The Forestry Value Chain: Stakeholder Engagement and Strategy Session

Date: October 31, 2019
Venue: Genome BC, Vancouver
Supported by: Genome BC, Genome Alberta, Genome Quebec

SUMMARY

The major challenge to the Canadian forestry sector has been the declining harvestable land base because of climate change. The effects include stress to trees due to insects, pathogens, heat and drought, that have collected led to low fiber supply. There is a clear need for resilient trees with resistance to these biotic and abiotic stresses. Furthermore, the land base decline has led to increased emphasis on value-added forestry products from the residual fiber - from biofuels to specialty materials. Cross-laminated timber as a value-added product has been an important advance, but more work is needed in this area. There is also a case for the use of forests for carbon sequestration in the amelioration of climate change, something that will have to be rationalized with respect to other forestry activities. The session brought forward topics such as understanding plant-microbe interactions and soil carbon stocks in forests, the decline in urban forests, effects on forest-dependent communities and the understanding and acceptance of the applications of biotechnology in forestry which were highlighted as important considerations for this sector.

INTRODUCTION

On October 31st, 2019, in an effort led by Genome BC and co-championed by Genome Alberta and Genome Quebec, a locally attended and web-based forestry stakeholder engagement and strategy session was held in Vancouver (see Appendices for the final program and presenters' slides). The goal of the meeting was to bring together stakeholders in the Canadian forestry sector to discuss the challenges and opportunities facing the industry. This report is a record of the Forestry session and is intended to inform the Request for Applications (RFA) of forest sector priorities for the Large Scale Applied Research Project (LSARP) competition which Genome Canada is expected to launch in early 2020.

The meeting was attended by those with interests in the Canadian forestry sector from government, industry, and academia. The program included nine presentations, emphasizing national and regional issues, both technical and societal, as well as past Genome Canada-supported research.

INVITED PRESENTATIONS

LSARP 2020 and GE^{3}LS – Karen Dewar, Director of Programs, Genome Canada

Karen Dewar spoke of the upcoming LSARP competition in 2020 on Natural Resources and the Environment and approaches to successful GE^{3}LS research. The competition, focusing on Natural Resources and the Environment, will likely be announced in January 2020, and Registrations will be received through regional centers likely in March 2020. Other regional genome centers will be holding stakeholder engagement and strategy sessions on various topics such as Conservation and Wildlife Management, Mining and Energy, and BioProducts and BioManufacturing, relevant to the Natural Resources and Environment competition.

In terms of GE^{3}LS research, Dr. Dewar emphasized that projects could be GE^{3}LS-led or be integrated into a project which includes technical/genomics research. In the latter case, the level of integration is important - the test for the strength of GE^{3}LS integration is the predicted effect of removing the GE^{3}LS component from the project.

Successful GE^{3}LS *integration* at the proposal stage relies on relevant expertise, pre-existing relationships with collaborators, early involvement in proposal development, and recognition of end user needs. Along similar lines, successful *execution* of funded projects requires mutual respect among collaborators, good communication, user involvement, and good guidance from the research oversight committee.

The Canadian Forestry Sector – (James Farrell, James Sandland, Andy Benowicz, Jean-Pierre Saucier and Werner Kurz) – speaker affiliations and their presentations are appended

Based on the presentations in the forestry sector session, in Canada, the sector provides $64B in annual revenues, $21B in GDP which is 1.7% of GDP. Almost all regions are involved in forestry to some extent. Forestry is particularly important to British Columbia, which accounts

for 46% of Canada's softwood lumber production. The industry is very export dependent – Canada is the 4th largest forest products exporter in the world, and a leader in softwood lumber and newsprint exports. The U.S. is Canada's biggest market, but other markets are increasing in importance, especially China, Japan, and the E.U. Most forest products are derived from crown land, although, in Nova Scotia, more than 50% of the land base is private.

In recent years, harvest has declined dramatically. For example, in BC, they peaked in 2005 and have been falling since then. Much of this decline is linked to climate change and the concomitant effects of heat, drought, insects and pathogens, most significantly the Mountain Pine Beetle infestation (see below). On the demand side, Ontario has been affected by a downturn in the market for newsprint.

Werner Kurz discussed climate change along with possible mitigation strategies. He emphasized that mean temperature changes at higher latitudes have been larger than near the equator. In Canada, some regions have seen seasonal mean temperature increases of more than 5 C over the last 50 years. Regionally, climate change may enhance or reduce growth and mortality in forests. The net effect of this is very difficult to predict. It is expected that vegetation zones will continue to shift over time. It is also notable that climate change can increase the risk of forest fires, with detrimental effects on CO_2 levels. Thus, it is important, within regions, to be able to predict the direction and magnitude of changes in tree growth and mortality and soil carbon stocks. An additional issue with respect to climate change is the thawing of permafrost and the subsequent release of greenhouse gases into the atmosphere.

A major theme with respect to challenges and opportunities in the Canadian forest sector is the effort needed to move from volume to value. Historically, the value proposition in the forestry sector has been based on high volumes of fibre for low value products with small margins, *e.g.*, lumber, pulp products, and pellets. *As harvestable land area declines, it has become increasingly important to squeeze more value from trees.* Thus, the challenge is to shift to higher value, lower volume products relating to materials, chemicals, energy and engineered wood. Cross laminated timber (CLT) is a good example of a "major step forward" in value-added forest product development with applications in the construction industry. Other possibilities include the production and application of high value ingredients and products such as lignin, nanocrystalline cellulose (NCC), biofuels, chemicals and polymers.

On a somewhat longer timescale, given the decades from planting to harvest, tree improvement will continue to be important for dealing with existing and future issues, especially the effects of heat, drought, insects and pathogens on forest health and productivity. In Alberta, more than 90 million trees are planted annually (mostly white spruce and lodgepole pine). However, only 15% of reforestation seed is improved. Thus, there is further opportunity for tree improvement, although there are issues with understanding the value of various traits (especially in changing environments), measurement of the effectiveness of improvements, and important bottlenecks in the mass deployment of genetically improved trees. In Quebec, there are ongoing genomics projects relating to the improvement of three species of spruce. This work has leveraged the knowledge of spruce genomes to allow for early selections of individual trees, prior to phenotypic testing (*i.e.*, genomic selection), highlighting the importance of genomics in advancing forest sector outcomes.

Each of the 2010 and 2015 Large Scale Applied Research Programs (LSARPs) funded five forestry-related projects on four topics - climate change adaptation, marker-assisted selection, forest health diagnostics, and biomass valorization. Many of these projects (AdaptTree, CoAdaptTree, SMarTForest, Spruce-UP, RES-FOR, POPCAN) involved support for tree breeding and enhanced our understanding of the genetics of abiotic (heat, drought) and biotic stress (insect, microbe) resistance, through the use of genome sequencing, genetic mapping, genomics tools development, metabolic profiling and/or mathematical modelling. In other projects (SYNBIOMICS, "Microbial Diversity") microbes and microbial enzymes were investigated with the goal, for example, of the conversion of lignocellulose to useful products. The TAIGA and bioSAFE projects dealt with disease and pathogen diagnostics and invasive alien species, respectively.

A presentation was given on Genomics and Society with emphasis on forest-dependent communities. It was noted that GE^{3}LS research has explored the effects of the application of genomics to trade and market access and the effects of national policies and regulations on the uptake of genomics-based applications. There is a clear need to understand the effects of genomics applications on forest-dependent communities, to consider these impacts early on and to take into consideration community values. Of prime importance is the need to find ways to engage and work with First Nations communities as true partners with joint decision-making and respect for their rights related to conservation of the environment.

THE BRAINSTORMING SESSION

Forest Health and Productivity

In this first section of the brainstorming session, the topics discussed fell generally under the categories of desirable tree traits, urban forestry, carbon sequestration and invasive species. In terms of desirable tree traits, the question was asked with respect to planting for reforestation - "Do we know enough about desirable traits?". Climate change is considered to be one of the biggest challenges for this. Disease and insect research are important and there is an important role for genomics and related research in this area. A comment was made that tree performance in natural plantations are not a good predictor of the performance of genetically improved trees in forests.

Urban forests were discussed at some length. It was noted that in recent years, we have seen considerable loss of trees from urban environments. Trees in urban areas affect microenvironments; they ameliorate pollution and provide shade, reduce energy costs and improve human health. They tend to be more at risk from invasive species. The relatively small area of urban forests may prevent significant investment in their protection. Genomics and related research could be applied to the non-commercial species in these forests. One of the challenges is the need for less expensive ways of genotyping individual trees.

The genetic modification of non-commercial species was discussed. Chestnut was raised as an example of an urban species for which transgenic trees with blight resistance have been generated in the U.S. It was indicated that GM chestnut had public support a result of the

consideration of the trade-off between dealing with an invasive species and the use of genetic modification. It was suggested that newer gene-editing methods may be more socially acceptable than the traditional (*Agrobacterium*-mediated) methods of genetic modification used for GM chestnut. It was also noted that from a regulatory point of view, in the E.U., gene editing is equivalent to other forms of genetic modification.

There were comments and questions about the role of forests in the amelioration of climate change through carbon sequestration. It was noted that use of forests is one of the cheapest ways to sequester carbon. Thus, forests may be asked to provide the "environmental service" of carbon sequestration. This would have to be funded and prioritized relative to other forestry activities. It was suggested that broadleaf species may be important for this – they are fast-growing, relatively fire-resistant and have a positive effect on surface reflectance.

Carbon sequestration also came up in discussions of microbial ecology and plant-microbe interactions. There is a positive correlation between tree species diversity and soil carbon storage. In soils, carbon storage is mediated by microbes. More work needs to be done to understand these processes and the details of how particular tree species mediate soil processes.

Invasive species were discussed. The Canadian Food Inspection Agency (CFIA) is responsible for limiting pest and pathogen transfer via imports and exports through appropriate testing. In some cases, product treatments are required, especially those mandated by importing countries. Unfortunately, the requirement for treatments is not always made on scientific grounds. There may be an opportunity to reduce these treatments and the use of the chemicals involved.

Fibre Supply and Bioprocessing

The theme of "value over volume" in the face of the declining harvestable land base was important throughout the meeting and was reflected in the discussion of fibre supply and bioprocessing. It is important to get more value and product diversification from forests and this idea should be central to the Request for Applications.

The question of the use of low-quality fibre sources was raised. Can low quality, underutilized, and non-commercial fibre sources be exploited? Can low quality fibre be converted to high quality fibre? Can there be a concomitant reduction in wildfire risk? "This represents a cost/technology puzzle."

Bioprocessing of forest products, in general was discussed. What products should be made? For example, from lignin? The sentiment was that "we're not there yet" in finding new value-added forest products and that more research is needed in this area. In addition to lignin utilization, mention was made of bioplastics, renewable natural gas and cellulosic nanomaterials (to replace plastics and in some cases, metals). The question of relevant tree traits important for bioprocessing was also raised. Comments were made about forest sector bioprocessing being a "work in progress" with an "exciting future" with a "role for genomics" research. In terms of product diversification, a comment was made about the possibilities for non-timber forest products, such as natural products from fungi and medicinal plants.

A few comments were made about forest product traceability. More than half of tropical forest products are mislabelled. There is value in the ability to trace forest products back to sustainably managed forests. Thus, methods for optimizing traceability to such Canadian forests would be useful.

Issues relating to tree breeding programs were discussed. It was noted that, in the last 20 years many tree genomes have been sequenced, especially in Canada, the U.S. and Sweden. A major issue in the exploitation of this genomic data, in breeding programs, is the cost of genotyping individual trees. Ideally this should be US$10 per tree or less. Costs are currently US$25-30 per tree (or US$40 to track 50,000 markers). Commercial methods are more expensive than non-proprietary ones. Cost per tree can be reduced if the numbers are large, *e.g.*, in consortia. Also, new, cheaper methods are being developed, including those based on multiplex PCR and exome capture.

Forest-dependent Communities, Genomics and Society

Forest-dependent communities are experiencing major direct and indirect challenges linked to low fibre supply especially in BC, where mill closures are affecting the livelihood of whole communities. It was noted that forest health can also affect the tourism industry.

There was an extended discussion about the perceptions of genomics and related technologies. For example, even industry leaders have been found to conflate the use of genomic tools with genetic modification. Better communication is needed with industry. Social scientists have made progress in understanding how to engage different groups about biotechnology including the molecular breeding of trees and genetic modification. It was found that “how you ask makes a big difference”. There is a need to carefully define technical terms. There is less support for genetic modification than for other approaches. In some studies, even the introduction of trees from outside of their native range was viewed negatively. On the other hand, as mentioned above, there has been public support for transgenic chestnut for urban environments which is resistant to blight.

The management of issues related to invasive species was discussed. There are threats to forest from invasive species, both known and alien. Despite many developments relating to rapid DNA/RNA-based testing, regulators have been very slow to implement these. The value of such tests and the barrier to beneficial regulatory implementation needs to be addressed.

APPENDICES – Agenda, Presentations

STAKEHOLDER ENGAGEMENT & STRATEGY SESSION

FORESTRY VALUE CHAIN

October 31, 2019 | 9:30 AM – 12:30 PM Pacific Time

(**Call-in information**: INSTRUCTIONS: "At the time of the meeting click on this link to join" - Join Zoom Meeting https://genomebc.zoom.us/j/927074793) – more details below

Facilitator: Roger Foxall | **Recorder**: Patrick Covello

PROGRAM

- Introduction
- Housekeeping
- Purpose of this session
- LSARP2020 & GE3LS – **Karen Dewar**
- Canadian Forestry Sector – National and Regional perspectives
    - National Forest sector – **James Farrell**
    - BC Regional Forest sector – **James Sandland**
    - AB Regional Forest sector – **Andy Benowicz**
    - QB Regional Forest sector – **Jean-Pierre Saucier**
    - Forest sector: other jurisdictions – **James Farrell**
    - Climate Change impacts on the forest sector and potential mitigation strategies – **Werner Kurz**
- Past Genome Canada supported forestry research - **Rahul Singh**
- Genomics and Society: Forest-dependent communities – **Kate Harland**
- **Break – 10 minutes**
- Brainstorming session topics – **Roger Foxall**
    - Forest Health and Productivity
    - Fibre Supply and Bioprocessing
    - Forest-dependent Communities, Genomics and Society
- Next steps & Session close

ZOOM INSTRUCTIONS: "At the time of the meeting click on this link to join" - Join Zoom Meeting

https://genomebc.zoom.us/j/927074793

Topic: Genome BC - Forest Sector Value Chain Stakeholder Engagement and Strategy Session

Time: Oct 31, 2019 09:30 AM Pacific Time (US and Canada)

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Meeting ID: 927 074 793

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The Canadian Genomics Enterprise (CGE)

Stakeholder Engagement & Strategy Session:

Forest Value Chain

Purpose of Session

- Purpose:
  - Stakeholder consultations
  - Strategy for the forest sector
  - Prioritization
  - Inform RFA

GE³LS Research

GE³LS research investigates the implications of genomics in (and on) society.

It can be either the major focus of the project or an integrated component that is shaped by, and helps shape, the overall project by investigating key factors that may facilitate or hinder the uptake of the genomic-based application(s) being developed by the project.

It aims to inform responsible genomics research and enable uptake of applications.

> *E.g. exploring the effects of national policies and/or regulations on the uptake of genomics-based applications and the impact on sector competitiveness and productivity.*

Review of GE^{3}LS Research

GE^{3}LS research is considered as part of the overall research activities.

In general, there will be an examination of the level of integration of GE^{3}LS research within the overall project.

Review committee members have expertise in multiple aspects of the proposal, including GE^{3}LS research fields.

Pathway to Success for Integrated GE³LS

Integrated Development – Success Factors

- Finding GE³LS researchers with the right expertise for the problem.
- Pre-existing working relationships and/or familiarity with others' work.
- Early involvement of GE³LS researchers in planning.
- Understanding users' needs and working back from these to help GE³LS deliver results.

Integrated Execution – Success Factors

- Mutual respect to overcome the disciplinary divide.
- Strong communication mechanisms.
- User involvement in project.
- Valuable GE³LS guidance from the Research Oversight Committee.

Genome Enterprise: Forest Sector Information Session

October 31st, 2019

Cornerstone of Canada's Economy

$20.9B GDP
(2018)

600 Dependent Communities
(Estimate from Provincial Associations)

$73.6B Revenue (2017)

232K Employees
(2017)

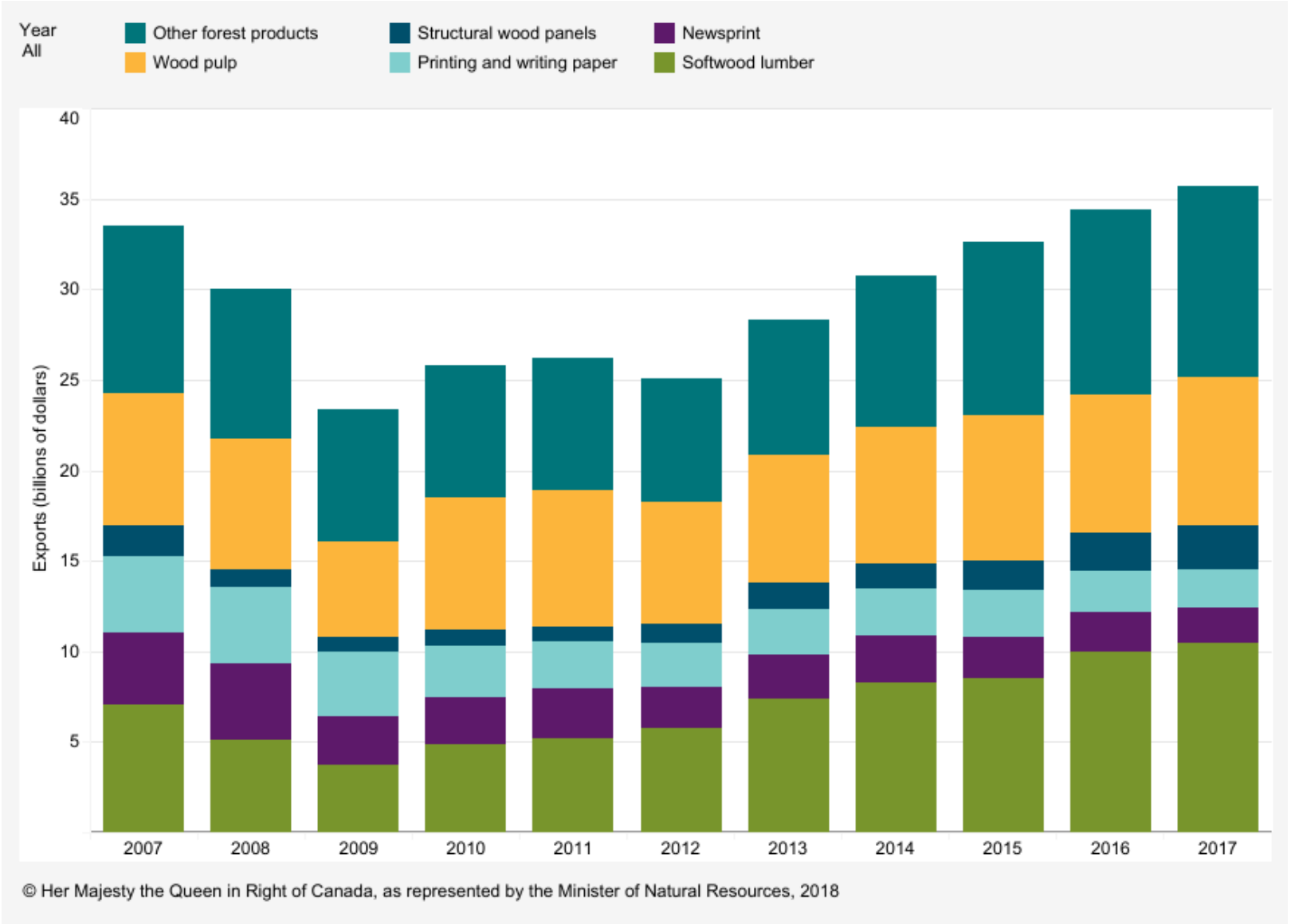
177 Export Countries
(2018)

8% of Manufacturing
(2018)

$38.5B Exports (2018)

Exports of Canadian forest products, 2007–2017

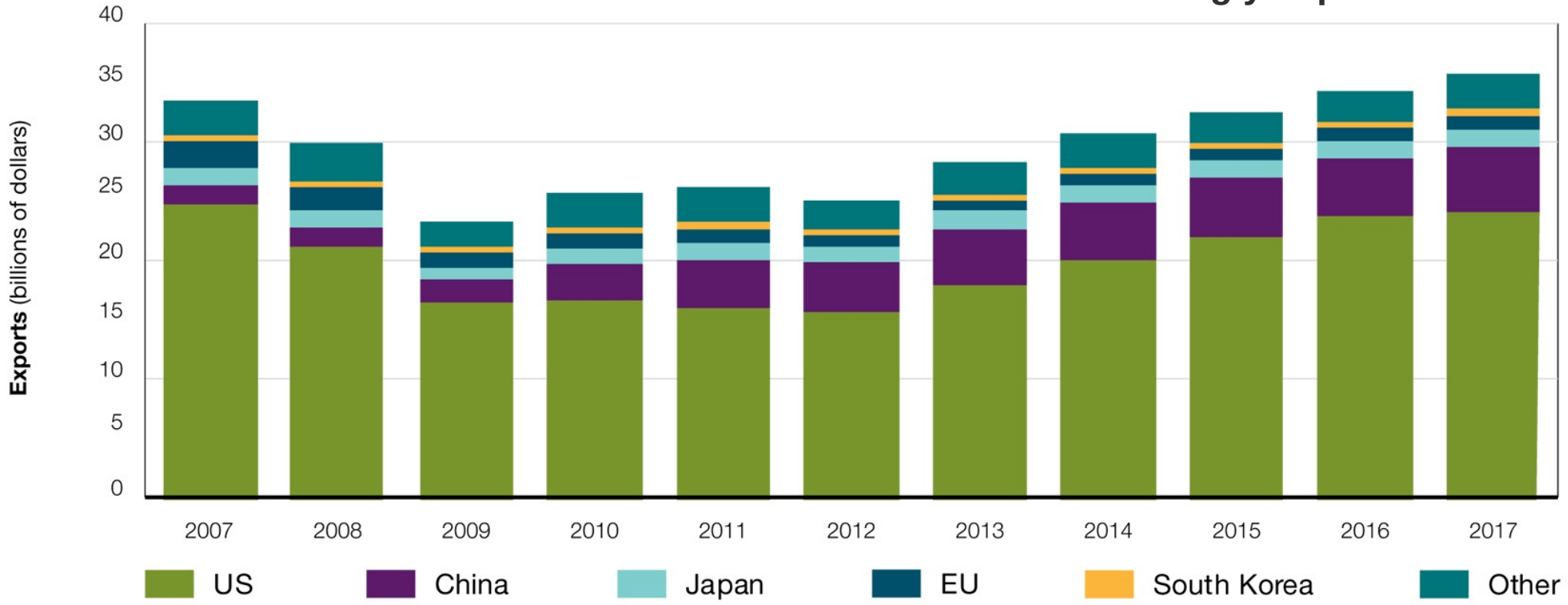
By value, Canada is the fourth-largest forest product exporter in the world, behind the United States, China and Germany, **and the leading exporter of softwood lumber and newsprint**.



https://www.nrcan.gc.ca/our-natural-resources/forests-forestry/state-canadas-forests-report/how-does-forest-industry-contrib/indicator-exports/16558

Exports of Canadian forest products by market, 2007–2017

The United States (US) remains Canada's primary export destination for forest products; however, **over the last decade, exports to other international markets have become increasingly important**.



https://www.nrcan.gc.ca/our-natural-resources/forests-forestry/forest-fact-book/forest-industry-national-picture/21683

Squeezing more value from trees

- From bio-oil and biopharmaceuticals to bioactive paper and biobuildings, applications for substances derived from wood (such as lignin and nanocrystalline cellulose(NCC)) now reach into nearly every imaginable corner of use.

Lignin

NCC

biofuels

biochemicals

wood-based polymers

CLT

Considerations

- Forest Fibre
  - Quality; quantity; cost; availability
  - Changing climate
  - Pressures: pest and fire losses; land use; habitat change
- Markets
  - Diversification
  - Shifting production/demand
- Products
  - Diversification
  - Increasing interest in wood
  - Bio-processing
- Regulation
  - Public resources; public policy; increasing expectations
- Indigenous engagement
  - Increasing influence on/responsibility for forests

Opportunities

- Forest growth, health and productivity
- Bio-processing
- Invasive species
- Science grounded regulation
- Informing increasingly challenging decision making

Ministry of Forests, Lands, Natural Resource Operations and Rural Development

British Columbia's Forest Sector Today & Tomorrow

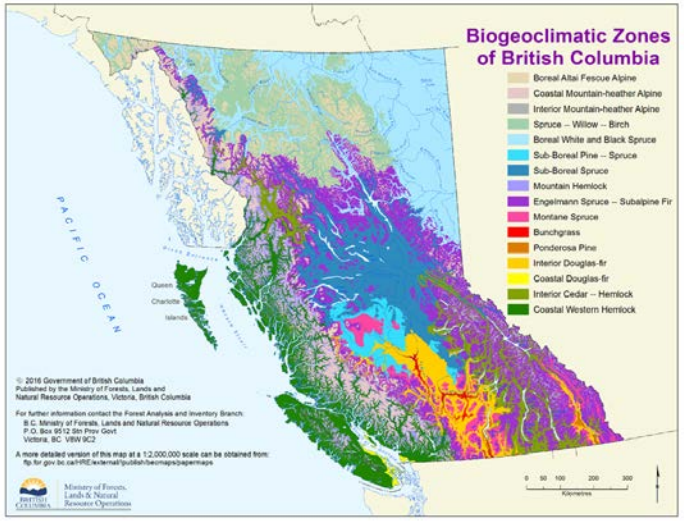
Genome B.C.

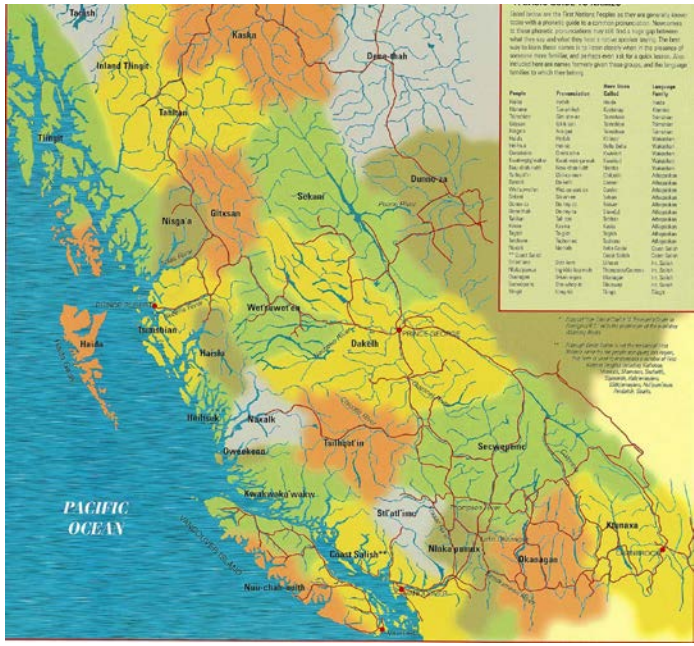
Stakeholder Engagement & Strategy Session for the Forest Value Chain

OCTOBER 31, 2019

B.C. Forest Land Base

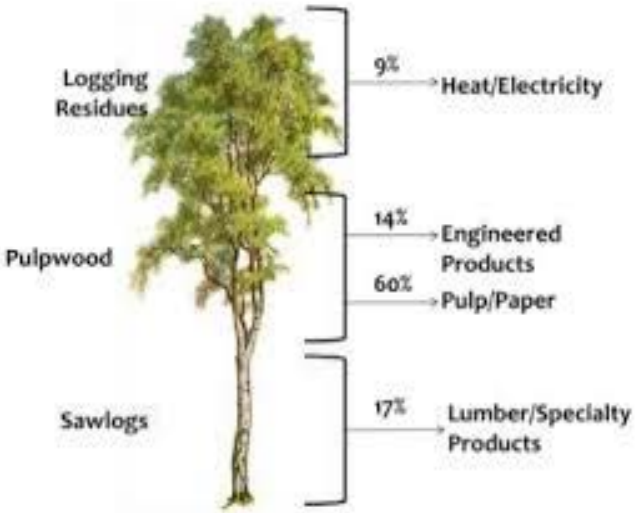
- The total area of B.C. is 95M hectares and 93% is provincial Crown land; total forested area is 55M Ha's and 22M Ha is considered timber harvesting land base (THLB)
  - ~200,000 hectares of the THLB is harvested annually
  - Harvest level peaked in 2005 at ~ 90M m^3, been falling since with theoretical long-run sustained yield of ~70M m^3 (*not considering climate change impacts and enhanced wildlife protection – e.g. Caribou)
- Significant component of B.C.'s economy (32% of exports)
  - 30.6M m^3 of lumber, or 46% of Canada's total softwood lumber production (2017)
  - 4.3M tonnes pulp products
  - 1.78M tonnes pellets
  - ~170K m^3 of CLT production
- Highest degree of biodiversity in Canada
- Highest degree of indigenous diversity in Canada comprising 203 First Nations, 26 cultural groups and at least 32 languages

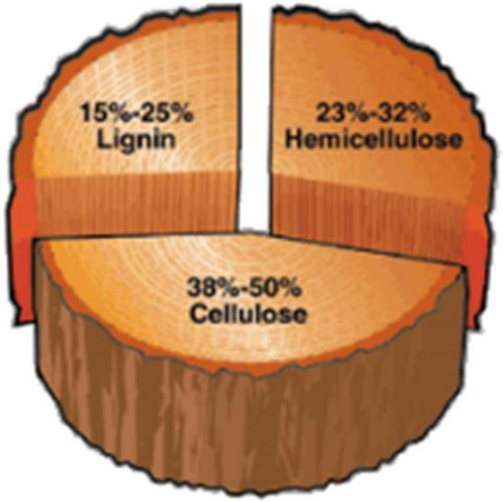




B.C. Forest Sector Challenges

- Predominantly still a “saw-log” mentality when it comes to the forest resource
- Current value proposition hinges on the need for high volumes of fibre, to produce relatively low value, commodity-type products with small margins (e.g. dimensional lumber, primary pulp products, pellets)



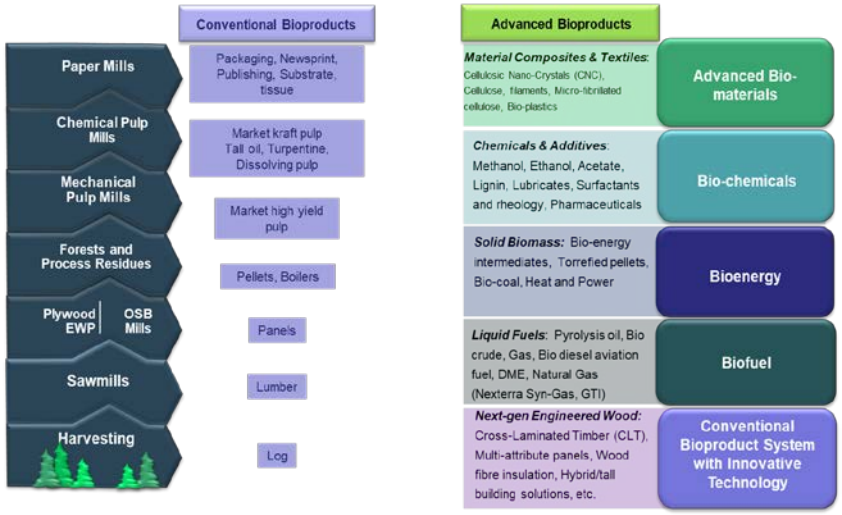


How do we help shift the sector to consider broader lens towards our forest resource potential…?

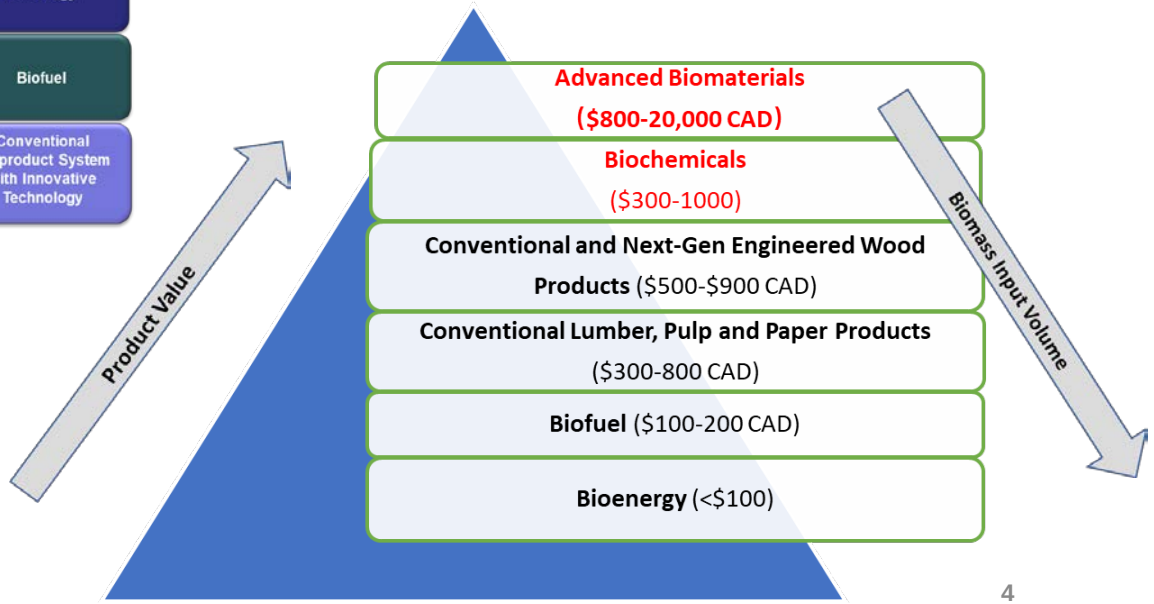
How do we position ourselves in the emerging forest bioeconomy…?

B.C. Forest Bioeconomy Opportunities

Forest Bioproduct Categories

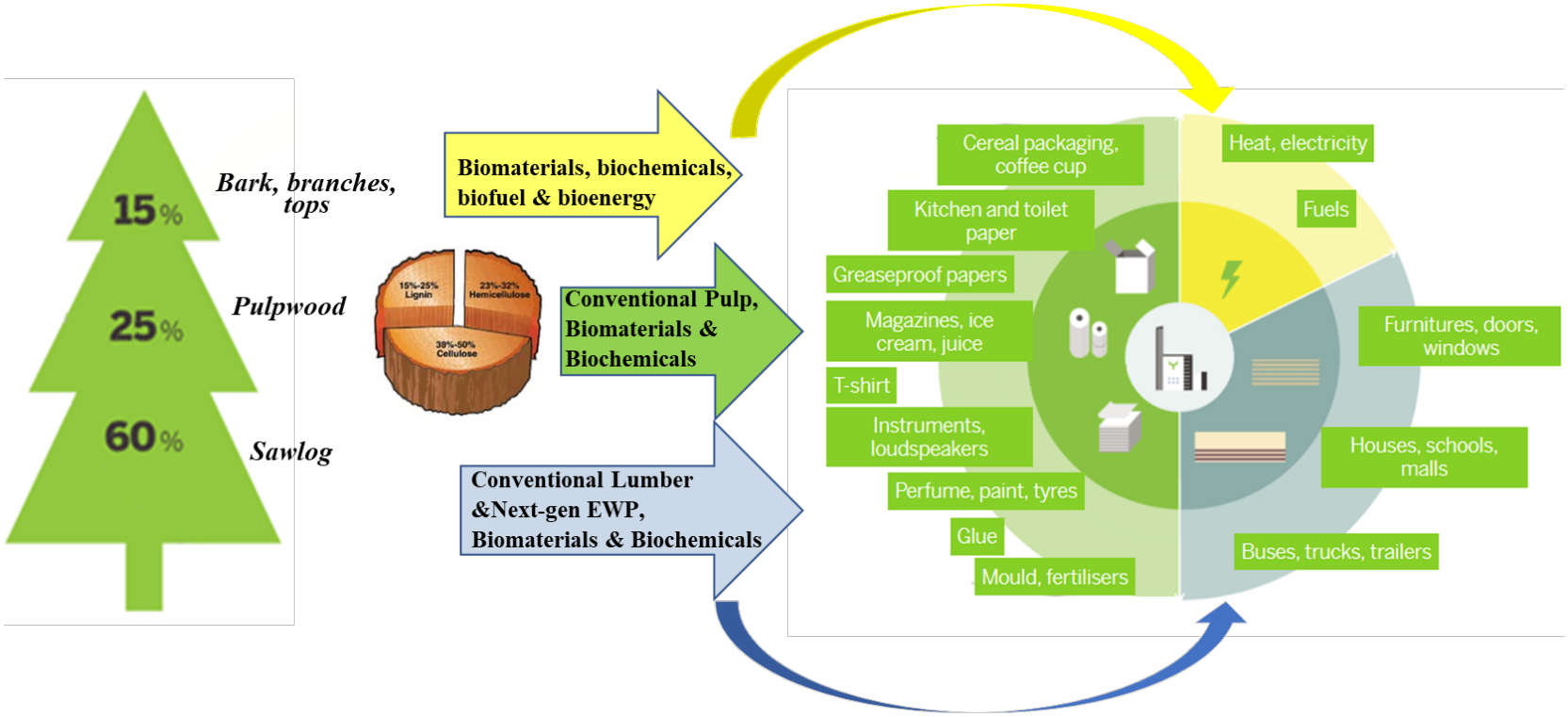


Bioproduct Metrics
Economic Value Assessment



Economic Output Value per odt Biomass Input in Bioproduct Production

Forest Bioproduct Value Chain



Thanks

James Sandland
Director - Innovation, Bio-Economy & Indigenous Opportunities (IBIO) Branch
Ministry of Forests, Lands, Natural Resource Operations & Rural Development

Genome Canada Stakeholder Engagement & Strategy Session Forestry Value Chain

Andy Benowicz
Forest Genetics Specialist
Forest Health and Adaptation Section
Forest Stewardship and Trade Branch
Alberta Agriculture and Forestry

31 October, 2019

Forestry in Alberta

- **Essentially all of the forested area in AB is public land**
- **84 K ha harvested annually, 64 K ha planted (8-year average)**
- **24 M m^3 harvested annually (17 M m^3 softwoods, 7 M m^3 hardwoods)**
- **303 K ha burned annually (20-806K ha range)**
- **Over 90 M seedlings planted annually; almost all of it white spruce and lodgepole pine**

Tree Improvement Programs in Alberta
Ownership/management

1. **Programs run by the industry**
2. **Co-operative programs (industry partners, industry-government)**
3. **Programs run by the provincial government**

Tree improvement is regulated (Alberta Forest Genetic Resource Management and Conservation Standards).

Challenges

1. **Secure fibre supply (MPB outbreak, fires, climate change, land-use change, caribou habitat protection, social license, wood transportation challenges).**
2. **Foreign competition, trade issues/access to markets**
3. **Tree-improvement related:**

- **Costs of tree improvement ($ and time)**
- **Low deployed gain (low genetic gain and limited seed supply)**
- **Uncertain realized gain (pure stands, mixed stands, ingress, stand management)**
- **Value of selection traits other than height**
- **Value of non-market benefits (e.g. impact on soil erosion, air quality, recreation)**

Opportunities

1. Large room to increase deployed gain in growth
   - Only 15% of all reforestation seed is improved
   - Low gain of deployed seed (long rotations, 1st generation orchards, pollen contamination)
2. Cost reduction (e.g. remote sensing and image analyses)
3. Rapid screening for a suit of traits
4. Tree improvement and growth and yield modelling
5. Optimize deployment (matching genetics to sites)
6. Burnt area planting
7. Use of non-local species/seed sources
8. Deciduous species improvement (aspen mass propagation)

Quebec Regional Forest Sector

Jean-Pierre Saucier

Directeur par intérim

Direction de la recherche forestière, Ministère des Forêts, de la Faune et des Parcs

Quebec Forest Branch Genomic Research Need

Ministère des Forêts, de la Faune et des Parcs

Forestry Value Chain Stakeholder Engagement & Strategy Session, Thursday October 31, 2019

Ministère des Forêts,
de la Faune et des Parcs

Québec

MFFP Genomic collaborations

Past

- Since 2002, we have collaborated with Jean Bousquet's team from Laval University to realize many Genome Canada projects
  - Arborea, Arborea II, SMartForest and FastTRAC

Ongoing

- Spruce-Up (LSARP) – white spruce
- Planning *FastTRAC* II (GAPP) – black spruce and red spruce

Québec

Operational Genomic Selection

- In summer 2018, we made the first genomic selection at operational level thanks to result gained from the FastTRAC project
  - Recommendation of white spruce Multi-varietal somatic embryogenesis lines

  (Perron *et al*. 2018. AT-SGRE-17)

- A white spruce breeding strategy that integrates genomic selection has been proposed and accepted by the authorities

FastTRAC
Tests Rapides pour l'Amélioration des Conifères

Québec

MFFP Genomic research need

Genomic field

- Genomic selection
  - continue the development of this young tool
  - more economic analysis

- Population Genomics
  - for conservation requirement

- Traceability
  - Operational clonal certification
  - Pedigree reconstruction

Québec

MFFP Genomic research need

Challenges

- Genomic selection
  - actual genotyping cost and year to year budget variation
  - decreasing genotyping cost in order to increase the number of trees genotyped for the same number of SNPs
- Population Genomics and traceability
  - fast and cheap genotyping tool to genotype thousand trees for a few hundred markers and low level of raw data manipulation
- High throughput phenotyping
  - for complex traits for adaptation and pests resistance

Québec

Genome BritishColumbia
Leading ▸ Investing ▸ Connecting

GenomeAlberta

GenomePrairie

GenomeCanada

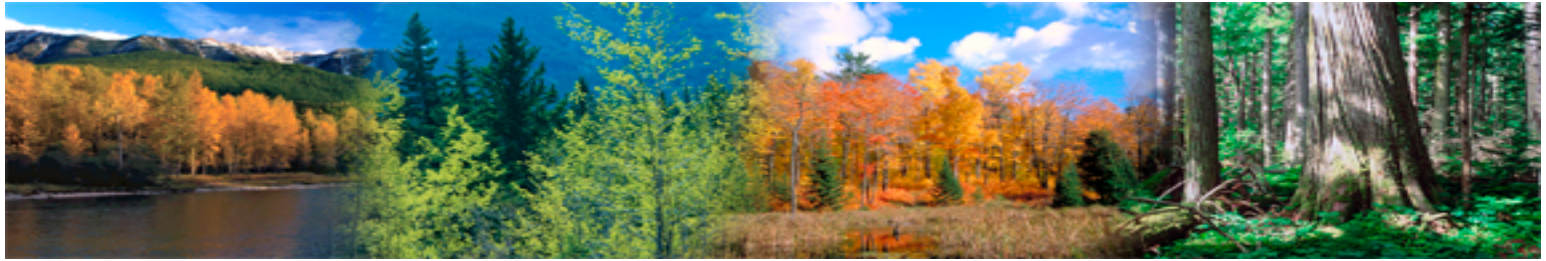
Ontario Genomics

GenomeQuébec

GenomeAtlantic

Forest Sector – Other Canadian Jurisdictions

Jim Farrell



Climate Change Impacts on the Forest Sector and Potential Mitigation Strategies

Werner A. Kurz
Natural Resources Canada, Canadian Forest Service
Victoria, BC, Canada

Genome BC Stakeholder Engagement and Strategy Session
Forestry Value Chain

Vancouver, October 31st 2019

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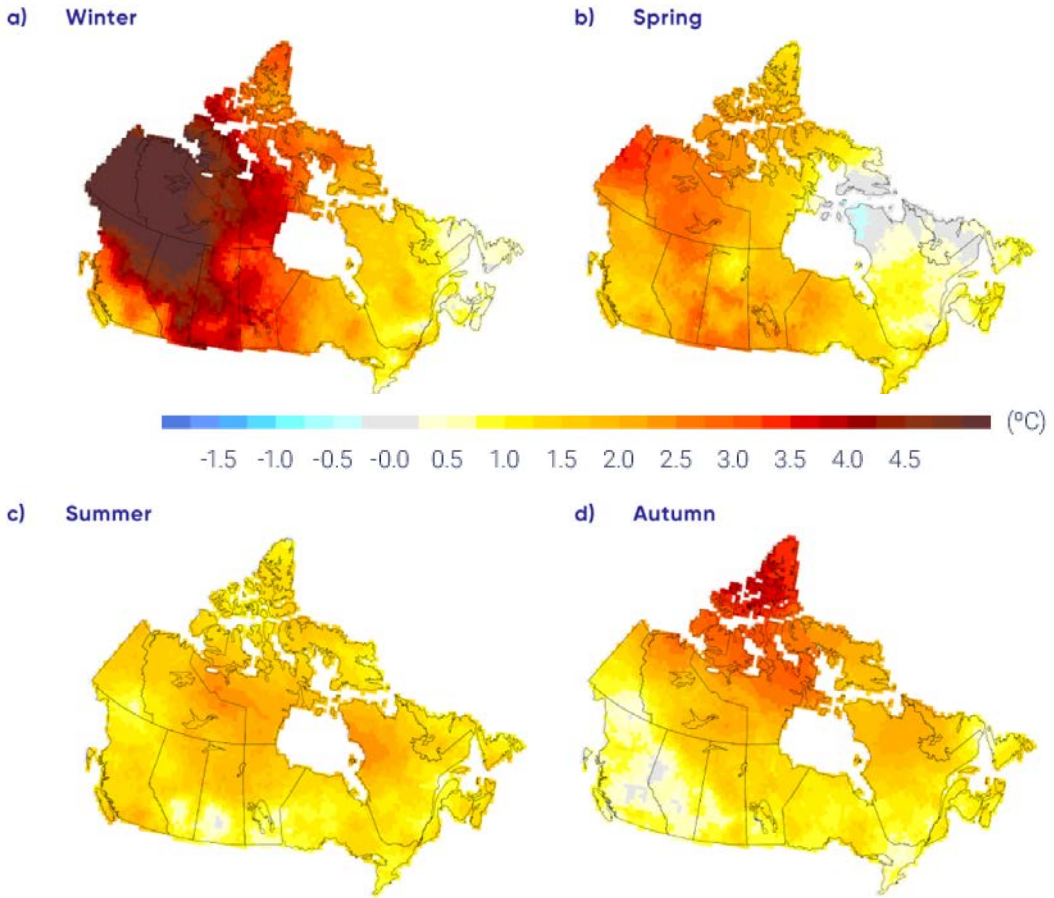
Natural Resources Canada | Ressources naturelles Canada

Canada

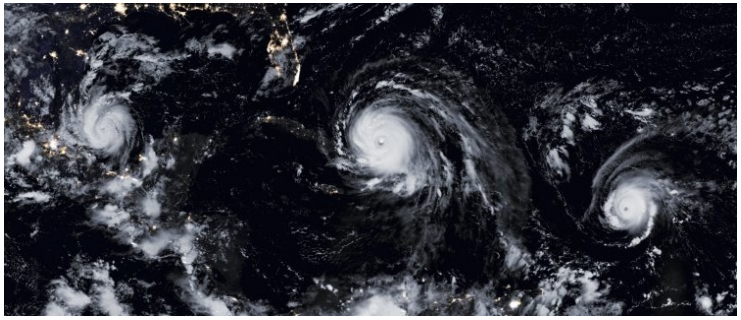
Temperature increases in northern regions higher than global averages

Observed changes (ºC) in seasonal mean temperatures between 1948 and 2016.



Source: Environment Canada 2019

Climate change impacts are already felt around the world.



… and many release more GHG or change energy balance (albedo).

Fate of anthropogenic CO_2 emissions (2007–2016)

Sources = **Sinks**

34.4 $GtCO_2$/yr

88%

Fossil fuel burning, cement

12%

4.8 $GtCO_2$/yr

Deforestation, land-use change

17.2 $GtCO_2$/yr

46%

30%

11.0 $GtCO_2$/yr

24%

8.8 $GtCO_2$/yr

Can sink be sustained or enhanced?

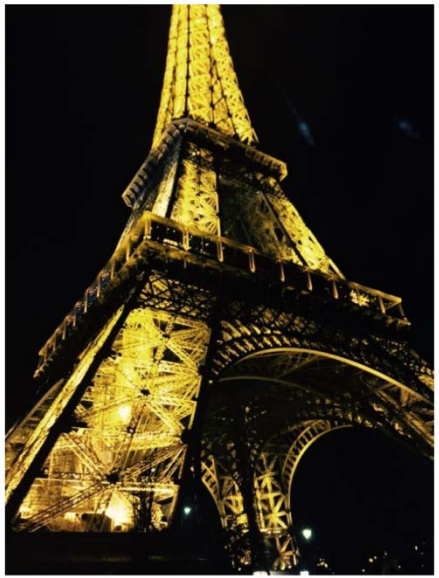
Source: CDIAC; NOAA-ESRL; Houghton and Nassikas 2017; Hansis et al 2015; Le Quéré et al 2017; Global Carbon Budget 2017

United Nations

Framework Convention on Climate Change

2015 Paris Agreement

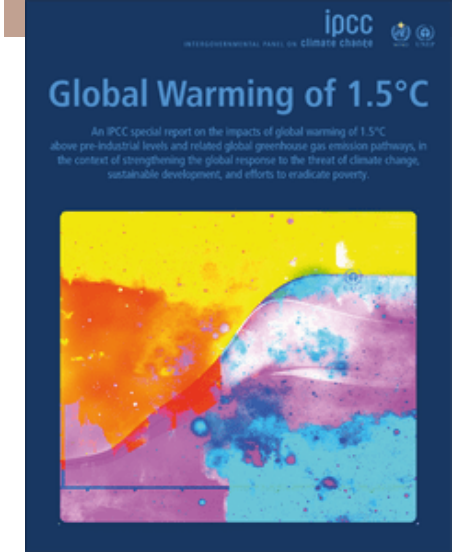
- Goal: **limit temperature rise** to well below 2ºC
- All countries must establish **targets to limit emissions by 2030**
- Countries required to **further reduce emissions after 2030**
- Most countries plan to **include forests** in their efforts
- Aim to achieve **net-zero global emissions** in the second half of the century



Source: K Simonson

ipcc
INTERGOVERNMENTAL PANEL ON climate change

GLOBAL WARMING OF 1.5 °C



- Limiting global warming to 1.5°C **requires rapid and far-reaching transformations in energy systems, land, industry, buildings, transport and cities.**
- **Net negative emissions** are required later this century: CO_2 removals from the atmosphere must be greater than emissions.
- **We cannot keep warming below 2 ºC without land sector contributions!**

Climate change impacts

- Impacts of environmental changes on forests will be **both positive and negative**: growth, mortality, disturbances.
- Understanding **where, when and how** these impacts will occur is necessary to design effective climate change mitigation and adaptation strategies for the forest sector.

Climate change impacts

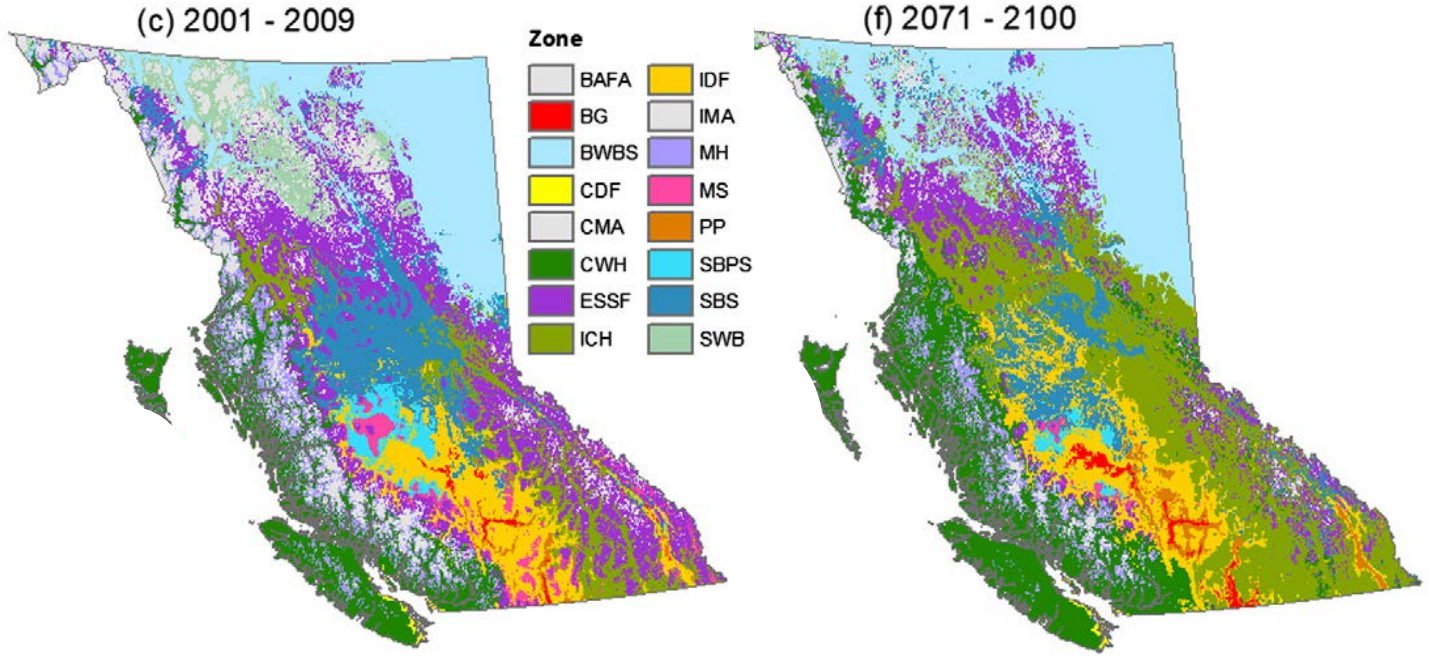
- Climate change impacts will be regionally-differentiated
  - Enhanced or reduced growth and mortality rates (CO_2, N, T)
  - Shifting vegetation zones
  - Increased disturbances
  - Increased decomposition rates
  - Thawing permafrost

Net effects are difficult to predict

– but there is an asymmetry of risk (slow in – fast out).

Climate change will alter distribution and area of ecosystems – including transition from forest to non-forest

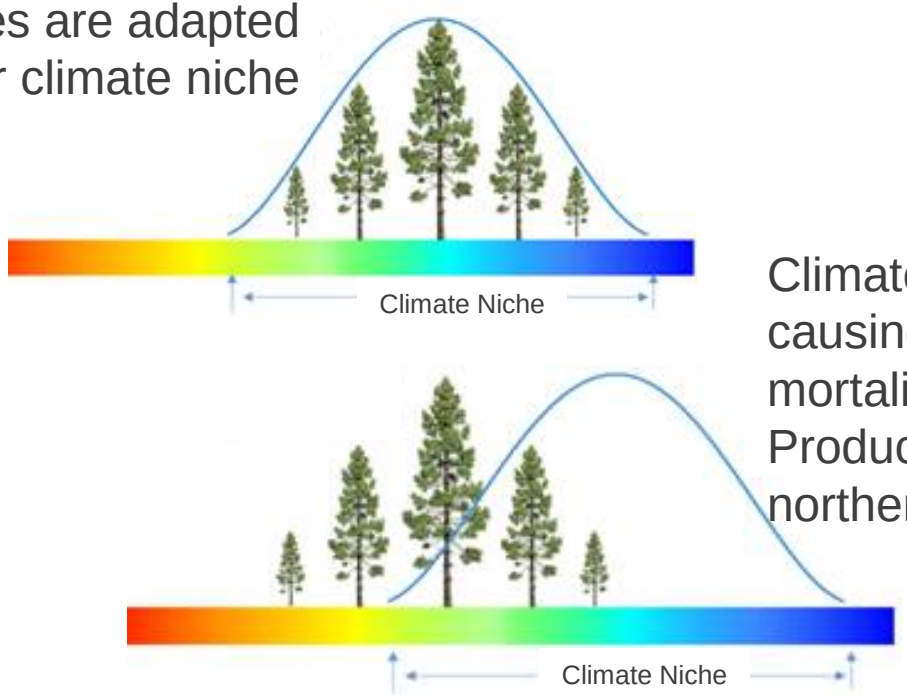
What will our responses be when millions of hectares of forest are stressed or dying?



Source: Wang et al. 2012

Shifting climate niches (latitude or elevation) contribute to species maladaptation, stress and tree mortality

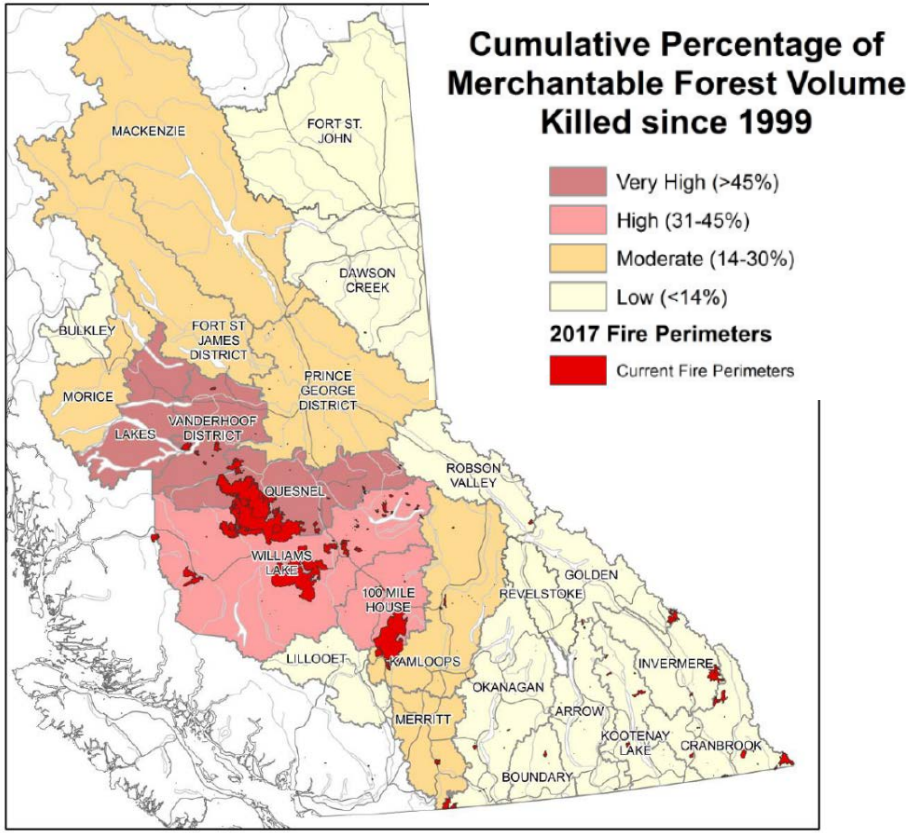
Tree species are adapted to their climate niche



Climate change shifts niches causing maladaptation, stress and mortality.
Productivity may increase at the northern (high elevation) boundary.

Source: Modified from Tongli Wang, UBC

Climate change impact spiral: Drought/heat, stress, insects/diseases, fires, … ?



Source: BC Ministry FLNRORD 2018

In British Columbia, 2017 and 2018 annual direct wildfire emissions estimated at ~3 times the emissions from all other sectors

The warming feeds the warming!

Knowledge Gaps on Climate Impacts

- Prediction of the **direction and magnitude of changes in tree growth and mortality** rates.
- Prediction of the **direction and magnitude of changes in soil carbon stocks and decay rates**.
- Prediction of rates and intensity of **future disturbances**.
- These knowledge gaps limit our ability to project future timber supply, GHG balances and ecosystem services.

Can Genomics Research …

- enhance predictive ability of environmentally-sensitive tree growth and mortality models?
- help identify and select tree species that are more resilient and resistant to climate stresses, pathogens, and insects?
- contribute to understanding soil microbial responses to warming and drying conditions?

Moonshot: Can genomics help reduce methane emissions from thawing permafrost systems, e.g. by increasing methanotrophic bacteria in permafrost soils.

Conclusions

- Keeping temperature increase to below 2 ^{o}C requires **net negative emissions** before 2100 (within the lifetime of children born today!)
- Requires **drastic reductions of emissions** in all sectors.
- Not achievable without also greatly increasing **forest sinks**.
- But forests are also at **risk from climate change**.
- How can **genomics research contribute** to these goals?
- **We still have options** – but the longer we delay action, the more severe the consequences will be.

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Publications at:

http://cfs.nrcan.gc.ca/publications/search?query=Kurz

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FORESTRY VALUE CHAIN STAKEHOLDER ENGAGEMENT & STRATEGY SESSION

Rahul Singh, PhD
Sector Manager, Agri-food and Natural Resources
Genome BC

Large Scale Applied Research Projects (LSARPs)

2010

- **Targeted sectors**: forestry and environment
- **Other eligible sectors**: agriculture/fisheries/human health

2015

- **Target area:** Natural Resources and Environment: *sector challenges – genomic solutions*
- **Focused area:** *energy, mining, forestry, water stewardship, wildlife management/conversation and bioproducts*

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Forestry Projects Funded via LSARPs

2010	2015
GC Investment: $18.05M/5 projects (Total: $24.97M/8 projects)	**GC Investment : $12.23M/5 projects (Total:~$33M/13 projects)**
▪ Climate change adaptation (1) ▪ Marker assisted selection (2) ▪ Forest health diagnostics (1) ▪ Forest biomass valorization (1)	▪ Climate change adaptation (1) ▪ Marker assisted selection (2) ▪ Forest health diagnostics (1) ▪ Forest biomass valorization (1)

GC: Genome Canada

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Climate Change and Adaptation

AdaptTree (2010)


- **Research**: mapped the genetic variations associated with adaptation to the climate change within native species (lodgepole pine and interior (white) spruce)
- **GE3LS:** focused on challenges, knowledge gaps and opportunities among stakeholders, and towards forest management using genomics

CoAdaptTree (2015)




- **Research**: using genomics strategy for climate adaptation by testing the ability of Douglas fir, lodgepole pine, western larch and jack pine to resist heat, cold, drought and disease within and outside of the natural environment
- **GE3LS:** identifying barriers for uptake of genomic and non-genomic adaptation strategies; stakeholder engagement to develop decision tools

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Images source: world wide web for non-commercial purpose

Marker Assisted Selection

SMarTForest (2010)

- **Research**: sequenced spruce genomes and developed tools for genomic selection in spruce breeding programs (white, interior, black, Norway, Sitka spruce)
- **GE3LS:** decision support tools and economic models to support integration of conifer genomics into policy and decision-making

Spruce-UP (2015)

- **Research**: accelerating spruce (white, interior white and Sitka)breeding programs to ensure future forest health, wood quality and productivity in the light of climate change
- **GE3LS:** decision support dashboard comprising risks/benefits, opportunities/constraints, policy analysis, and community engagement model

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Images source: world wide web for non-commercial purpose

Marker Assisted Selection

POPCAN (2010)

- **Research**: genomic tools for rapid genetic improvement of black cotton wood balsam poplar as source of bioenergy
- **GE3LS:** established a framework for land use and policy recommendations; analyzed economics related to timber, carbon prices and financially viability

RES-FOR (2015)

- **Research**: integrating genomics, metabolic profiling and mathematical modeling into existing tree breeding programs to generate pest & drought-resistant trees with improved wood quality (lodgepole pine and white spruce)
- **GE3LS:** assessing tree breeding strategies in climate change adaptation planning; stakeholder engagement and assessment; economic analysis

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Images source: world wide web for non-commercial purpose

Forestry Health Diagnostics

TAIGA (2010)


- **Research**: forest disease diagnostics and pathogen detection and monitoring using genomic tools (Dutch Elm Disease and Ash Dieback)
- **GE3LS:** risk assessment, evaluation of phytosanitary management practices, source tracking of disease outbreaks; eradication or containment of tree diseases

bioSAFE (2015)



- **Research**: genomics tool to diagnose Invasive Alien Species (Asian Long-horned Beetle, Dutch Elm Disease, Sudden Oak Death and Asian Gypsy Moth)
- **GE3LS:** model-based decision-support tool to help reduce uncertainty with regard to invasive outbreak outcomes

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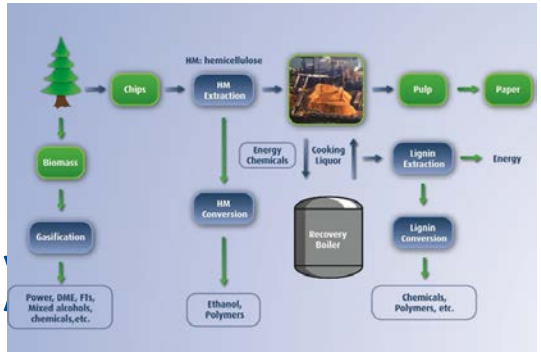
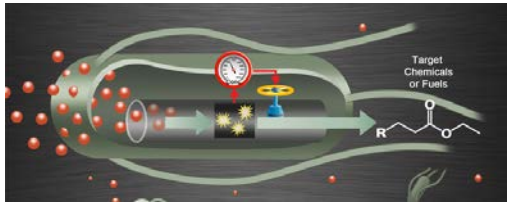
Forest Biomass Valorization

Harnessing Microbial Diversity for Sustainable Use of Forest Biomass Resources (2010)

- **Research**: examined the potential of soil microorganisms (a) as indicators of forest health and (b) to convert lignocellulose to useful products
- **GE3LS:** identified key technical, commercial, and social issues at an early phase of the technology development; identified barriers from invention to innovation





SYNBIOMICS (2015)

- **Research**: upgrading biopolymers from trees, using microbial enzymes, to create high value bioproducts, such as resins, coatings, bioplastics and adhesives
- **GE3LS:** bioproduct & biotechnology development cycle with end-users; TEA models; and predictive tools for effluent treatment and energy recovery

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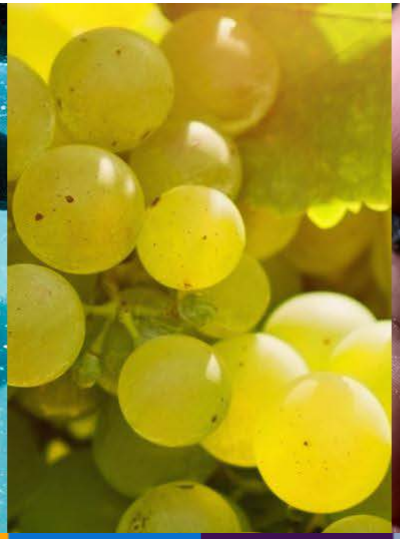
Genomics & Society – GE3LS & Forest dependent communities

Kate Harland




GE3LS Questions

RFA 2015

"[Examples] include, but are not limited to, the following:

- investigating the effects of the application of genomics on international trade and market access to exports of Canadian natural resource products; and,
- exploring the effects of national policies and/or regulations on the uptake of genomics-based applications and the impact on sector competitiveness and productivity."

What was missing?

- Understanding how forest-dependent communities might be affected by or be engaged in discussions around application of genomics
- Understanding the value added of genomics to the communities in question.
- And more…….

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Responsible Innovation

We can't start too early…

Questions surrounding potential implementation of genomics technologies need to be addressed early.

Reciprocal exchange…

Taking into account values & management goals of resource-dependent communities in question.

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Indigenous communities –more than consultation

In light of..

UN Declaration of Rights of Indigenous Peoples, Canadian Supreme Court decisions (e.g. 2014 Tsilhqot'in Decision) & ongoing reconciliation….

We need to work as true partners

- Shared governance, joint decision-making
- Collaborative stewardship & land use planning
- Right to conservation & protection of the environment and productive capacity of their lands

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BRAINSTORMING TOPICS

- Forest Health and Productivity
- Fibre Supply and Bioprocessing
- Forest Dependent Communities, Genomics and Society

2020 LSARP Stakeholder Consultation Themes

- Genome BC– Forest Value Chain (October 31, 2019)
- Genome Alberta – Mining and Energy (November 8, 2019)
- Genome Quebec – Ecotoxicity Monitoring (November 22, 2019)
- Ontario Genomics – BioManufacturing (November 26, 2019)
- Genome Prairie – Conservation and Wildlife Management (November 28, 2019)