	*S. viminalis* × (*S. viminalis* × *S. scherwinii*)
Owasco	*S. viminalis* × *S. miyabeana*	Bjorn	*S. viminalis* × *S. scherwinii*
Preble	*S. viminalis* × *S. miyabeana*	Olof	*S. viminalis* × (*S. viminalis* × *S. scherwinii*)
Tully	*S. viminalis* × *S. miyabeana*	Sven	*S. viminalis* × (*S. viminalis* × *S. scherwinii*)
Canastota	*S. sachalinensis* × *S. miyabeana*	Sherburne	*S. sachalinensis* × *S. miyabeana*

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.[135] 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 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; adaptation to short summers with the risk of growing-season frost; winter hardiness to temperatures as low as –50˚C; drought, insect and disease resistance; optimum form/architecture for maximizing machine harvesting. In addition, screening efforts focus on phosphorus mitigation via cultivar selection. AAFC is currently prioritizing native willow domestication and breeding, focusing on developing cultivars suitable for Canadian climates, particularly for biomass, bioenergy, and environmental applications.[136]

AAFC breeding methods include qualitative selection of parents for intra- and inter-specific hybridization, typically with only one generation. Breeding process includes nursery scoring for leaf rust, branch habit, and vigour; screening for water use efficiency ($\delta^{13}C$) and nutrient use efficiency ($\delta^{15}N$); and field testing for site adaptability, biomass growth, form and pest resistance. The breeding program includes over 2,500 genetic lines within 37 controlled pollination families. In the spring of 2024, two new hybrid willow clones are scheduled to be released for wetland and riparian planting.[137]

Using the AgCan*Salix* collection, a University of British Columbia study investigated the geographic pattern of genetic diversity of *S. famelica* and *S. eriocephala.* They used genotyping-by-sequencing (GBS) to determine whether geoclimatic variables influenced the population structure, and the level of genetic

[134] Blank, Martin – Pers. Comm.
[135] Soolanayakanahally, Raju - Pers. Comm.
[136] Soolanayakanahally, Raju - Pers. Comm.
[137] Soolanayakanahally, Raju - Pers. Comm.

variation within and among populations. Molecular variance revealed in the study showed that the highest genetic variation occurred within genotypes (69%), while 8% of the variation existed among clusters and 23% between genotypes within clusters. Uncovering the extent of diversity within the AgCan*Salix* collection and the relatedness of genotypes bolstered future efforts to breed willow varieties with superior adaptive traits for a host of Canadian climatic regions.[138]

Salix testing has been under way in Québec at the Institut de recherche en biologie végétale (Université de Montréal and Botanical Garden) since 2005. In 2023, researchers at the Jardin botanique de Montréal published a study comparing the yields and effects of site and coppicing frequency of different willow cultivars planted in five regions of Québec. Cultivars tested included *Salix* x*dasyclados* 'SV1', *Salix viminalis* '5027', *Salix miyabeana* 'SX61', 'SX64', and 'SX67'. They found that all cultivars studied, except for *S. viminalis* '5027', performed similarly, and yields were very good. Based on these results, the study concluded that the pedoclimatic conditions of most regions of Québec are favourable for growing willows. The study also found that coppicing did not affect subsequent growth for any of the willow cultivars tested.[139]

Research at the Institut de recherche en biologie végétale has focused on the use of willows for phytoremediation to extract or degrade contaminants, or, as evapotranspiration covers, to contain them in the soil. Their research since 2020 has focused on the efficacy of a Short Rotation Coppice (SRC) willow plantation when used as a vegetative filter in the pedoclimatic conditions of Québec to treat various loads of leachate from inoperative landfill cells and verifying the impacts on soil, runoff water, and willow yields. A study published in 2023 showed that the treatment of leachate by vegetative filters composed of willow coppice to be a cost-effective alternative to conventional costly methods.[140] In addition, Marie Guittonny at Université du Québec en Abitibi-Témiscamingue (UQAT) is researching the use of poplars and willows for mine waste revegetation in Northwestern Québec.[141]

Between 2020 and 2023, the Atlantic Forestry Centre in Fredericton New Brunswick was involved in willow domestication and conservation research. Development of selected, superior clones was 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. A study published by Mosseler and Major in 2023 assessed genetic variation in coppice growth traits of *Salix exigua*. In addition, they compared traits in *S. exigua*, *S. eriocephala* and *S. discolor* to determine allometric relationships in coppice growth traits to identify superior clones. The study also attempted to determine the effect of plant sex (male vs. female) on biomass production. They found that geographic regions, populations within geographic regions, and clones within populations accounted for large portions of total variation

[138] Murphy, E. K., E. P. Cappa, R. Y. Soolanayakanahally, Y. A. El-Kassaby, I. A. P. Parkin, W. R. Schroeder and S. D. Mansfield (2022). "Unweaving the population structure and genetic diversity of Canadian shrub willow." Scientific Reports **12**, 17254 (2022).
[139] Labrecque, M., S. Daigle and S. Olishevska (2023). "Comparing biomass yields of various willow cultivars in short-rotation coppice over six growing seasons across a broad climatic gradient in Eastern Canada." Canadian Journal of Forest Research **53**(7): 533-543.
[140] Benoist, P., A. Parrott, X. Lachapelle, L. C. Barbeau, Y. Comeau, F. E. Pitre and M. Labrecque (2023). "Treatment of landfill leachate by short-rotation willow coppice plantations in a large-scale experiment in Eastern Canada." Plants, **12**, 372.
[141] UQUAT Personnel Activities. https://www.uqat.ca/services/personnel/fiche.asp?Fiche=080082 (Accessed February 20, 2024).

in coppice growth traits. Their allometric analysis found that coppice stem number could be useful as an easily measureable, non-destructive indicator for biomass production and they concluded that plant gender was not a factor in growth performance.[142]

Another study published by Atlantic Forestry Centre scientists compared biomass yield of eight *Salix interior* clones grown on two site types comparing biomass yield of coppiced and uncoppiced plants. In addition, the study identified superior performing clones for both land reclamation and commercial biomass production on highly disturbed, low-fertility sites. They found differences among the eight clones tested in aboveground biomass which pointed to the opportunity for conducting clonal selection for the growth and ability to adapt to sites of differing quality. They demonstrated that genetic differences in growth and root-sprouting capacity could affect the ability of *S. interior* to colonize infertile and highly disturbed sites. The study concluded that these colony-forming willows eliminated the need for periodic plantation re-establishment, providing a cost advantage over species that do not continuously produce new stems via root sprouting.[143]

Scientists at the Atlantic Forestry Centre published the results of a study on bee pollinator behaviour on willows, specifically how bee foraging preferences on dioecious willows were influenced by plant gender, time of day, site, and *Salix* species. Their results showed a strong preference for male willow plants particularly the species *S. eriocephala* and *S. interior*. They summarized that retention of naturally existing willow populations in the vicinity of crop plants may be useful in increasing and promoting pollinators. In addition, the establishment of largely male, or male-only, willow populations would have the added benefit of avoiding willow seed dissemination and unwanted vegetative competitors into agricultural fields.[144]

Salix Ex situ Conservation

In Canada conservation of *Salix* genetic resources is mainly done by Agriculture and Agri-Food Canada in the province of Saskatchewan. A key to this work has been the establishment of the Agriculture Canada *Salix* (AgCan*Salix*) germplasm collection. The collection includes native willow germplasm from wild populations of *S. amygdaloides*, *S. bebbiana*, *S. discolor*, *S. eriocephala*, *S. famelica*, *S. interior*, and *S. petiolaris*. The collection includes *Salix* genotypes from Alberta, Saskatchewan, Manitoba, Ontario, Québec, New Brunswick, Prince Edward Island, Nova Scotia, and Newfoundland and Labrador. Their goal was to assemble a large genetically diverse base populations from which parents could be selected to develop locally adapted genotypes tailored for specific applications. The *ex-situ* collection and resulting common garden trials have provided opportunities for a variety of studies in population genetics, phytoremediation, long-term phenology responses of provenances and ecophysiology studies. In addition, the collection provides foundation stock for basic research as well as trait-assisted breeding for nutrient interception, salinity mitigation and pollinator habitats.[145]

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[142] Mosseler, A. and J. E. Major (2023). "Coppice growth traits in sand dune willow (*Salix cordata*) and comparisons with two common North American shrub willows used for biomass production." Biomass & Bioenergy **174**, 106846.
[143] Mosseler, A. and J. E. Major (2022). "Clonal variation in coppiced and uncoppiced growth, root sprout stem formation, and biomass partitioning in *Salix interior* on two highly disturbed site types." Canadian Journal of Forest Research **52**(1): 1-10
[144] Mosseler, A., J. Major, D. Ostaff and J. Ascher (2020). "Bee foraging preferences on three willow (*Salix*) species: Effects of species, plant sex, sampling day and time of day." Annals of Applied Biology **177**(3): 333-345.
[145] Soolanayakanahally, Raju – Pers. Comm.

Examining Genetic Variation in Salix and its Hybrids

Researchers at Agriculture and Agri-Food Canada and the University of British Columbia examined the genetic diversity and population structure of 324 genotypes from two Canadian willow species, *Salix famelica* and *S. eriocephala*, across 33 sites. Using SNPs, researchers identified five clusters primarily influenced by geoclimatic factors. Genetic variation was highest within genotypes (69%), with potential for pan-Canadian breeding programs to leverage this diversity. The study lays the groundwork for selecting locally-adapted genotypes and identifying traits resilient to environmental stresses, such as insect herbivores. [146] In an earlier study, they had compared the cell wall composition and wood ultrastructure of two Canadian willow species, *S. famelica* and *S. eriocephala*, harvested from a common garden plot. Lignin content and composition varied within and between species, affecting glucose and xylose release after pretreatment and enzymatic digestion. The study underscored the significance of the innate variability in willow cell wall traits and suggested potential genotypes for future bioenergy production strategies in Canada.[147]

A related study investigated resource use efficiencies in heart-leaved willow (*S. eriocephala*) populations, focusing on water (WUE) and nitrogen (NUE). Through carbon and nitrogen isotopic compositions, it identifies population-level variations in WUE, NUE, and N uptake/assimilation traits. Results suggested a genetic plastic trade-off between WUE and NUE, but not linked to local adaptation. Hydroponic experiments reveal genotypic differences in nitrate uptake efficiency, possibly related to latitude and water availability. They showed that genotypes with higher WUE tend to originate from water deficient sites. Interestingly, no trade-offs were found between $\delta^{13}C$, C/N ratio, and nitrate uptake efficiency, indicating independent selection for growth and resource use efficiencies.[148]

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[146] Murphy, E. K., E. P. Cappa, R. Y. Soolanayakanahally, Y. A. El-Kassaby, I. A. P. Parkin, W. R. Schroeder and S. D. Mansfield (2022). "Unweaving the population structure and genetic diversity of Canadian shrub willow." Scientific Reports **12**, 17254 (2022).
[147] Murphy, E. K., Y. Mottiar, R. Y. Soolanayakanahally and S. D. Mansfield (2021). "Variations in cell wall traits impact saccharification potential of *Salix famelica* and *Salix eriocephala*." Biomass & Bioenergy **148**, 106051.
[148] Hu, Y., R. D. Guy and R. Y. Soolanayakanahally (2022). "Genotypic variation in C and N isotope discrimination suggests local adaptation of heart-leaved willow." Tree Physiology **42**(1): 32-43.

3. Plant Health, Resilience to Threats and Climate Change

a) Biotic Factors

Insects and diseases are the main biotic factors that threaten the success of poplar, willow, alder, and other fast-growing trees in all regions of Canada. They either kill trees or prevent them from reaching their potential growth. As tree culture becomes more intense and with increased exchange of breeding and planting stock, that can introduce new insect pests and pathogens, the threat of biotic agents increases in Canada. In addition, the changing climate, particularly warming, increases the potential for new pests and diseases to become established in regions where they previously were not an issue.

Highlighted Biotic Factors (2020 -2023)

Between 2020 and 2023, new information was reported for several biotic factors. This was mainly done through research conducted at Canadian institutions and/or field observations by provincial forest health specialists.

Apioplagiostoma populi (Bronze leaf disease)

Bronze leaf disease (BLD) affects poplar, aspen and their hybrids and is characterized by the infected, dark purplish-brown to bronze-coloured leaves and branches on infected trees. It is caused by the fungal pathogen *Apioplagiostoma populi* Barr. The disease was first reported in eastern Canada in 2002 and has since spread westward and is now present throughout the Prairie Provinces. BLD is causing premature mortality of poplars in the *Leuce* section including *Populus* ×*canescens* Smith (Tower poplar), *P. tremula* (Swedish columnar aspen), and *P. tremuloides* (trembling aspen)[149]. Disease symptoms resemble drought injury and include chlorosis and affected leaves and branches typically become necrotic and bronze in colour. Symptoms become severe in late summer, producing dried leaves and subsequent dieback, thus reducing the aesthetic and commercial value of the poplars. So far, the disease is mainly a threat to hybrid aspens used for ornamental purposes and there is no evidence of BLD in Canadian aspen forests.[150]

The BLD pathogen can be difficult to isolate and confirm from infected plant tissues. It is identified mainly by disease symptoms and morphological characteristics of *A. populi* fruiting bodies on infected leaves or branches. Airborne spores and nursery shipments containing infected plants play an important role in the movement of the pathogen. Canadian research has identified pathogen-specific genomic sequences which indicated that branches and petioles were the most effective tissues for detecting *A. populi*. In the study, BLD samples from symptomatic trees in Canada were examined microscopically for *A. populi* perithecia and asci. In addition, the study characterized the relationship and epidemiology of *A. populi*. This led to the development of a rapid diagnostic test that could help restrict the extent of further losses in plantings of aspen and poplar.[151]

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[149] Kawchuk, L.M., R.J. Howard, M.L. Kalischuk,P.R. Northover,M. Desjardins and R.C.J. Spencer (2010). First report of bronze leaf disease on poplar in Alberta, Canada and sequence of Apioplagiostoma populi. Plant Dis. **94**: 377.
[150] McIntosh, Rory – Pers. Comm.
[151] Wijekoon, C. P., M. L. Kalischuk, P. Brunelle, R. J. Howard and L. M. Kawchuk (2022). Characterization of bronze leaf disease in western Canadian aspen and poplar trees. Canadian Journal of Plant Science **102**(1): 11-19.

Melampsora epitea (Willow tree rust)

In June 2021, laurel willow (*Salix pentandra*) near Slave Lake, Alberta, was found to be infected by a *Melampsora* species. The disease produced bright yellow urediniospores in uredia that were present on catkins, leaves, and stems. All *Melampsora* species previously reported in Canada are recorded as infecting leaves; therefore, further investigation was undertaken to ascertain the identity of this pathogen. From these results, the fungal disease was determined to be *Melampsora epitea*. This was the first reported observation of *M. epitea* on *Salix* in Canada.[152] The presence of this diseas is of concern for bioenergy production in Canada and growers will monitor willow plantings fo this pathogen.[153]

Neodothiora populina (Running canker)

Widespread growth declines and mortality of trembling aspen (*Populus tremuloides*) in the Yukon has mostly been linked to drought. This drought-induced aspen dieback often interacted with outbreaks of herbivorous and wood-boring insects and fungal pathogens, resulting in a “sudden aspen decline” throughout much of aspen’s range in the territory, exacerbating sensitivity to both drought and pest and pathogen outbreaks. Associated with the combined stresses of drought and the leaf miner outbreak, “aspen running canker” is likely to have been instrumental in aspen mortality. The “aspen running canker” pathogen, discovered in Alaska and previously new to science, has been recently named *Neodothiora populina* Crous, G.C. Adams, & Winton. Running canker has been found at a large number of sites in Alaska where that state borders with British Columbia and the Yukon Territory. Therefore, it is highly likely *N. populina* has established in this part of Canada as well. Yukon and British Columbia foresters are diligently monitoring aspen stands for this disease. [153]

Sphaerulina musiva (syn. *Septoria musiva*) on *Populus*

Canker on *Populus* stems and branches, caused by the fungus *Sphaerulina musiva* (Peck) Quaedv., Verkley and Crous *(syn. Septoria musiva* Peck), is the most economically important disease and the major limiting factor to the production of *Populus* species and hybrids as a commercial crop in Canada. *S. musiva* causes necrotic lesions on the leaves and cankers on highly susceptible poplar clones, leading to stem deformation that is often lethal and predisposes the tree to colonization by secondary organisms; this deformation often leads to stem breakage. Due to the invasiveness of *S. musiva*, it is regarded as a high-priority pathogen in Canada. The only practical way to prevent its spread is by planting resistant hybrid poplars. An experimental trial in Alberta indicated that controlled inoculation experiments may help determine the resistance of hybrid poplar clones to infections of *S. musiva*.[154] Researchers at the University of British Columbia have found that the expansion of poplar cultivation has resulted in the emergence of a new lineage of *Sphaerulina musiva* that causes stem infections on a new host, *P. balsamifera*. This suggests a host shift since balsam poplar was not a known host. The study

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[152] Ramsfield, T. D., N. Feau, P. Tanguay, R. C. Hamelin, P. Herath and T. Bozic (2023). "First report of *Melampsora epitea* causing stem cankers on *Salix pentandra* in Alberta, Canada." Frontiers in Forests and Global Change **6**, 1172889.

[153] 2022 Yukon Forest Health Report. https://yukon.ca/en/2022-yukon-forest-health-report (Accessed February 16, 2024).

[154] Niemczyk, M. and B.R. Thomas (2020). Growth parameters and resistance to *Sphaerulina musiva*-induced canker are more important than wood density for increasing genetic gain from selection of *Populus* spp. hybrids for northern climates. Annals of Forest Science **77**, 26.

suggested that new lineage likely emerged via hybridization and introgression, host shift, adaptation and incipient speciation.[155]

A related species, *Septoria populicola* (Septoria leaf spot), causes only an endemic leaf spot on native poplars and susceptible hybrids. This leaf spot is commonly found on planted and natural balsam poplar stands throughout Canada.[156]

Provincial Tree Health Updates

Tree health specialists from each province and territory were consulted for an update on insect and disease issues in their respective provinces and territories. Specialists were asked to comment on the incidence and scale of damage to poplar, willow and alder to biotic and abiotic factors from 2020 through 2023. They were also asked to describe the impact and severity of damage. The following summarizes submissions from reporting provinces.

British Columbia

Sphaerulina musiva has been repeatedly detected on hybrid *Populus* in nursery and clonal plantations along the lower Fraser River of British Columbia. The negative impacts of the disease have led British Columbia to restrict the use of and the importation of clones known to be susceptible to *S. musiva* into British Columbia.[157]

The cumulative effects of biotic damage have led to significant mortality in trembling aspen in British Columbia. The main insect vector contributing to aspen damage was the serpentine leaf miner (*Phyllocnistis populiella*) in 2020 with reduced incidence from 2021 to 2023. Disease vectors included widespread Venturia blight (*Venturia macularis*) damage in 2020 (coinciding with record regional rainfall events), cytospora canker (*Valsa* species) and the possibility of aspen running canker (*Neodothiora populina*) disease in northern populations of aspen bordering Alaska and the Yukon Territory. For *Salix*, the poplar and willow borer (*Chryptorhynchus lapathi*) has caused widespread extensive damage resulting in many large willows essentially removed from the landscape.[158]

Red alder (*Alnus rubra*) trees form an essential component of coastal stream communities in British Columbia. Canopy dieback has been observed in British Columbia red alder for several years. Three pathogens were identified on red alder growing along the British Columbia coast. These pathogens include: *Phytophthora cambivora, P. syringae* and *P. pseudosyringae*. A study published in 2022 showed that only *P. pseudosyringae* has the potential to cause both stem canker and aerial symptoms. This was the first isolation of *P. pseudosyringae* in Canada.[159]

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[155] Feau, N., B. D. Dhillon, M. Sakalidis, A. L. Dale, K. L. Sondreli, S. B. Goodwin, J. M. LeBoldus and R. C. Hamelin (2023). "Forest health in the Anthropocene: the emergence of a novel tree disease is associated with poplar cultivation." Philosophical Transactions of the Royal Society B-Biological Sciences **378**, 1873.
[156] Leaf spot (*Mycosphaerella populicola*). https://tidcf.nrcan.gc.ca/en/diseases/factsheet/1000068 (Accessed February 15, 2024).
[157] British Columbia Chief Forester Guidance, BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development.
[158] Woods, Alex – Pers. Comm.
[159] Feau, N., M. McDonald, B. van der Meer, Y. S. Zhang, P. Herath and R. C. Hamelin (2022). "*Phytophthora* species associated with red alder dieback in British Columbia, Canada." Canadian Journal of Plant Pathology **44**(4): 549-558.

Alberta

From 2020 to 2023, dieback of trembling aspen continued in the northern half of Alberta. In Alberta, the most damaging biotic factors affecting *Populus* were defoliators affecting 1,543,200 hectares. Fixed-wing aerial forest health surveys during the reporting period identified the major biotic factorss in Alberta *Populus* and *Salix* forests during the reporting period. The insects and diseases and forest area affected by each vector were as follows: forest tent caterpillar (*Populus*) - 77,603 hectares; large aspen tortrix (*Populus*) – 260,500 hectares; Bruce spanworm (*Populus*) – 243,954 hectares; aspen serpentine leafminer (*Populus*) – 819,271 hectares; tomentosus root rot (*Populus*) – 234 hectares; aspen two-leaf tier (*Populus*) – 171,061 hectares; willow leaf miner (*Salix*) – 34,696 hectares.[160]

At the City of Calgary Biosolid willow plantation, managed by Sylvis[161], the incidence of insect and disease infestations is monitored regularly. The main issues in established willows (planted before 2020) were the disease cytospora (*Valsa* spp.) and a Calligrapha leaf beetle (C*alligrapha verrucosa*). In 2023, surveys aphids (*Aphidoidea* spp.) and spider mites (*Tetranychidae* spp.) were also found in the established plantings.[162]

Between 2020 and 2023, a new pervasive unidentified moth larva that quickly defoliates newly planted willows was observed. The other main insect present during the reporting period was the leaf beetle (*Calligrapha verrucosa*). The moth larvae were controlled with a ground sprayer whereas the leaf beetles were controlled with aerial pesticide application. Currently, Slyvis has not attempted control measures for the disease and fungal issues encountered in the plantings. Instead, the problem is addressed by removal of infected willows (via harvest) and ensuring the willows have adequate nutrients and water to reduce negative impacts of these pressures.[163]

In 2021, a survey of pests in selected Alberta willow test plantations, including the 343-hectare City of Calgary (Keoma) willow plantation, was conducted. The objectives were to identify the insects and pathogens associated with the various willow cultivars, compare the incidence and severity of the pest agents, and to provide recommendations for future cultivar selection. The most serious pest agents found in the survey were cytospora canker (*Valsa* spp.), willow blight (*Venturia saliciperda,*), poplar and willow borer (*Cryptorhynchus lapathi*), willowleaf blotch miner (*Micrurapteryx salicifoliella*), leaf tiers (*Caloptilia stigmatella*), spider mites (*Tetranychidae* spp.), grasshoppers (*Melanoplus* spp.), leaf beetles (C*alligrapha verrucosa*) and, aphids (*Aphidoidea* spp.). Pathogens, insects, vertebrates and abiotic factors encountered at Ohaton, Keoma, and Beaverlodge willow test sites during a 2021 pest survey are listed in the following table.

[160] Tellier, David – Pers. Comm.
[161] Sylvis – Willow Biomass Crop. https://www.sylvis.com/our-work/willow-biomass-crop (Accessed February 24, 2024).
[162] Coombs, Alexandra – Pers. Comm.
[163] Coombs, Alexandra – Pers. Comm.

Pathogens, insects, vertebrates and abiotic factors at Ohaton, Keoma, and Beaverlodge in 2021.[164]				
Pest / Agent	**Common Name**	**Ohaton**	**Keoma**	**Beaverlodge**
Pathogens:				
Valsa spp.	Cytospora canker	light-severe	trace-severe	light-severe
Venturia saliciperda, Colletotrichum salicis	Willow blight (incl. willow scab & black canker)	trace-light	trace-moderate	
Root and stem insects:				
Agrilus criddlei	Flat headed wood borer		trace	
Cryptorhynchus lapathi	Poplar & willow borer	trace-heavy	trace-heavy	trace
Proctorus decipiens			trace	trace
Mayetiola rigidae	Willow beaked-gall midge	trace		
Pontania sp.	Willow redgall sawfly			trace
Rabdophaga spp.	Willow gall midge	trace	trace	trace
Leaf miners:				
Micrurapteryx salicifoliella	Willow leaf blotch miner	trace	trace	trace
Coleophora pruniella		trace		
Leaf tiers:				
Caloptilia stigmatella	Willow leaf tip roller	trace	trace	
Choristoneura rosaceana	Oblique-banded leafroller			light
Clepsis persicana	White triangle tortricid			trace
Epinotia columbia				trace
Epinotia nisella				trace
Orthotaenia undulana	Dusky leafroller			trace
Pandemis canadana	Green aspen leaftier			trace
Defoliators:				
Alticini spp.	Flea beetles		trace	trace
Calligrapha verrucosa	Leaf beetle		trace-moderate	
Calligrapha multipunctata	Leaf beetle	trace		
Polydrusus formosus	Green immigrant leaf weevil		trace	
Tricholochmaea decora	Grey willow leaf beetle	trace	trace	trace
Acronicta dactylina	Fingered dagger moth	trace	trace	
Acronicta impressa			trace	
Dasychira vagans	Variable tussock moth	trace	trace	
Digrammia mellistrigata			trace	
Limenitis arthemis	White admiral butterfly	trace		
Lophocampa maculata	Banded woolly bear	trace	trace	
Macaria loricaria				trace
Nymphalis antiopa	Mourning cloak butterfly	trace	trace	
Orthosia hibisci	Speckled green fruitworm			trace
Papestra cristifera				trace
Spilosoma virginica			trace	
Cimbex americana	Elm sawfly	trace	trace	
Nematus calais			trace	
Melanoplus spp.	Grasshoppers	trace	trace-heavy	
Sap feeders:				
Aphidoidea spp.	Aphids	trace	trace-light	trace

[164] Pohl, G., Seung-Il, L. Tomm, B., Ramsfield, T. and C. Myrholm (2021). "Pest surveys of willow plantations in central Alberta, 2019 and 2021." Natural Resources Canada Canadian Forest Service, Edmonton, Alberta.

Cicadellidae spp.	Leafhoppers	trace	trace	trace
Pentatomidae spp.	Stink bugs		trace	trace
Tetranychidae spp.	Spider mites	light-heavy	trace-heavy	
Internal tissue feeders:				
Eriophyidae spp.	Eriophyid mites	trace	trace-light	trace
Vertebrate pests:				
Ungulate browse			trace	trace
Deer rubbing			trace	
Rabbit browse			trace	
Rodent girdling			trace	trace
Abiotic agents:				
Frost		trace	trace	trace
Hail			trace	
Winterkill			trace	

Saskatchewan

In Saskatchewan, annual damage surveys conducted from 2020 through 2023 showed defoliation over an extensive area of the trembling aspen in the provincial crown forest and parkland areas of the province. The surveys showed the following areas affected: 2020 – 9,021 hectares, 2021 – 31,018 hectares, 2022 – 4,450 hectares and 2023 – 14,599 hectares. In Saskatchewan, the surveys group all hardwood defoliation together as a defoliator complex that includes forest tent caterpillar (*Malacosoma disstria*) and large aspen tortrix (*Choristoneura conflictana*). Ground verification is used to confirm the causal agent. From 2020 to 2023, forest tent caterpillar or large aspen tortrix were the dominant disturbance agents. From 2020 to 2023, there was no control action for insects and diseases in provincial forest. [165]

Over the reporting period, the incidence and severity of tree pests and diseases were recorded during site visits to farm shelterbelts as well as urban landscapes and parks across the province. Damage severity varied according to species or cultivar and was rated as common (affected all cultivars in species), occasional (affected specific cultivars only) or rare (isolated occurrences).[166]

[165] McIntosh, Rory – Pers. Comm.
[166] GreenTree Agroforestry Solutions – Pers. Comm.

Biotic and abiotic factors found in Saskatchewan poplar and willow plantings between 2020 and 2023.[167]			
Vector	**Common Name**	**Poplar**	**Willow**
Disease			
Valsa spp.	Cytospora canker	common	occasional
Venturia saliciperda,	Willow blight	- -	rare
Marssonina brunnea	Marssonina leaf spot	occasional	- -
Septoria populicola	Septoria leaf spot	occasional	- -
Melampsora medusa	Melampsora leaf rust	occasional	- -
Sphaerulina musiva	Septoria canker	occasional	- -
Apioplagiostoma populi	Bronze leaf disease	rare	- -
Stem Insects			
Cryptorhynchus lapathi	Poplar & willow borer	common	common
Plectrodera scalator	Cottonwood borer	common	- -
Saperda calcarata	Poplar borer	common	- -
Aceria parapopuli	Poplar bud gall mite	common	- -
Pemphigus populitransversus	Poplar petiole gall aphid	common	- -
Mordvilkoja vagabunda	Poplar vagabond gall aphid	common	- -
Pontania sp.	Willow redgall sawfly	- -	common
Rabdophaga spp.	Willow gall midge	- -	common
Leaf Miners, Rollers and Defoliators			
Micrurapteryx salicifoliella	Willow leaf blotch miner	- -	rare
Phyllocnistis populiella	Aspen leafminer	common	- -
Zengophora scutellaris	Poplar black mine beetle	common	- -
Caloptilia stigmatella	Willow leaf tip roller	- -	rare
Chrysomela scripta	Cottonwood leaf beetle	common	- -
Malacosoma disstria	Forest tent caterpillar	common	- -
Pterocomma smithiae	Black willow aphid	common	common
Orthotaenia undulana	Dusky leafroller	- -	rare
Tricholochmaea decora	Grey willow leaf beetle	- -	common
Melanoplus spp.	Grasshoppers	common	common
Abiotic Factors			
Ungulate and rodent browse		common	common
Hail		common	common
Winterkill		common	common
Drought		common	common
Salinity		common	common
Herbicide drift		common	common

[167] GreenTree Agroforestry Solutions – Pers. Comm.

Québec

In Québec, forest tent caterpillar (*Malacosoma disstria*) outbreaks in *Populus* stands were observed during the reporting period. No control measures were taken as forest tent caterpillar rarely results in tree mortality. Fungus-causing canker (*Sphaerulina musiva*) is now widespread throughout Québec. The disease continues to spread throughout the province and is getting worse in some regions. In addition, leaf spot and trunk cankers are causing damage and reduced wood quality. These diseases are having a negative impact on the promotion of poplar culture in the province. No control measures are used, rather the goal is to develop and deploy resistant poplar clones.[168]

For all *Salix viminalis* hybrids, potato leaf hopper (*Empoasca fabae*) is the main insect to cause problems in Québec willow plantings. The other insects commonly encountered in the province were willow sawfly (*Janus abbreviates*), woolly aphids (*Erisoma lanigerum*) and giant willow aphids (*Tuberolachnus salignus*), but these insects do not have a major impact on willow yield or survival. The main disease issue observed on *Salix* in Québec between 2020 and 2023 was bacterial blight (*Pseudomonas syringae* pv. *Syringae*).[169]

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[168] Otis-Prud'homme, Guillaume – Pers. Comm.
[169] Allard, Francis – Pers. Comm.

Major Biotic Factors Reported 2020-2023 (Yukon, British Columbia, Alberta, Saskatchewan, Ontario and Québec)

Region	Vector	Common Name	Genera Affected		
			Populus	Salix	Alnus
Yukon[170]	*Phyllocnistis populiella*	Aspen serpentine leafminer	x		
	Choristoneura conflictana	Large aspen tortrix	x		
	Micrurapteryx salicifoliella	Willow blotch beetle		x	
	Neodothiora populina	Aspen running canker	x		
British Columbia[171]	*Saperda* spp.	Poplar borers	x		
	Septoria musiva	Septoria canker	x		
	Chryptorhynchus lapathi	Poplar and willow borer		x	
	Alniphagus aspericollis	Alder bark beetle			x
	Malacosoma californicum	Western tent caterpillar			x
	Liriomyza brassicae	Serpentine leaf miner	x		
	Phyllocnistis populiella	Aspen serpentine leafminer	x		
	Neodothiora populina[172]	Aspen running canker	x		
	Venturia macularis	Venturia blight	x		
	Valsa sordida	Cytospora canker	x		
	Valsa umbrina	Cytospora canker			x
	Sphaerulina musiva	Septoria canker	x		
Alberta[173] [174]	*Armillaria* root disease	Armillaria root disease			
	Operophtera bruceata	Bruce spanworm	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	
	Enargia decolor	Aspen twoleaf tier	x		
	Inonotus tomentosus	Tomentosus root rot	x	x	
	Leucoma salicis	Satin moth	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	

[170] 2022 Yukon Forest Health Report. https://yukon.ca/en/2022-yukon-forest-health-report (Accessed February 17, 2024).
[171] Woods, Alex – Pers. Comm.
[172] Likely a new pathogen found in neighboring Alaska but not positively identified in British Columbia, Woods, Alex – Pers. Comm.
[173] Tellier, David – Pers. Comm.
[174] Gamache, Winston – Pers. Comm.

	Apioplagiostoma populi	Bronze leaf disease	x		
	Sphaerulina musiva	Septoria canker	x		
	Armillaria root disease	Armillaria root disease	x		
	Melampsora epitea[175]	Willow leaf rust		x	
	Melampsora medusae	Poplar leaf rust	x		
	Valsa sordida	Cytospora canker		x	
Saskatchewan[176]	*Malacosoma disstria*	Forest tent caterpillar	x		
	Micrurapteryx salicifoliella	Willow leaf blotch miner		x	
	Calligrapha verrucosa	Leaf beetle		x	
	Pyrrhalta decora	Gray willow leaf beetle		x	
	Cryptorhynchus lapathi	Poplar and willow borer		x	
	Apioplagiostoma populi	Bronze leaf disease	x		
	Sphaerulina musiva	Septoria canker	x		
	Melampsora medusae	Poplar leaf rust	x		
Ontario[177]	*Malacosoma disstria*	Forest tent caterpillar	x		
	Choristoneura conflictana	Large aspen tortrix	x		
	Plagiodera versicolor	Willow leaf beetle		x	
	Venturia macularis	Shoot blight of aspen	x		
Québec[178]	*Malacosoma disstria*	Forest tent caterpillar	x		
	Janus abbreviates	Willow shoot sawfly		x	
	Pterocomma salicis	Black willow aphid			
	Erisoma lanigerum	Woolly Aphid		x	
	Tuberolachnus salignus	Giant willow aphid		x	
	Plagiodera versicolora	Willow leaf beetle		x	
	Venturia moreletii	Shoot blight	x		
	Venturia saliciperda	Willow blight		x	
	Glomerella miyabeana	Black willow fungus		x	
	Valsa sordida	Cytospora canker	x		
	Discosporium populeum	Dothichiza canker	x		
	Entoleuca mammata	Hypoxylon canker	x		
	Marssonina brunnea	Marssonina leaf spot	x		
	Sphaerulina musiva	Septoria canker	x		
	Melampsora spp.	Leaf rust		x	
	Melampsora medusae	Poplar leaf rust	x		
	Pseudomonas syringae pv. Syringae	Bacterial blight		x	

[175] New discovery (2023) in Alberta, Ramsfield, Tod – Pers. Comm.
[176] McIntosh, Rory – Pers. Comm.
[177] Forest Health Conditions in Ontario 2022. https://www.ontario.ca/files/2023-05/mnrf-forest-health-conditions-2022-en-2023-05-09.pdf (Accessed February 22, 2024).
[178] Otis-Prud'Homme, Guillaume – Pers. Comm.

Ungulates and Rodents

Herbivory of *Populus* and *Salix* by ungulates (mainly moose and deer) and rodents (beavers, rabbits, and voles) was reported in all Canadian provinces and territories. Damage can be severe and impacts aboveground growth and biomass accumulation and sometimes results in mortality. 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 another browse is scarce. Tall grass and other heavy ground cover around trees increases the likelihood of damage by mice and voles feeding on the bark during winter, especially in years with high populations. Poplar and willow are injured by ungulates rubbing their antlers on stems or by gnawing or stripping bark off trees with their incisor teeth. Secondary fungal infections often enter trees through wounds caused by animals, compounding the damage. In Alberta, browsing damage by deer, moose and elk is an issue as most plantations are not fenced due to high cost.[179]

b) Abiotic Factors

Abiotic disturbances can produce symptoms that resemble those produced by insects, disease, or other biotic agents. Careful observation is required to distinguish issues caused by abiotic factors from those caused by biotic agents. Often abiotic stress is overlooked as a causal agent in *Populus* or *Salix* decline. In Canada, abiotic stress in *Populus* and *Salix* falls into three broad categories: human activity-related (e.g., de-icing salts, herbicides); soils-related (e.g., nutrient availability, drought, salinity) and weather-related (e.g., precipitation, snow load, temperature, wind). The most restricting abiotic factors affecting *Populus* and *Salix* in Canada are drought, temperature, and soil salinity.

In Saskatchewan, between 2020 and 2023, over 63,000 hectares of trembling aspen forest were affected by abiotic factors. The major issues reported were flooding - 17,194 hectares; drought – 30,125 hectares; wind – 13,743 ha; and hail – 2,867 hectares.[180] In Alberta, the major abiotic factors were windthrow (*Populus* – 9,420 hectares); flooding (*Salix* – 2,613 hectares); drought (*Populus* – 1,500 hectares); chemical (*Populus* – 910 hectares) and snow damage (*Populus* – 229 hectares).[181]

In Alberta, drought conditions during the reporting period were a challenge when establishing willow plantings. This necessitated extensive fill-planting and, in extreme cases, replanting. Drought and weed competition make plantation establishment difficult. For moisture conservation and vegetation management, a year of chemical and mechanical site preparation prior to planting is recommended considered essential for successful establishment of willow plantings.[182]

Drought

Drought is a major factor impacting health and productivity of *Populus*, *Salix*, *Alnus* and other fast-growing trees in Canada. Research published by University of Saskatchewan researchers in 2020 studied drought resistance in two hybrid poplar clones: ‘Walker’ and ‘CanAm’. Using real-time transpiration data, they showed that ‘CanAm’ poplar had higher sap flow rates, and therefore higher transpiration

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[179] Blank, Martin – Pers. Comm.
[180] McIntosh, Rory – Pers. Comm.
[181] Tellier, David - Pers. Comm.
[182] Blank, Martin – Pers. Comm.

rates, than 'Walker' poplar under all soil water conditions including drought. Under increasingly severe water stress, the 'CanAm' poplar was much more water-use efficient with regards to growth and survival than was 'Walker' poplar. They concluded that 'CanAm' poplar is likely better suited to the warm, dry conditions prevalent in the southern semiarid Canadian prairies.[183]

Soil Salinity

Soil salinity is a limiting factor restricting establishment of poplar and willows, particularly on arid and semiarid agricultural soils in the Canadian prairies as well as saline petroleum well-pad sites and oil sands reclamation areas. Between 2020 and 2023, three salinity research projects related to fast-growing trees were completed at Canadian institutions.

A study at the University of Alberta, published in 2021, screened 222 balsam poplar clones using process-affected discharge water from an oil sands processing facility in Fort McMurray, Alberta. The study suggested there is opportunity to select genetically suitable native clones of balsam poplar that are tolerant to challenging growing conditions, making them more suitable for planting on saline sites.[184]

A University of British Columbia study, published in 2020, assessed the stress tolerance of native Canadian genotypes of *Populus balsamifera*, *Salix eriocephala*, and one hybrid willow (*S. discolor* × *S. dasyclados*) to salinity and hydraulic fracturing wastewater. The research showed that the salt-treated willows demonstrated a far greater tolerance to saline conditions than the balsam poplar, and that balsam poplar was likely unsuitable for reclamation of Na^{+}-dominated soils. They also identified native willow genotypes that could ultimately be used in ecological restoration of disturbed and marginal landscapes in the northern boreal forest and plains.[185]

A second study at the University of British Columbia screened willow genotypes native to the Canadian prairies and commercially available hybrid genotypes under treatments tailored to local soil salinity conditions in prairie soils. The results demonstrated that with moderate salinity treatment (7 dS m^{-1}), hybrid willows had better growth, as they established quickly while managing salt transport and mineral nutrition balance, but native willows showed higher potential for long-term survival under severe salinity.[186]

c) Resilience to Threats and Climate Change

Specific to fast-growing trees in Canada, a changing climate will lead to alterations in biotic factor regimes including changes to pest distribution, severity, and frequency. As the climate warms, the

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[183] Cutforth, H. W. and K. G. Wall (2020). "Water stress, sap flow and transpiration for medium and highly drought resistant poplars grown in the semiarid Canadian prairie." Canadian Journal of Plant Science **100**(4): 456-458.
[184] Hu, Y., D. Kamelchuk, R. Krygier and B. R. Thomas (2021). "Field Testing of Selected Salt-Tolerant Screened Balsam Poplar (*Populus balsamifera* L.) Clones for Use in Reclamation around End-Pit Lakes Associated with Bitumen Extraction in Northern Alberta." Forests **12**(5).
[185] Bilek, M. A., R. Y. Soolanayakanahally, R. D. Guy and S. D. Mansfield (2020). "Physiological Response of *Populus balsamifera* and *Salix eriocephala* to Salinity and Hydraulic Fracturing Wastewater: Potential for Phytoremediation Applications." International Journal of Environmental Research and Public Health **17**(20).
[186] Huang, X. Y., R. Y. Soolanayakanahally, R. D. Guy, A. S. K. Shunmugam and S. D. Mansfield (2020). "Differences in growth and physiological and metabolic responses among Canadian native and hybrid willows (*Salix* spp.) under salinity stress." Tree Physiology **40**(5): 652-666.

likelihood of ongoing poplar and willow decline is possible given the potential for increased frequency of drought events, particularly since poplar and willow generally have a low tolerance for water deficits. Warmer spring temperatures could also result in early spring flush followed by late spring frosts. Given the recent and historical observations of increased incidence of insect and disease in poplar and willow, the continuation and expansion of research to gain a better understanding of potential impacts of a changing climate will be required by Canadian resource managers and researchers.

It is predicted that climate-driven environmental changes will increase the vulnerability of natural ecosystems. Plant domestication combined with anthropogenic movement of plant material adds complexity by increasing the spread of fungal pathogens worldwide. These processes could result in major shifts in the reciprocal evolutionary dynamics found in natural ecosystems between hosts and pathogens and induce significant changes in pathogen populations. On the other hand, it is possible poplar and willow yields could be positively impacted by CO_2 and 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. During the reporting period, Canadian scientists have studied the potential impacts of a changing climate on fast-growing tree species, particularly poplar and willow. This research has suggested that, as the extreme weather events are projected to increase in their frequency and intensity, the investigation of the effects of extreme weather conditions in Canada will need more prominence in the future.

Of the direct climate impacts expected in Canada, changes in the hydrological balance of forest ecosystems may be the most important driver of changes to forest species makeup. A 2022 Alberta study identified the common western forest tree species (including trembling aspen) as being most exposed to climate-change-induced drought conditions. They found that climate change projections primarily increase water deficits for tree populations that are already in vulnerable positions. However, the observed dieback in trembling aspen populations in Canadian forests was caused by a rare extreme drought event that was not directly linked to climate change.[187]

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 important for the sustainability of both forests and wood supply for the forest industry. Frost-free period is related to warmer temperatures and longer growing season, which in combination with elevated atmospheric CO_2, could lead to an increase in tree productivity. An Alberta study, published in 2021, indicated that longer frost-free periods will increase the growth of deciduous trees such as balsam poplar if moisture is not limiting.[188] An earlier Alberta study by the same authors, using established permanent sampling plots in the boreal forest, found significant interactions between intraspecific competition and climate that suggested an increase in intraspecific competition would lead to a reduction in tree growth for trembling aspen and balsam poplar in warmer regions.[189]

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[187] Levesque, K. and A. Hamann (2022). "Identifying western North American tree populations vulnerable to drought under observed and projected climate change." Climate **10**(8):114.
[188] Oboite, F. O. and P. G. Comeau (2021). "Climate sensitive growth models for predicting diameter growth of western Canadian boreal tree species." Forestry **94**(3): 363-373.
[189] Oboite, F. O. and P. G. Comeau (2020). "The interactive effect of competition and climate on growth of boreal tree species in western Canada and Alaska." Canadian Journal of Forest Research **50**(5): 457-464.

A study at the Atlantic Forestry Centre in New Brunswick examined assimilation efficiencies and gas exchange traits for the willow species *Salix cordata*, *S. discolor*, *S. eriocephala* and *S. interior* under the interactive effect of atmospheric CO_2, soil moisture, and soil fertilization treatments. They found that *S. interior* was the most drought and saline tolerant of the willow species tested. The stem suckering feature of this species along with its drought tolerance allowed for more CO_2 capture to help mitigate climate change impacts.[190]

An Alberta study conducted by researchers at the University of Alberta demonstrated that, compared to conventional mineral fertilizers, pulp mill biosolids application reduced greenhouse gas (GHG) emissions. In addition, they suggested that combined applications of biosolids and urea fertilizer could reduce GHG emissions and improve soil stability and fertility. The study provided empirical support that soil microorganisms played an important role in the regulation of GHG emissions and may serve as a mechanism underlying GHG emissions in different fertilization treatments. The Alberta results suggested that recycling paper mill biosolids into hybrid poplar plantation soils had both ecological (less GHG emissions) and potential economic (N and P fertilizer savings) benefits.[191]

A study in Prince Edward Island determined the effect of *Salix viminalis* buffers on GHG emissions at the soil-atmosphere interface in agricultural-riparian transition zones downslope of potato cropping systems. The study concluded that *Salix* buffer strips on downslope field edges bordering riparian zones was an effective strategy for mitigating agriculturally derived nitrous oxide (N_2O) emissions in riparian areas on Prince Edward Island and provided an additional benefit of high biomass accrual with associated carbon and nutrient sequestration.[192]

Natural Climate Solutions

Canada's landscapes are already experiencing the effects of climate change, including the thawing of permafrost that releases greenhouse gases, shifts in ecotones and species composition, and increases in tree mortality from drought, wildfire, and insect outbreaks. In a 2021 paper published in Science Advances, the authors suggest that to reduce further climate damage in Canada and beyond, reduced emissions from fossil fuels while increasing removals and decreased emissions of GHG associated with land sector activities is required. However, they identified 24 natural climate-based pathways that related to the protection, management, and restoration of natural systems that could also deliver numerous co-benefits, such as enhanced soil productivity, clean air and water, and biodiversity conservation. The pathways associated with fast-growing trees were: 1.) tree intercropping on crop and hay land; 2.) silvopasture systems to simultaneously manage tree crops, livestock grazing, and forage; 3.) riparian tree planting in agricultural zones where forests are the natural land cover; 4.) reduced removal of existing shelterbelts from agricultural land; 5.) improved forest management associated with set-asides of old growth forests, enhanced forest regeneration in postharvest stands, and utilization of

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[190] Major, J. E., A. Mosseler and J. W. Malcolm (2022). "Assimilation Efficiencies and Gas Exchange Responses of Four *Salix* Species in Elevated CO_2 under Soil Moisture Stress and Fertilization Treatments." Forests **13**(5):776.
[191] Chen, X. L., B. R. Thomas, S. Pattison, Z. F. An and S. X. Chang (2023). "Pulp mill biosolids mitigate soil greenhouse gas emissions from applied urea and improve soil fertility in a hybrid poplar plantation." Journal of Environmental Management **344**, 118474.
[192] Wilts, H. D. M., D. L. Burton and A. A. Farooque (2022). "Cultivating *Salix Viminalis* in agricultural-riparian Transition areas to mitigate agriculturally derived N_2O emissions from potato cropping systems on Prince Edward Island." Water Air and Soil Pollution **233**(489).

harvest residues (logging slash) that would have otherwise been burned for bioenergy, as well as increased use of saw logs for long-lived wood products; 6.) reduced forest conversion to agriculture, oil/gas, mining, industry, forestry roads, transportation networks, municipal, and recreation development; 7.) restoration of forest cover with locally adapted native tree species in areas where forests historically occurred but do not currently exist; and 8.) increased average urban tree cover from 24 to 36 percent.[193]

In 2020 the Government of Canada announced a ten-year Natural Climate Solutions Fund initiative. This initiative included three separate but related programs: Natural Resources Canada's 2 Billion Trees Program, Environment and Climate Change Canada's Nature Smart Climate Solutions Fund, and Agriculture and Agri-Food Canada's Agricultural Climate Solutions Program.[194] These programs include opportunities for the use of fast-growing trees as a natural climate solution.

The 2 Billion Trees Program commits to planting an additional two billion trees by 2030. The program works with diverse partners across Canada to plant two billion incremental trees over ten years. This includes support for targeted Indigenous-led projects, forest habitat restoration and projects that contribute to community resiliency.[195] The Nature Smart Climate Solutions Fund is a ten-year fund meant to reduce greenhouse gas emissions by 2-4 megatonnes annually. The fund will achieve this by supporting projects that conserve, restore, and enhance wetlands, peatlands, and grasslands to store and capture carbon.[196] Agricultural Climate Solutions is a multi-stream program to help develop and implement farming practices to tackle climate change. By developing, evaluating, adopting, and surveying agricultural technologies and practices, this program is focused on sequestering carbon, reducing greenhouse gas emissions, and delivering environmental benefits.[197]

4. Production Systems for the Bioeconomy

a) Nursery Practices

The nursery production of hybrid poplar and willow and other fast-growing trees in Canada is conducted through a combination of private and public nurseries. In Western Canada (Manitoba, Saskatchewan, Alberta, and British Columbia) private nurseries propagate most of the poplar and willow planted. In Saskatchewan there is one publicly funded nursery, SaskPower Shand Greenhouse, which grows a limited number of rooted poplar and willow. Under the SaskPower program, rooted poplar and willow cuttings are provided free of charge on a first-come first-serve basis to landowners or environmental groups for the following purposes: land conservation, reclamation, phytoremediation, shelterbelts, and

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[193] Drever, C.R. et al. (2021). "Natural climate solutions for Canada." Science Advances **7**, eabd6034.
[194] Natural Climate Solutions Fund. https://www.canada.ca/en/campaign/natural-climate-solutions.html (Accessed February 23, 2024).
[195] 2 Billion Trees Commitment. https://www.canada.ca/en/campaign/2-billion-trees.html (Accessed February 23, 2024).
[196] Nature Smart Climate Solutions Fund. https://www.canada.ca/en/environment-climate-change/services/environmental-funding/programs/nature-smart-climate-solutions-fund.html (Accessed February 23, 2024).
[197] Agricultural Climate Solutions. https://agriculture.canada.ca/en/environment/climate-change/climate-solutions?utm_source=ext_web&utm_medium=vanity_url&utm_campaign=not_applicable&utm_content=2021-06-29_01 (Accessed February 23, 2024).

the creation of new habitat for wildlife; or the afforestation of portions of Saskatchewan in order to assist in the mitigation of carbon dioxide emissions. [198]

In the absence of the former federal government Prairie Shelterbelt Program, which was terminated in 2013, the majority of landowners access poplar and willows from private prairie nurseries in Manitoba, Alberta, and Saskatchewan as well as a conservation nursery (Lincoln-Oakes Nurseries) in Bismarck, North Dakota, USA[199].

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 TreeTime.ca in Edmonton, Alberta[200], Select Seedling Nursery in Saskatoon[201] and Prairie Shelterbelt Program in Sundre, Alberta[202]. One private nursery near Kelliher, Saskatchewan is dedicated to the production of poplar hardwood cuttings. They produce approximately 100,000 hardwood poplar cuttings annually. These cuttings are supplied to farmers, and commercial nurseries.[203] Poplars can also be obtained from many private commercial nurseries across Canada, but they are generally larger caliper stock for landscaping applications. Prairie nurseries also produce rooted willow cultivars that are mostly dedicated to shelterbelt planting.

[198] SaskPower Shand Greenhouse, Estevan, SK. https://www.saskpower.com/our-power-future/our-environmental-commitment/shand-greenhouse (Accessed February 15, 2024).

[199] Lincoln-Oakes Nurseries. Bismarck, North Dakota. http://lincolnoakes.com/stock/pc/viewcontent.asp?idpage=22 (Accessed Feb. 15, 2024)

[200] Tree Time Services. Edmonton, AB. https://treetimeservices.ca/ and https://treetime.ca/ (Accessed February 5, 2024).

[201] Select Seedling Nursery. Saskatoon, SK. https://selectseedlingnursery.com/collections/all?sort_by=title-ascending&filter.p.product_type=Poplar (Accessed Feb 15, 2025).

[202] Prairie Shelterbelt Program. Sundre, Alberta. https://prairieshelterbeltprogram.ca/store/contact-us (Accessed February 10, 2024).

[203] De Gooijer, Henry – Pers. Comm.

Poplar species and hybrids propagated by nurseries in the Canadian prairies

Clone	Parentage
‘Okanese’	*P.* × ‘Walker’ × *P.* x*petrowskyana*
‘Northwest’	*P. deltoides* × *P. balsamifera*
‘Tower’	*P.* ×*canescens*
Balsam	*P. balsamifera*
‘Assiniboine’	*P.* × ‘Walker’
‘Sundancer’	*P.* × ‘Walker’ × *P.* ×*canadensis* ‘serotina de selys’
‘Prairie Sky’	*P.* ×*canadensis* ‘Prairie Sky’
‘Walker’	*P. deltoides* × *P.* ×*petrowskyana*
‘Tristis’	*P. tristis*
‘Québec’ (38P38)	*P. simonii* × *P. balsamifera*
‘Hill’	*P. deltoides* × *P.* ×*petrowskyana*
Swedish columnar aspen	*P. tremula erecta*
Trembling aspen	*P. tremuloides*
Cottonwood	*P. deltoides* var. *occidentalis*
‘Prairie Sunrise’ aspen	*P. tremuloides*

Willow species and cultivars propagated by nurseries in the Canadian prairies.

Cultivar	Parentage
Acute willow	*S. acutifolia*
Golden willow	*S. alba ‘Vitellina’*
Laurel leaf willow	*S. pentandra*
Silver leaf willow	*S. alba* var. *sericea*
Peach leaf willow	*S. amygdaloides*
Pussy willow	*S. discolor*
Beaked willow	*S. bebbiana*
Heart leaf willow	*S. eriocephala*
Sandbar willow	*S. exigua*

Plantations established using 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 have been established using the Danish Egedal planter. This planting unit requires whips of about 2 m in length, which are then cut by the machine, during the time of planting, into 20 cm long cuttings, which are planted directly into the ground. In a willow plantation near Forestburg, Alberta, unrooted short willow cuttings (10 cm billets) were planted by being buried horizontally using the Hendriksson HSAB Billet Planter. The advantage of this system is that less cuttings material is needed for a given land area.[204]

In Québec, the principal willow nursery is operated by Ramo of St-Roch de l'Achigan, Québec.[205] Besides Québec, Ramo is currently the main supplier of willow across Canada for phytoremediation or bioenergy projects. They produce licensed varieties from State University of New York College of Environmental Science and Forestry, Cornell University and the Lantmannen breeding program in Sweden. In addition, the Ramo nursery produces hydrids of *Salix miyabeana*, *S.dasyclados,* and *S. viminalis*.[206]

Ramo also produces many native willow species for environmental/restoration/reclamation projects. The willow clones propagated include the native *Salix discolor*, *S. eriocephala*, and *S. interior*. Cuttings are provided as 20 cm dormant cuttings or 1-4 m shoots. Ramo cultivates willows using a rigorous production regime. For vegetation engineering projects, willows are mechanically harvested in the fall, and the stems are kept in a dormant state in a refrigerated warehouse until transportation to the customer. Between 2020 and 2023, Ramo produced 8-10 million willows trees/shrubs annually in different formats, including cuttings, rooted plants, living stems. Ramo anticipates their production capacity could reach up to 30 million plants per year. [207]

In 2023, Ramo acquired Bionera Resources from Pacific Regeneration Technologies to become a nation-wide provider of environmental solutions in Canadian residuals management and reclamation. Ramo, founded in Québec in 2006, is North America's largest willow-based nursery and environmental services group. The company provides cost-effective solutions to biosolids/residuals management, effluent/landfill leachate volume reduction and reclamation with short rotation willow crops. From 2009 to 2023, Bionera Resources had planted 15 million willows in western Canada. This acquisition unifies willow development nationwide under one company, promoting reclamation systems, biosolid management and leachate volume reduction technologies in addition to the marketing of wood fibre products.[208]

Conservation foresters in Ontario can access hybrid poplar from the Ferguson Tree Nursery in Kemptville, Ontario, which provides stock as either rooted or unrooted cuttings.[209] 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.

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

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[204] Krygier, Richard – Pers. Comm.
[205]Ramo. St-Roch de l'Achigan, Québec. https://ramo.eco/en/soil-bioengineering (Accessed Feb. 15, 2024).
[206] Allard, Francis – Pers. Comm.
[207] Allard, Francis – Pers. Comm.
[208] Ramo Press Release. Ramo-x-Bionera.pdf (Accessed February, 15, 2024).
[209] Ferguson Tree Nursery. Kemptville, Ontario. https://www.fergusontreenursery.ca/hybrid-poplar-1-1-b-hybrid-poplar-1-1 (Accessed Feb 15, 2024).

seedlings are made available to other conservation authorities.[210] Somerville Nursery, near Alliston, Ontario, also supplies seedlings to conservation authorities.

In western Canada, trembling aspen production in nurseries is largely from seed using a protocol that maximizes total non-structural carbohydrate reserves in the roots. This is done by promoting the induction of premature bud set using a hormonal shoot growth inhibitor during the growing season that allows continued photosynthesis and fertilization. A 2020 study investigated whether this nursery protocol developed exclusively with Canadian boreal trembling aspen seed sources would produce similar results for other aspen seed sources. The study found that seedlings from Utah and New Mexico seed sources differed in their response to the protocol from the Alberta seed source, developing smaller root-to-stem ratios and sequestering less carbohydrate and nutrient reserves. The results indicated that aspen nursery protocols would benefit from regional modification to optimize seedling stock quality and trait consistency.[211]

In Québec the Ministère Ressources naturelles et des Forêts (MRNF) controls hybrid poplar nursery production and distribution through its provincially owned nurseries, Pépinière de Grande-Piles and Pépinière de Berthierville. The Berthierville nursery was opened in 1908 and encompasses 155 ha, of which 52 ha are for bare-root and container production, 26 ha for seed orchards, 2 ha for a hybrid larch cross breeding park and, 50 ha for natural forest and plantation.[212] The Grande-Piles nursery was founded in 1915 by the Laurentide Paper Company and sold to the Québec government in 1936. This nursery has an area of 337 ha, of which 45 ha are reserved to produce plants for seed orchards.[213]

In Québec, most of the poplar stock is grown as bareroot rooted cuttings. Hybrid poplar plants grown with bare roots are produced in the ground in beds prepared for this purpose. The cuttings, 12 cm to 15 cm long and with a diameter greater than 4 mm, are transplanted vertically, leaving only a single bud protruding above the ground. Growing cuttings requires the usual care of irrigation, fertilization, and weeding, as well as root pruning treatments to limit the development of roots near the plants. The production schedule is a single growing season. The plants are usually dug out in the fall, while they are dormant. Depending on the clones, the height of the plants varies between 100 cm and 220 cm. After extraction, the plants are sorted, dressed (i.e., they undergo root pruning), packaged and stored until ready for delivery. No forest plants are produced from genetically modified seeds or cuttings. [214]

The MRNF produce approximately 600,000 rooted cuttings of 30 different hybrid poplar clones annually. The rooted cuttings are distributed to landowners for outplanting on both private and public lands. The MRNF has experimented in the past with the use of unrooted poplar whips, which are potentially attractive due to lower costs of production, handling, storage, transport, and planting.

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[210] Grand River Conservation Authority – Burford Tree Nursery. Burford, Ontario. https://www.grandriver.ca/en/our-watershed/Burford-Tree-Nursery.aspx (Accessed February 12, 2024).
[211] Howe, A. A., S. M. Landhäusser, O. T. Burney, J. M. N. Long and K. E. Mock (2020). "Regional differences in aspen (*Populus tremuloides* Michx.) seedling response to an established nursery protocol." New Forests **51**(2): 367-378
[212] Government of Quebec – La pépinière de Berthier. Berthierville, Quebec. https://mffp.gouv.qc.ca/forets/semences/semences-pepinieres-berthierville.jsp (Accessed February 15, 2024)
[213] The Nursery at Grand Isles. https://mffp.gouv.qc.ca/les-forets/production-semences-plants-forestiers/pepinieres/publiques/grandes-piles (Accessed February 15, 2024).
[214] Production from hybrid poplar cuttings. https://mffp.gouv.qc.ca/les-forets/production-semences-plants-forestiers/plants/techniques/feuillues/boutures (Accessed February 15, 2024).

However, for nursery production reasons and given that most of the planting in Québec takes place on forest soil, the use of rooted cuttings is prioritized as it ensures survival and good growth in all reforestation situations.[215] Additionally, since the vast majority of planting in Québec takes place on public land, and there is a 'no-herbicide' policy in place, rooted stock is required to ensure survival.[216] The MRNF also provides a list of private nurseries that produce forest seedlings for landowners and forest companies.[217]

The most common method of propagating willow in Canada is by unrooted dormant woody cuttings. However other techniques have also been attempted including microcuttings, rods and unrooted billet material. Not commonly used with willow, *in vitro* micropropagation culture is used for large-scale propagation of many herbaceous and woody species. Despite the large popularity of *Salix miyabeana* for various environmental applications in different parts of the world, most propagation techniques rely mainly on cuttings. However, *in vitro* propagation could be a more reliable solution when selection of new commercial clones and varieties is the goal of propagating willows. A Québec study published in 2023 developed a protocol to grow *S. miyabeana* via *in vitro* propagation. Their results identified an effective sterilization procedure to ensure healthy plants. In their study, material obtained from apical explants showed higher survival rate, budding ability and lower microbiological contamination compared to lateral explants.[218]

In Québec researchers at the Institut de recherche en biologie végétale developed an innovative method for establishing willow on disturbed sites. In their study, they tested 5 cm long microcuttings to evaluate their potential to cover disturbed soil rapidly and prevent establishment of undesirable tree species. *Salix eriocephala* 'S25'microcuttings were scattered uniformly and horizontally at a density of 90 microcuttings and 120 microcuttings per square metre and covered with about 5 cm of compost. The study showed that the use of willow microcuttings was an alternative approach to establishing a dense shrub cover and showed good potential to restore disturbed sites.[219]

Bigleaf maple is a large deciduous tree native to the Pacific west coast of Canada, and the only commercially important maple in the region. Natural populations of bigleaf maple trees contain, at low frequency, individuals with stems that have attractive and valuable wavy grain in the wood. To maintain the genotype of these individuals, vegetative propagation is desired. Propagation by rooting of bigleaf maple stem cuttings is inefficient and unreliable. In comparison, *in vitro* micropropagation can produce many new plants from limited starting material and provide responsive starting material for conventional rooting of cuttings. Researchers at Simon Fraser University developed a procedure for successful *in vitro* propagation of bigleaf maple. They discovered that removal of the shoot tip from

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[215] Otis-Prud'Homme, Guillaume – Pers. Comm.
[216] Otis-Prud'Homme, Guillaume – Pers. Comm.
[217] Government of Quebec. Les pépinières forestières privees. https://mffp.gouv.qc.ca/forets/semences/semences-pepinieres-privees.jsp (Accessed February 15, 2024)
[218] Nissim, W. G., G. C. Fadel and M. Labrecque (2023). "Assessment of different procedures for *in vitro* propagation of *Salix miyabeana*." Plant Biosystems. DOI: 10.1080/11263504.2023.2293035.
[219] Desrochers, V., C. Frenette-Dussault, W. G. Nissim, J. Brisson and M. Labrecque (2020). "Using willow microcuttings for ecological restoration: An alternative method for establishing dense plantations." Ecological Engineering **151**, 105859.

explants released growth of axillary shoots and, in combination with the use of DKW medium and 0.1 µM TDZ, resulted in a three- to four-fold increase of shoots.[220]

b) Planted Forests

Québec is the province with the largest area of hybrid poplar plantations in Canada with an estimated total of about 12,000 hectares. There are 700 hectares of hybrid poplar planted annually, with Domtar Forest Industries planting around 400 hectares per year[221] on the company's privately owned land parcels near their pulp and paper mill at Windsor, Québec. As of 2020, the company had over 8,000 hectares. Domtar makes information about its hybrid poplar plantations available on-line.[222] Domtar began its hybrid poplar plantation program in 1998 and the first harvest was in 2012.[223] It is assumed that the area planted, and the area harvested are now approximately equal so that the area in production from year to year is stable.

Hybrid poplar as a source of wood has decreased in the rest of Canada. The main reasons for this are likely economic and only partly technical. The price of agricultural crops and agricultural land continue to increase, while aspen poplar on Crown land is adequate for wood processors. Technical challenges continue to include the availability of adapted clones that are resistant to insects and diseases and the lack of registered herbicides for weed control.

The largest hybrid poplar planting program in western Canada was the Hybrid Poplar Farming Program of Alberta-Pacific Forest Products (Al-Pac) in Boyle, Alberta, which discontinued new plantings in 2012. Performance of most of the plantations was limited by soils, diseases, insects, and mammals. The better plantations were harvested for pulp by Al-Pac. The company also has 100 hectares of hybrid aspen which are being monitored for growth, disease resistance and other selection criteria.[224]

In Alberta, the Western Boreal Aspen Corporation, through three of its member companies – Mercer, West Fraser, and Weyerhaeuser – has planted 170 hectares of improved aspen from 2022 to 2024.[225] These are pilot plantations which also serve as larger scale performance trials for improved selections.

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[220] Zhou, C. and J. Mattson (2021) "Development of Micropropagation in Bigleaf Maple (Acer macrophyllum)." Horticulturae 7(7).
[221] Otis-Prud'Homme, Guillaume – Pers.Comm.
[222] Domtar Forest Industries https://mirador.domtar.com/app/carte (Accessed February 18, 2024).
[223] Domtar Forest Industries. 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 February 17, 2024).
[224] Kamelchuk, Dave – Pers. Comm.
[225] Thomas, Barb – Pers. Comm.

c) Naturally Regenerating Forests

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 Yukon Territory.[226] Of these, trembling aspen has by far the greatest volume of harvestable wood. Aspen, often in association with balsam poplar, 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. It is a pioneer species that dominates many cutblocks or after forest fires in coniferous forests. Other naturally occurring poplar species that are harvested in smaller quantities in Canada are black cottonwood (*P. trichocarpa*) in British Columbia, plains and eastern cottonwood (*P. deltoides*) in the southern prairies and southern Ontario, and largetooth aspen (*P. grandidentata*) in eastern Canada.[227]

Aspen forests are usually harvested by clear-cutting. Because this species regenerates prolifically from root suckers after harvest or forest fire, it is not necessary to plant it. The suckers self-thin as the stand matures and light becomes the limiting factor.[228]

Forest fires are an annual occurrence throughout Canada. Generally, they are caused by lightning strikes and their extent and severity depend on the soil moisture and weather conditions at the time. Recent increases, likely attributable to climate change, have caused evacuations of some towns or even cities. They have also seriously affected air quality in Canada's most populous regions. An Alberta information sheet said that conifers burn much faster than deciduous trees and recommended the planting or maintenance of poplar and/or birch buffer forests around "FireSmart" communities.[229]

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.[230] 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.

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[226] Canadian Council of Forest Ministers. National Forest Database – Harvest Table 5.1 Net merchantable volume of roundwood harvested by jurisdiction and species group. http://nfdp.ccfm.org/en/data/harvest.php (Accessed January 28, 2024).

[227] Farrar, J. (1995) "Trees in Canada." Fitzhenry & Whiteside and the Canadian Forest Service. ISBN 1-55041-199-3 502pp.

[228] Doucet, R. (1989) "Regeneration silviculture of aspen." The Forestry Chronicle February, 1989: 23-27.

[229] Government of Alberta (2012) "How different tree species impact the spread of wildfire." https://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/formain15744/$FILE/tree-species-impact-wildfire-aug03-2012.pdf (Accessed February 23, 2024).

[230] Oregon State University – Oregon Wood Innovation Center. Corvallis, Oregon. Red Alder (*Alnus rubra*). http://owic.oregonstate.edu/red-alder-alnus-rubra (Accessed February 20, 2024).

d) Agroforestry and Trees Outside Forests

Because of their fast growth, hybrid poplars continue to be recommended for certain agroforestry applications, especially shelterbelts. However, unless harvest of the trees for economic wood value is part of the plan, their relatively short lifespan and relatively high-water use become a drawback when the goal is a long-term stable tree planting in an agricultural setting. For shelterbelts, hybrid poplar should usually be complemented by additional rows of long-lived, albeit slower-growing, conifers or hardwoods.

A recent Québec publication recommends the use of poplar for agroforestry uses, including shelterbelts and alley-cropping (intercropping) systems.[231] Alley-cropping systems can be effective at combining crop production with poplar trees and/or high-value hardwoods, such as oak or ash for improved overall productivity. However, because the wood marketing systems that exist in Europe to encourage such agroforestry practices do not exist in Québec, the landowner must take responsibility for marketing the wood. Landowners are also advised to prune trees to maximize wood value. The Québec publication advises landowners to become familiar with the characteristics of the available clones of hybrid poplar before planting it so that they can plan an effective program of planting, maintenance, and harvest.

5. Application of New Knowledge, Technologies, and Techniques

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

Strip-cut harvest methods for trembling aspen are being considered in Canada, especially in Alberta. With the strip-cut method of understory protection, aspen are removed in strips with non-harvested wind buffers 3 to 10 m wide retained every 50 m or less. In boreal mixedwood stands dominated by aspen and white spruce, growth of aspen peaks before that of white spruce. In this case, partial cutting to remove some or all the aspen at this age is similar to natural succession while allowing harvest of the aspen when it is still sound and mature. The wind buffers are oriented perpendicular to the prevailing direction of the wind. An Alberta study demonstrated the potential to apply understory protection harvesting in aspen-dominated stands that have a white spruce understory and suggest an opportunity to increase aspen yields through the mid-rotation harvesting of aspen, while also increasing spruce yields in these stands.[232] In many jurisdictions, aspen-dominated forests are clear-cut, allowing aspen to regenerate naturally from abundant root suckers.

A Québec study evaluated the extent that hybrid poplar bioenergy buffers planted along hayfields respond to thinning including the regrowth from cut stumps following gap harvesting and the effects on soil microclimate and nutrient availability. This study showed a strong and rapid growth response of hybrid poplar to thinning after canopy closure, however, gap harvesting was not an effective treatment

[231] Cogliastro, A., A. Vézina and D. Rivest (2022) "Guide d'amènagement de systèmes agroforestiers." 97 p. ISBN 978-2-7649-0659-0 (pdf). Centres de référence en agriculture et agroalimentaire du Québec (CRAAQ).
[232] Bjelanovic, I., P. Comeau, S. Meredith and B. Roth (2022). "Emulating succession of boreal mixedwood forests in Alberta using understory protection harvesting." Forests **13**(4).

to regenerate the stand from shoots growing from cut stumps because of the high incidence of deer browsing.[233]

The BioBaler WB-55 Harvesting System uses the single pass concept. With one operator, the BioBaler cuts and compacts biomass into dense round bales. These bales are collected on site at any time after harvest. The shape and density of bales allowscost-efficient transportation from the field to the power plant using conventional equipment. It is reported that these biomass bales do not deteriorate during storage over a long period, even though when harvested in wet conditions. An advantage of this technology is that biomass bales dry out naturally without risk of spontaneous combustion. Each bale contains over 1 MW/hr of energy depending on the type of biomass. The BioBaler can produce up to 40 bales/hr (20 tonnes/hr) in plantations and 15-18 bales/hr (8-10 tonnes/hr) in natural environments. The BioBaler works with different species of shrubs and trees including willow and poplar up to 15 cm in diameter.[234]

The City of Calgary and Sylvis operate a 343-hectare willow plantation used to manage the city's dewatered biosolids.[235] The willows are harvested using a modified Case sugar cane harvester. The machine cuts the willows at the base and processes the long willow stems into "billets", pieces approximately 8-10 cm in length. Harvesting is done on a three-year cycle that aligns with biosolids applications. Certain areas of the plantation are chosen each year, harvested, and treated with biosolids to provide nutrients for the willows to regrow. Machine harvesting is done in April or November. In 2023, a total of 45 hectares were harvested with a yield of 173 wet tonnes. Since the program's inception, cumulative harvest has been 3,818 wet tonnes.[236] A small portion of the plantation is harvested 'by hand' (with chainsaws) each week, year-round, to supply food and enrichment to animals at the Calgary Zoo-Wilder Institute, but much of the harvested material is delivered to the City of Calgary's Composting Facility.[237]

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 15 m 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.[238]

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233 Fortier, J., B. Truax, D. Gagnon and F. Lambert (2022). "Thinning and Gap Harvest Effects on Soil, Tree and Stand Characteristics in Hybrid Poplar Bioenergy Buffers on Farmland." Forests **13**(2).

234 BioBaler™ turning woody area into biomass energy. https://biobaler.com/en/wb-55.html (Accessed February 24, 2024).

235 Sylvis (2023) "Calgary biomass production and marginal land improvement program". 2023 Report. City of Calgary.

236 Sylvis (2023) "Calgary biomass production and marginal land improvement program". 2023 Report. City of Calgary.

237 Coombs, Alexandra – Pers. Comm.

238 Nyiraneza, J., Y. F. Jiang and T. D. Fraser (2022). "Shrub willow chips incorporated after potato harvest enhance soil properties in Prince Edward Island, Canada." Canadian Journal of Plant Science. **103**(1): 123-127.

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. For the most part, poplar wood is used for pulp or oriented strandboard (OSB). In Alberta, a project of the West Fraser Timber Co., funded through Emissions Reduction Alberta, involved the development of a new manufacturing process for OSB and engineered strand-based products (ESP) which would result in new products and use some of Alberta's "surplus poplar source."[239]

In Québec, Domtar, at its Windsor Integrated Paper Mill, uses the wood from its 8,000 hectares of plantations for its pulp feedstock.[240] The hybrid poplar may grow fast, but it is not very dense, with a GMT/DMT ratio of 0.38 to 0.4.[241] However, since its fibres are longer, its physical and chemical properties are suitable for paper manufacturing. Domtar also uses hybrid poplar as a source of biomass to supply its two turbines, which produce 50 MW of energy.

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. These trials are still in place, but no harvesting has been completed. One of the projects, a 32-hectare hybrid poplar trial in northwest Saskatchewan planted between 1998 and 2004, is scheduled for harvest by Tolko Industries in the next decade.[242]

The Ramo Company in Québec produces several products from harvested willow. This includes fragmented ramial wood (BRF) which is a mixture of chips resulting from the fragmentation of branches (diameter < 7 cm). Coming from the most active and nutrient-rich part of the tree, this mulch stimulates microbial activity in the soil and activates the biological processes responsible for its transformation into stable humus. Through its effect on the humus content of a soil, BRF constitutes a simple and effective means of improving the fertility of a soil in the long term.[243]

Ramo also markets willow-based noise barriers and fencing in Québec, for use in urban areas and along roadways elsewhere.[244] Ramo manufactures these noise barriers under licence from Danish company Pilebyg and German company Heinrich Fahlenkamp using locally sourced willows.

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[239] Emissions Reduction Alberta. 2024. Product and production innovations for using Alberta's surplus poplar to enhance carbon sequestration. https://www.eralberta.ca/projects/details/product-and-production-innovations-for-using-albertas-surplus-poplar-to-enhance-carbon-sequestration/ (Accessed February 24, 2024).
[240] Hybrid poplar: Domtar grows mature trees in just 15 years. https://www.canadianbiomassmagazine.ca/domtar-grows-mature-trees-in-just-15-years-6762 (Accessed February 24, 2024).
[241] Radio Canada Highlights Windsor Mill's Circular Economy Initiatives. Radio Canada Highlights Windsor Mill's Circular Economy Initiatives - DOMTAR Newsroom (Accessed February 24, 2024).
[242] Cubbon, Dave – Pers. Comm.
[243] Discover Ramo Mulch. https://ramo.eco/paillis (Accessed February 25, 2024).
[244] Ramo Inc. 2023 Noise Barriers 2023. https://ramo.eco/wp-content/uploads/2024/01/Brochure_Noise_barriers_2023_US_compressed-1.pdf (Accessed February 27, 2024).

In Alberta, a large willow plantation at Keoma, Alberta, operated by Sylvis manages biosolids from the City of Calgary. The willow stands were designed to facilitate an annual biosolids fertilization, harvest and re-growth occurring concurrently on a three-year rotation. Since its establishment in 2013 over 54,000 dry tonnes of biosolids have been applied to the three even-aged willow stands that span 343 hectares. In 2020, the program was accepted into the Government of Canada's Low Carbon Economy Challenge. This has enabled Sylvis and the city to expand the willow plantation each year. [245] The willows, when of suitable size, are harvested for use as feedstock for the city's composting program. A small portion is harvested weekly, year-round, to supply food and enrichment to animals at the Calgary Zoo-Wilder Institute.[246]

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 334 thousand m^3 of hardwood was used nationally in 2020 for fuelwood and firewood[247]. Many wood-processing companies use sawdust, bark, and branches to produce power for their mills through co-generation facilities[248].

Selected clones of hybrid poplar and willow can be grown for use 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-to-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 and from Uppsala, Sweden. 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.

The Alberta Woodlot and Extension Society is evaluating *Salix* and *Populus* species and clones for their use in tree fodder silvopasture systems. The project involves developing guidelines for growing both coppiced and pollarded trees above graze height as well as determining harvest times and crop cycles and animal nutrition of different poplar clones. Poplar cultivars in the project include the hybrids 'Okanese' (*P.* ×Walker × *P.* ×*petrowskyana*), 'Griffin' (*P. deltoides* × *P.* ×*petrowskyana*), 'Sundancer' (*P.* ×Walker × *P.* ×*serotina de selys*), 'Northwest' (*P.* ×*jackii*), 'Prairie Skyrise' (*P. tremuloides)*, Swedish Columnar Aspen (*P. tremula 'Erecta'*), 'Tower' (*P.* x*canescens*), 'Tristis' (*P. tristis*) and 'Walker' (*P. deltoides* × *P.* ×*petrowskyana*). *Salix* cultivars included are: 'Laurel leaf' (*S. pentandra*), Golden' (*S. alba 'Vitellina'*), 'Acute' (*S. acutifolia*) and 'Silver leaf' (*S. alba* var. *sericea*).[249]

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[245] Biosolids Use in Marginal Land Conversion and Willow Plantation Establishment. https://www.sylvis.com/our-work/biosolids-use-marginal-land-conversion-and-willow-plantation-establishment (Accessed February 26, 2024).
[246] Coombs, Alexandra – Pers. Comm.
[247] Canadian Council of Forest Ministers. National Forestry Database. http://nfdp.ccfm.org/en/index.php (Accessed February 24, 2024).
[248] Radio Canada Highlights Windsor Mill's Circular Economy Initiatives. Radio Canada Highlights Windsor Mill's Circular Economy Initiatives - DOMTAR Newsroom (Accessed February 24, 2024)
[249] Gamache, Winston – Pers. Comm.

6. Environmental and Ecosystem Services

The ecological value of Canada's natural forests for habitat and other ecosystem services is well recognized by the people, governments, and forest industries of Canada.

On Crown land forests that are available for wood harvesting, provincial and territorial governments throughout Canada prioritize the sustainability and protection of these ecosystem services when they develop leases with forest industries. Many such conditions of the leases are prescribed in provincial or territorial legislation or policies. Safeguarding the habitat of fish and other aquatic organisms is addressed by defining protected riparian buffers. Harvest agreements include Annual Allowable Cuts, regulations for replanting harvested forest blocks, specifications for forest roads, bridges, and culverts. These considerations apply to poplar (aspen) as well as to softwood forests. Aspen regenerates naturally after harvest from root suckers so there is no requirement to replant. Willows in natural forests are not of significant interest for commercial harvest and often occur in the riparian buffers and are therefore protected. As well as being a critical component of riparian ecosystems, willows provide many other ecosystem services – for example, as early producers of pollen for insects and as browse for mammals.

On non-forest land, improved or selected hybrids and clones are used in novel and interesting environmental applications, partly because they are highly visible and imposing. Their fast growth makes them attractive for shelterbelts, visual screens, and other amenity plantings; for the rapid uptake of pollutants, nutrients, or wastewater; and for carbon sequestration for greenhouse gas reduction. Their coppiceability means that they can be used for biofuels, biochar or other products and their ability to root vegetatively means that clones will grow predictably and uniformly, and the ability to use willow or poplar stakes that will root after planting also makes them attractive for streambank or other soil stabilization projects.

The discussion in this section will focus on the purposeful planting of improved poplars and willows in non-forest land for environmental and ecosystem services. This includes agricultural land, corporately owned land, other private land, and land owned by municipal governments.

a) Site and Landscape Improvement

Riparian and Streambank Protection

On agricultural land and highly populated areas, many provinces have a framework of municipal or watershed-based organizations, governed by boards of directors representing municipalities, landowners, and other stakeholders within the area. In most cases, these organizations receive much of their funding from municipal, provincial and federal governments and also generate their own revenue to conduct projects or programs that address environmental concerns on their land base. In most cases, riparian and streambank protection is one of their priorities. Nationally, the Canadian Wildlife

Federation promotes the use of native shrub willows for bioengineered protection of degraded streambanks.[250]

A recent Québec publication proposed various tree-based design options for riparian protection, including the use of poplars and other trees to provide shade to streams, and willows and other shrubs for stabilizing banks and intercepting runoff and pollutants from agricultural cropland.[251] For example, of the existing riparian buffer strips in the Montérégie region south and east of Montréal, 10% contain poplars. Extrapolation from sampled sites resulted in an estimate of 1,000 km of riparian buffer strips and shelterbelts include poplar in their composition.[252]

The Province of Ontario's Ministry of Natural Resources recommends the use of willow for restoring degraded shorelines of lakes and rivers and provides information on where to get the stock and how to establish them.[253] Ontario Streams, an environmental charity dedicated to the conservation and rehabilitation of streams and wetlands, uses ten species of native willow and two species of native poplar to stabilize and restore streambanks by applying bioengineering methods, using unrooted dormant poplar and native willow cuttings, stakes and poles.[254]

In Ontario, 36 watershed-based conservation authorities (CAs) are members of Conservation Ontario and over 95% of Ontario's 15 million people live in these CAs.[255] The main responsibility of a CA is to monitor and manage the water resources within its jurisdiction, but each CA owns and manages recreational conservation areas (parks and beaches) by which it can generate its own income. The Grand River Conservation Authority is the oldest such organization in Canada with a history dating back to 1934 and it includes almost one million inhabitants within its boundaries.[256] It has its own Burford Tree Nursery near Brantford, Ontario, which provides many species of trees and shrubs for its conservation programming including willows (S*alix nigra* and *Salix discolor*) and poplars (*Populus deltoides* and *Populus tremuloides*).[257] In addition, trees for GRCA projects and applicants are available from Somerville Nursery near Alliston, Ontario.[258] The Grand River CA and other CAs use only native tree species in their conservation programming and routinely use native willow species for bioengineering projects to stabilize eroded streambanks.

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250 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 February 9, 2024).
251 Cogliastro, A., A. Vézina and D. Rivest (2022) "Guide d'amènagement de systèmes agroforestiers." 97 p. ISBN 978-2-7649-0659-0 (pdf). Centres de référence en agriculture et agroalimentaire du Québec (CRAAQ).
252 Rivest, David – Pers. Comm.
253 Government of Ontario, Land Owner Resource Centre. "Restoring shorelines with willows." 4pp. http://www.lrconline.com/Extension_Notes_English/pdf/willows.pdf (Accessed Febrary 11, 2024).
254 Heaton, M.G., R. Grillmayer and J.G. Imhof (2002) Ontario's Stream Rehabilitation Manual. https://www.ontariostreams.on.ca/Resources-Education#Resources (Accessed February 11, 2024).
255 Conservation Ontario. https://conservationontario.ca/ (Accessed February 9, 2024).
256 Grand River Conservation Authority. https://www.grandriver.ca/en/index.aspx#gsc.tab=0 (Accessed February 9, 2024).
257 Grand River Conservation Authority. https://www.grandriver.ca/en/our-watershed/Burford-Tree-Nursery.aspx#gsc.tab=0 (Accessed February 9, 2024).
258 Munn, Nathan – Pers. Comm.

Various research projects across Canada showed the effectiveness of willow riparian buffers to store carbon and protect streams and rivers from nutrient loading. In Québec, the Eastern Townships Forest Research Trust studied the factors affecting carbon and excess nutrient capture in hybrid poplar riparian buffers. In another Québec study, researchers quantified different ecosystem services – carbon, nitrogen and phosphorus storage, biomass production and other conservation benefits provided by hybrid poplar riparian buffers along farm streams.[259] In Prince Edward Island, the East Prince Agri-Environment Association studied the beneficial environmental effects of planting willow trees along riverbanks in an island-wide project with twelve sites.[260] Another PEI study used the clone, *Salix viminalis* '5027' planted between the agricultural field and the water body. The trees were harvested on a three-year rotation to maximize nutrient uptake. A follow-up study found that willow wood chips could be added to a potato field after harvest to immobilize free nitrogen and reduce nitrogen leaching.[261]

Shelterbelts

Widespread planting of 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 were planted and most of these trees are still in place. Farmyard shelterbelts continue to be planted in the Prairie Provinces, with a major recent increase being attributable to the financial support of the federal 2 Billion Trees Program.[262]

Although there continues to be a need for seedlings for protection of farmyards, the establishment of field shelterbelts has decreased, partly because of the increased cost and greater difficulty of obtaining trees since the federal program was discontinued. Another factor is the decline in the number of farms, as farms have become larger with larger, high-capacity, precision-guided tractors and combine harvesters that have resulted in the removal of old field shelterbelts and native aspen and willow stands, such as those bordering on wetlands and depressions.[263]

Where field shelterbelts are still being planted, they do not generally include poplars or willows because they are relatively short-lived and, where tile drainage is used, there is a concern that poplar roots may clog the drains. However, poplar field shelterbelts are still sometimes planted because of their fast

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[259] Fortier, J., B. Truax, D. Gagnon 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).
[260] Murphy, E. (2021) "Where there's a willow, there's a way." http://www.poplar.ca/upload/audiovideo/emilymurphy_presentation.mp4 (Accessed February 23, 2024).
[261] Uwituze, Y., J. Nyiraneza, Y. Jiang, J. Dessureault-Rompré and T.D. Fraser (2023) "Soil C, N and P bioavailability and cycling following amendment with shrub willow chips." Can. J. Soil Sci. **103**: 428–445.
[262] Canart, Ryan – Pers. Comm.
[263] Statistics Canada (2021) "Census of Agriculture 2021." https://www150.statcan.gc.ca/n1/pub/71-607-x/71-607-x2022006-eng.htm (Accessed February 15, 2024).

growth.[264] In Québec, it was estimated that 1,000 km of shelterbelts and riparian buffers contain poplar in their composition.[265]

As the fastest-growing trees available in Canada, hybrid poplars are often used for shelterbelts by new homeowners in rural areas who desire rapid shelter and greenery around their properties. They often prefer male clones because female clones shed voluminous cottony seeds, which are annoying and inconvenient.

Willow shelterbelts are effective snow traps along roadsides (living snow fences). One example is near La Pocatière, Québec,[266] 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. Roadside shelterbelts were also established along the Trans-Canada Highway in Manitoba in the 1990s incorporating hybrid poplars and shrubs. Living snow fences have been used elsewhere in Canada, such as along the heavily travelled Highway 401 between Toronto and Windsor, but those shelterbelts typically consist of conifers rather than poplars or willows.

In 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.[267]

Carbon Sink

Tree dry weight (cellulose, hemi-cellulose, lignin) consists of almost 50% carbon and so the use of fast-growing poplar and willow has received attention as an opportunity to accumulate carbon and to reduce Canada's net greenhouse gas (GHG) emissions. The federal government's ten-year 2 Billion Trees program is focused on trees as a carbon sink to help address Canada's GHG reduction obligations and targets. The program is an important source of funding/support for tree planting across the country. For the years 2021 and 2022, the 2BT program supported the planting of 6.4 million willows and 1.4 million poplars.[268] These trees were used for a variety of environmental applications, including urban plantings, riparian and phytoremediation projects, and shelterbelts.

There have been studies and assessments to quantify and evaluate the carbon offset of poplar or willow plantings.[269] Whether or not programs or markets are created 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 of what happens to the carbon in the trees at the end of their rotation (harvest for pulp, bioenergy, biochar, etc.). Poorly planned or managed tree-

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[264] Derbowka, Dave – Pers. Comm.
[265] Rivest, David – Pers. Comm.
[266] Vézina, André – Pers. Comm.
[267] Grand River Forestry Fact Sheet. Trees & Field Drainage Tiles. https://www.grandriver.ca/en/our-watershed/resources/Documents/Tree_fact_sheets/Trees_factsheets_drainage.pdf (Accessed February 23, 2024).
[268] 2 Billion Trees Program – Pers. Comm.
[269] Anderson, J.A., A. Long and M.K. Luckert (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.

planting schemes may have a negative effect as the inputs may release more GHG than the carbon fixed by the trees. Full-life-cycle analyses are needed for tree-planting programs and schemes.

In Manitoba, a 2011-2020 initiative to plant hybrid poplar for carbon sequestration included a 25-hectare poplar research plantation northeast of Winnipeg, which included a solar-powered eddy co-variance flux tower – a collaborative research project with the University of British Columbia.[270]Details and outcomes of this project could not be found.

The federal agriculture department, Agriculture and Agri-Food Canada funded projects under the 2010-2021 Agricultural Greenhouse Gas Program to study ways to reduce net emissions from agriculture and to develop Beneficial Management Practices (BMPs) that can be adopted by farmers to mitigate GHG emissions.[271] Five of these projects focused on agroforestry practices that included poplar and willow in the system.

Other Environmental Applications

Many willows flower very early in the spring and can be an important source of early pollen for insects. For example, in the Atlantic provinces of New Brunswick, Prince Edward Island, Nova Scotia and Newfoundland and Labrador, native bees are important for pollinating managed fields of wild blueberries (*Vaccinium angustifolium*), which require insect pollination for fruit set. Plantings of selected early-flowering willows have been incorporated into commercial blueberry harvesting operations to provide habitat and a food source to such native pollinators.[272]

Some wood from hybrid poplar plantations near Armstrong, BC, is currently being used for small amounts of biochar. In the opinion of Dave Derbowka of Passive Remediation Systems, there is scope for the development of major markets and applications of biochar from poplar plantations in the future.[273]

Urban Forestry

The federal 2 Billion Trees program, provincial and municipal programs and many programs by non-profit groups or community tree-planting programs by corporations support the planting of trees in urban areas. These may involve poplars or willows, but hybrid poplars are generally used less than other hardwoods which live longer, even though they may grow more slowly. For special applications, such as in riparian zones, willows may be used.

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[270] Government of Manitoba (2022) "Five-Year Report on the Status of Forestry April 2016 – March 2021." https://www.gov.mb.ca/nrnd/forest/pubs/forest_lands/5yr_report2022.pdf (Accessed February 22, 2024).
[271] Agriculture and Agri-Food Canada (2021) "Evaluation of the Agricultural Greenhouse Gases Program (2016–17 to 2020–21) – Summary." https://agriculture.canada.ca/en/department/transparency/evaluation-agricultural-greenhouse-gases-program-2016-17-2020-21-summary (Accessed February 23, 2024).
[272] 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 21, 2024).
[273] Derbowka, Dave – Pers. Comm.

Several examples of poplar and willow use in urban settings follow:

A 100-metre "living wall" using willows in combination with a constructed noise barrier was established in Edmonton as a demonstration in 2014-2015 and was evaluated in following years, including surveys of Edmonton residents.[274] The surveys showed that residents valued its appearance and its environmental value. The city was concerned that, even though there are "many installations in eastern Canada" poor survival in Edmonton's cold climate might be an issue. At the completion of the project, the willows had survived well, except where the irrigation system had been turned off prematurely.

The City of Montréal has a multi-year "Tree For My Neighbourhood" program which subsidizes individuals throughout the city to purchase trees for neighbourhood beautification and for shading, protection, habitat, fruit, or nuts. It warns that hybrid poplars and willows should be used with care because of their fast growth, large crowns, and aggressive roots. For these reasons, they should be planted far away from infrastructure (buildings, lines, pipes, gardens). [275]

b) Phytoremediation Projects and Initiatives

Ramo Inc., which is headquartered in Québec, has willow production and use as its primary focus [276]and a portion of its annual 8-10 million trees – both native and non-native willows – have been used in several large phytoremediation projects. In the 2020-2023 period, Ramo's willows plantings covered an estimated 590 hectares.[277]

Two large willow phytoremediation plantations were established in Alberta. The City of Calgary project was planted by Bionera (which is now part of Ramo)[278] and managed by Sylvis Environmental Services.[279] 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.[280] As of 2023, the City of Calgary plantation is 343 hectares with 37 hectares planted in 2023. Biosolids are applied at a rate of 12.9 dry tonnes per hectare in June, October and November. The clones used in the plantings include 'India', 'Olof', 'Vimi', 'Sx64', 'Millbrook', 'Owasco', 'Otisco' and 'Swedes'. The management of the plantation includes periodic coppice harvesting, with the harvested material going to a Calgary composter. Some of the willow shoots are supplied to the City of Calgary Zoo, which provides fodder for animals such as giraffes,

[274] City of Edmonton (2016) "Living wall demonstration project." https://www.edmonton.ca/public-files/assets/document?path=Living%20Wall%20Demonstration%20Project%20Closure%20Summary%20Report.pdf (Accessed February 23, 2024).
[275] City of Montreal (2024) "A Tree For My Neighbourhood." https://unarbrepourmonquartier.org/en/ (Accessed February 26, 2024).
[276] Ramo Inc (2023) Press Release: Ramo acquires Bionera Resources and welcomes Western CEO John Lavery. https://ramo.eco/wp-content/uploads/2023/11/Ramo-x-Bionera.pdf (Accessed February 11, 2024).
[277] Allard, Francis – pers. commm.
[278] Ramo Inc. https://ramo.eco/en/bionera/ (Accessed February 21, 2024).
[279] Sylvis Environmental Services. Edmonton, Alberta. https://www.sylvis.com/our-company (Accessed February 21, 2024).
[280] Ferguson, Doug (2021) "Willow farming takes step forward in Canada." The Western Producer. September 9, 2021. https://www.producer.com/news/willow-farming-takes-step-forward-in-canada/ (Accessed February 21, 2024).

moose, and gorillas. In 2022, the project received the APEGA 2022 Environment and Sustainability Award, which recognizes excellence in application of engineering or geoscientific methods towards preservation of the environment and the practice of sustainable development.[281]

In 2019, Sylvis and Bionera began establishing a 500-ha willow plantation at Forestburg, Alberta, in a coal mine reclamation project, called "BioSalix", with Westmoreland Mining Company. The City of Edmonton was scheduled to provide nutrients from municipal biosolids, while the biomass was to be used as a bioenergy crop. The project is supported by funding from the Government of Canada's Clean Growth Program,[282] and the Government of Alberta's Alberta Innovates program.[283]

These two Alberta phytoremediation projects include the evaluation of eight different willow clones. Planting of the willows was by the Danish Egedal Energy Planter[284] and the HSAB Billet Planter, which requires a smaller amount of plant material to establish the plantation.[285]

In British Columbia, phytoremediation poplar plantings at Armstrong continue to be monitored by Passive Remediation Systems (PRSI).[286] Some of the trees originally planted have been harvested and are re-sprouting from the roots, while additional trees were planted in 2017.

Waste Management Canada (WMC) 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.[287] 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. A complete report on the use of poplars and willows at the site can be downloaded from the WMC website.[288]

At the West Carleton Landfill near Ottawa, WMC first established 6.2 hectares of hybrid poplar and later, in 2014, expanded the plantation by 2.0 hectares with proposals to increase the tree plantations

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[281] Sylvis (2023) "Calgary biomass production and marginal land improvement program". 2023 Report, City of Calgary.
[282] Government of Canada. Clean Growth Program. https://www.nrcan.gc.ca/climate-change/canadas-green-future/clean-growth-programs/20254 (Accessed February 21, 2024).
[283] Government of Alberta (2019) "Alberta coal mine reclamation project to provide green energy source." https://albertainnovates.ca/news/alberta-coal-mine-reclamation-project-to-provide-green-energy-source (Accessed February 14, 2024).
[284] Ramo Inc. https://ramo.eco/en/bionera/ (Accessed February 21, 2024).
[285] Krygier, Richard – Pers. Comm.
[286] Derbowka, Dave – Pers. Comm.
[287] Waste Management Canada. Twin Creeks Landfill. (Watford, Ontario). https://www.wm.com/ca/en/twin-creeks-landfill (Accessed February 21, 2024).
[288] Waste Management Canada (2022) "Twin Creeks Environmental Centre site: 2022 fourth quarter & annual monitoring report - Volume 3 of 5: Poplar system monitoring program." 605pp. https://www.wm.com/content/dam/wm/assets/landfills/twin-creeks/2022-annual-report-vol3-poplar-system.pdf (Accessed February 23, 2024).

by several more hectares with a combination of poplar and willow.[289] The success of phytoremediation projects with poplars (or willows) is highly dependent on site factors (soil, climate, site history, etc.), which must be taken into account when planning the clones, spacing, irrigation, weed control and other maintenance.

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 activities. Working Groups address specific topics or issues. The mailing address of the Poplar and Willow Council is based in Edmonton, Alberta, in care of the PWCC Treasurer. The PWCC has a part-time executive assistant / technical director, who is responsible for handling administrative affairs (memberships, organizing meetings, managing the website www.poplar.ca, and other tasks, as required). The Council is a federally incorporated not-for-profit organization. The mailing address for the Council is:

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

The current executive assistant / technical director (as of 2024) is:
Dr. John Kort
Email: pwccpoplar@poplar.ca
Website: www.poplar.ca

The PWCC executive assistant / technical director coordinates member services, responds to member and public requests for technical information and administers PWCC communications, finances and administration.

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. As of the 2023 Annual General Meeting Council, membership was 5 corporate members, 9 individual members and 2 student members.

[289] 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 February 21, 2024).

The PWCC Board of Directors has three working groups – Genetics and Breeding, Plantation Health and Environmental Services and Bioenergy. The Genetics and Breeding Working Group maintains communication with researchers engaged in poplar genetics and breeding work across the country and reports new developments to the Board of Directors. It also maintains the Council's poplar and willow clone directory. The Working Group developed a series of ten factsheets describing the main hybrid poplar clones used in western Canada. The Plantation Health Working Group supports work to expand the number of approved agricultural herbicides and pesticides for use in poplar and willow plantations and acts as sponsor of these requests for approval. This group also has interest in the effects of insects and diseases and their prevalence. The Environmental Services and Bioenergy Working Group aims to improve the acceptance of the use of poplars and willows for environmental services.

Board of Directors and Executive Committee of Poplar and Willow Council of Canada (February 2024)

Name	Role	Organization	Province
Raju Soolanayakanahally	Chair	Agriculture and Agri-Food Canada	Saskatchewan
Barb Thomas	Past Chair	University of Alberta	Alberta
Annie Desrochers	Vice-Chair East	Université du Québec en Abitibi-Temiscamingue	Québec
Martin Blank	Treasurer	Canadian Forest Service	Alberta
Richard Krygier	Plantation Health WG Lead	Canadian Forest Service	Alberta
Francis Allard	Environment WG Lead	Ramo Inc.	Québec
Guillaume Otis-Prud'Homme	Genetics WG Lead	Ministère des Ressources naturelles et des Forêts	Québec
John Lavery	Director	Ramo Inc.	British Columbia
Fardausi Akhter	Director	Agriculture and Agri-Food Canada	Saskatchewan
Jim Richardson	Director	None	Ontario
Emily Murphy	Director	East Prince Agri-Environment Association	Prince Edward Island
John Kort	Ex Officio	None	Saskatchewan

b) Poplar and Willow Council of Canada Activities

The PWCC organizes an Annual General Meeting which includes technical and field sessions. The meetings provide an opportunity to network with other professionals and gain information on current poplar and willow trends. Annual meetings are held in different locations, thus offering its members the opportunity to interact in person and to see various poplar and willow projects and activities across the country. Often, these meetings are held in association with other organizations to improve the ability of PWCC members to maintain connections with fields of study or activities related to the use and development of poplar and willow.

The 2024 PWCC general meeting will be held on May 13-16, 2024, in association with the US Short Rotation Woody Crops (SRWC) Operations Working Group, at the 2024 SRWC International Conference in Columbia, Missouri.[290] The three-day meeting will be a combination of oral and poster presentations and field tours. Two PWCC Board members (Dr. Raju Soolanayakanahally and Dr. John Kort) are on the conference steering committee and the technical and student sub-committees. Dr. Soolanayakanahally will be a keynote speaker at the conference plenary session. The PWCC will co-sponsor the conference by awarding two student prizes to oral or poster presentations. This event also serves as a meeting venue for three International Union of Forest Research Organizations (IUFRO) Working Groups: WG 1.03.00 (Short-Rotation Forestry); WG 1.06.01 (Phytotechnologies for degraded sites in rural and urban communities); WG 2.08.04 (Poplars and Willows). This conference is especially relevant to those PWCC members who are interested in purpose-grown plantations of fast-growing woody species for wood/fibre supply or for environmental purposes, such as phytoremediation and agroforestry.

The PWCC's 2023 Annual General Meeting was held in Vernon, British Columbia, in conjunction with the annual conference of the Canadian Forest Genetics Association and the Western Forest Genetics Association.[291] The meeting included a field trip to view a poplar plantation established for phytoremediation by PWCC corporate member Passive Remediation Systems Inc. at Armstrong, British Columbia. One student prize was awarded.

The 2021 and 2022 meetings were held virtually because of national and provincial COVID-19 restrictions.

The PWCC was responsible for the 2020 Canada country report to the International Poplar Commission (IPC). It was prepared under a contract administered by the PWCC. Funding for the preparation of the report was provided to the PWCC by the Government of Canada (Natural Resources Canada).

The PWCC website (www.poplar.ca) was kept up to date with relevant reports, news items and upcoming events. Here members and visitors can find information on membership, council governance, database of poplar and willow clones in Canada, publications, statistics, news and upcoming events. Also available are meeting notices, a photo gallery, special publications and reports and links to relevant poplar and willow websites nationally and internationally. The PWCC website provides an avenue for poplar and willow enquiries, which are answered by the technical director or a PWCC member.

c) Difficulties and Lessons Learned

The PWCC membership has decreased in recent years and currently includes 16 members (5 corporate, 9 regular, 2 students). Maintaining the PWCC's relevance to the members is a constant challenge for a small organization. The PWCC continues to encourage student members by offering reduced

[290] University of Missouri. Center for Agroforestry. 2024 Short Rotation Woody Crops International Conference. https://woodycrops.wixsite.com/srwc2024 (Accessed February 23, 2024).

[291] Canadian Forest Genetics Association (2023) "Proceedings of Forest Genetics 2023: Discovery and Innovation in Changing Climates." https://cfga-acgf.com/wp-content/uploads/2023/12/Forest-Genetics-2023-Proceedings-FINAL.pdf (Accessed February 23, 2024).

membership fees. Student awards are disbursed annually to selected students to offset their costs to attend the Annual General Meeting and conference.

Much research and development continues in Canada related to aspen (*P. tremuloides*) management and use, because it is an important commercial wood species, being the main feedstock for several Canadian wood processors. These projects and developments involve industry, government, and university participants, some of which are members of the PWCC. However, the involvement of the PWCC, as an organization, is generally not required in ongoing research or developments in the management of these native poplars, although it may serve to distribute information to members and the public.

Much research also occurs throughout Canada on hybrid poplars and willows. Although they are not used to a very large extent, they are model species for research because of their fast growth, vegetative propagation, and well-documented genomes.

Some PWCC members are more involved in smaller-scale developments and projects that involve the use and management of poplar and willow hybrids and species. The possible use of these species or clones for environmental purposes (phytoremediation, riparian or erosion management, windbreaks, carbon capture, etc.) is of increasing interest. However, the commercial interest in fast-growing poplar plantations for wood production is not increasing, reflecting commercial and economic realities. This may change if the economics of biofuels changes, due to increased world-wide emphasis on reducing net GHG emissions. Under such conditions, the use of fast-growing willows in plantations may become more economically attractive. At present, environmental uses of these improved species or hybrids appear to be of the most interest. It is perhaps here that the continuing involvement of the PWCC as a coordinating or information disseminating organization is most relevant.

The PWCC continues to perform its core governance functions by the activities of board members, especially the treasurer and the chair. Part-time employment of the executive assistant / technical director is possible because of legacy funds from past projects. The PWCC, therefore, has a long-term challenge of raising funds, other than through membership fees.

Quadrennial funding from the Government of Canada is essential for the preparation of a comprehensive and complete IPC country report.

Maintaining links to international poplar and willow groups is an important role for the PWCC and its members. Participating in joint meetings between the PWCC and the United States is especially important because of our shared climate, land, and native species, as well as economic, cultural and other ties. Hosting our 2024 Annual General Meeting in Columbia, Missouri, while co-sponsoring and helping to organize the SRWC conference is an example of Canada-US coordination. In past years, the PWCC has held many other joint meetings, sometimes in the US and sometimes in Canada.

2. Literature

This list includes Canadian origin publications on poplars, willows, alder and other fast-growing tree species for the period 2020-2023. We recognize Canadians may co-author publications where research was conducted in countries other than Canada, those publications are not included in this list.

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12. Baah-Acheamfour, M. and J. M. Sobze (2022). "Assessing post-harvest interim seed storage conditions: a case study of four boreal plant species." Seed Science and Technology **50**(2): 183-194.
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3. Relations with Other Countries

The PWCC participates in conferences and other activities of the International Commission on Poplars and Other Fast-Growing Trees Sustaining People and the Environment (IPC), which brings together 38-member poplar councils ('National Poplar Commissions') from around the world. Dr. Barb Thomas of the University of Alberta, a PWCC board member, serves on the IPC Executive Committee. The PWCC held its 2000 Annual General Meeting in Vancouver, Washington, in conjunction with the IPC conference there. PWCC members were involved in the IPC 2000 organizing committee and helped to coordinate a Canadian field tour for the conference. The PWCC and its members also participate in International Union of Forest Research Organizations (IUFRO) conferences, in particular, the International Poplar Symposium (IPS), held every four years. In 2014, PWCC co-sponsored the 6th IPS in Vancouver, British Columbia, and many PWCC members were involved in its organization.

PWCC member Jim Richardson, who was the technical director for many years, co-edited two international poplar books. *Poplar Culture in North America* (2002 – ISBN 978-0-660-18145-5) was published in conjunction with the 2000 IPC conference and the FAO-published book, *Poplars and Willows: Trees for Society and the Environment* (2014 - ISBN 978-1-780-64108-9).

The PWCC has strong connections to poplar and willow colleagues in the United States, including the Short Rotation Woody Crops Operations Working Group. The 2024 Short Rotation Woody Crops International Conference at Columbia, Missouri on May 13-16, 2024, will be an opportunity for PWCC members to meet and exchange information with US and international colleagues. The PWCC will have its Annual General Meeting at this conference, as it did with past SRWC conferences in Pasco, Washington (2006); St. Paul, Minnesota (2008); Syracuse, New York (2010); and Rhinelander, Wisconsin (2018). Informally, poplar and willow academics and scientists maintain research collaborations with colleagues at universities and research institutes worldwide.

IV. Summary Statistics

Table 1: Total area of poplar, willow and red alder 2021 and area planted 2020-2023.

Land Use Category	Total Area 2023 (ha)*	Total area by forest function in %				Area planted from 2020 to 2023 (ha)
		Production		Protection (%)	Other (%)	
		Industrial round wood (%)**	Fuel wood biomass (%)			
Naturally regenerating forest						
Poplars	39,351,000	10		20	70	N/A
Willows****	59,000			16	84	N/A
Mix of Poplar & Willow						N/A
Red Alder***	187,000	1		15	84	N/A
Planted forest (plantations)						
Poplars	9,200	95			5	3,000
Willows****						
Mix of Poplar & Willow						
Red Alder						
Other land with tree cover						
Agroforestry and trees outside forests						
Poplars	2,544,000			1	99	200
Willows****	28,590				100	790
Mix of Poplar & Willow	16,000			100		200
Red Alder						
Trees in urban settings						
Poplars						
Willows						
Mix of Poplar & Willow						
Red Alder						
Grand Total	41,901,790					4,190

*Poplar area for "Naturally regenerating forest" and "Agroforestry and trees outside forests" is derived from the National Forest Inventory (https://nfi.nfis.org/en/data_and_tools). "Agroforestry and trees outside forests" is assumed to be in the agricultural and privately owned areas in the western prairies and the eastern mixedwood plains. Many natural aspen and willow stands surround low areas on the western prairies and natural willows occur in riparian zones throughout Canada. The "Agroforestry and trees outside forests" also includes an estimated 16,000 hectares of poplar and/or willows planted in agricultural zones as plantations, shelterbelts, phytoremediation or other purposes.

**Industrial roundwood is from the National Forest Database (http://nfdp.ccfm.org/en/data/harvest.php). Less than 0.2% of the available wood supply is harvested per year, but trees are normally about 40-50 years old when harvested. Most poplar plantations are assumed to be for industrial purposes. However, there are some poplar plantations on agricultural or other land that were planted as a carbon sink or for bioenergy.

***Red alder is used to a significant extent in BC (average ~160 thousand m^3/year) and is the most common deciduous tree in the Pacific maritime ecozone. The 187 thousand hectares reported in this ecozone in the National Forest Inventory as "Other Hardwoods" and "Unspecified Hardwoods" was therefore assumed to be red alder.

****Willows in "Naturally regenerating forests" were considered to be of the same area as in the most recent IPC report (Kort and Schroeder, 2020). Most of these are naturally occurring willows that protect riparian zones. Willows in "Agroforestry and trees outside forests" included 590 new hectares planted through Ramo Inc's distribution of 8-10 million trees annually. It is not known how many of these are planted in urban areas.

Table 2: Wood removals in 2020

Land use category		Wood removals 2020 (m^3) (in 1000's)				
		Total removals*	For industrial roundwood			For fuelwood, wood chips
			Veneer plywood	Pulpwood	Sawnwood	
Naturally regenerating forest						
	Poplars	18,315	9,848	8,133	0	334
	Willows					
	Mix of P&W					
	Red Alder	170			170	
Planted forest						
	Poplars	100		100		
	Willows					
	Mix of P&W					
	Red Alder					
Other Land with Tree Cover						
	Poplars					
	Willows					
	Mix of P&W					
	Red Alder					
Grand Total		18,585	9,848	8,233	170	334
Previous report		20,250	12,515	7,388	0	398

* 26.3 million m^3 of hardwoods were harvested nationally in 2020, according to the most recent data in the National Forest Database (NFD) of the Canadian Council of Forest Ministers (http://nfdp.ccfm.org/en/index.php). Some provinces report the poplar component of the hardwood harvest (Nova Scotia - 9%; New Brunswick - 19%; Québec - 38%; Ontario - 74%; Saskatchewan - 94%; Alberta - 96.4%; British Columbia - 86%). The others were assumed (Manitoba - 84%; Newfoundland and Labrador - 96.4%; Prince Edward Island - 19%; Northwest Territories - 96.4%)

** The NFD reports harvest as: Fuelwood and firewood; Logs and bolts; Other industrial roundwood; Pulpwood. For this table, the 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." No reports of the amount of wood harvested from hybrid poplar plantations was found – however, Domtar's harvest (Québec) was assumed to be for pulp at 250 m^3/ha and 400 ha/yr = 100,000 m^3/yr).

Table 3: Forest products in 2020 (i.e., Annual Harvest)*

		Forest Products in Roundwood Equivalents (m^3) (in 1000's)							
Land use category		**Fuel wood**	**Chips and particles**	**Sawn wood**	**Veneer sheets**	**Plywood**	**Particle board**	**Fibre board**	**Wood pulp**
Naturally regenerating forest									
	Poplars	**332**					**9,848**		**8,133**
	Willows								
	Mix of P&W								
	Red Alder			**170**					
Planted									
	Poplars								**100**
	Willows								
	Mix of P&W								
	Red Alder								
Agroforestry									
	Poplars								
	Willows								
	Mix of P&W								
	Red Alder								
Grand Total		**332**		**170**			**9848**		**8,233**

* Poplar data comes from the National Forest Database hardwood harvest data (most recent data is 2020) combined with provincial reports of the percentage of the provincial hardwood harvest that is poplar (aspen and balsam poplar). No reports of the amount of wood harvested from hybrid poplar plantations was found – however, Domtar's harvest (Québec) was assumed to be for pulp at 250 m^3/ha and 400 ha/yr = 100,000 m^3/yr).

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 conversion of planted forests of poplar to other species will...			X	
3b. The conversion of planted forests of willow to other species will...			X	
4a. The area of poplars for bioenergy plantations will	X			
4b. The area of willows for bioenergy plantations will	X			
4c. The area of other fast growing trees for bioenergy plantations will				X
5a. Government investments in poplars will ...	X			
5b. Government investments in willows will ...	X			
5c. Government investments in other fast growing trees will ...				X
6a. Private sector investments in poplars will ...			X	
6b. Private sector investments in willows will ...	X			

Table 4: Prevailing trends (continued)

	Increase	Decrease	Remain as it is	No comment
6c. Private sector investments in other fast growing trees will ...				X
7a. The significance of poplars for productive purposes will ...			X	
7b. The significance of willows for productive purposes will ...	X			
7c. The significance of other fast-growing species for productive purposes will ...				X
8a. The significance of poplars for environmental protection purposes will ...	X			
8b. The significance of willows for environmental protection purposes will ...	X			
8c. The significance of other fast-growing species for environmental protection purposes will ...				X
9a. The rejection by environmental groups of poplars will...				X
9b. The rejection by environmental groups of willows will...				X
9c. The rejection by environmental groups of other fast growing trees will...				X
10a. The acceptance by the general public of poplars as important natural resources will........	X			
10b. The acceptance by the general public of willows as important natural resources will........	X			
10c. The acceptance by the general public of other fast growing trees as important natural resources will........				X
11a. The introduction of poplars in agroforestry systems will........			X	
11b. The introduction of willows in agroforestry systems will........			X	
11c. The introduction of other fast growing trees in agroforestry systems will........				X

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