CIF/IFC e-Lecture Series: Innovative Solutions to Respond to the Challenges of a Changing Climate

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Canada`s Forests and the Bio-economy – Potential Solutions to Climate Change!

Introduction

Hello! Today's e-lecture, entitled “Canada`s Forests and the Bio-economy – Potential Solutions to Climate Change!” will highlight the collaborative work being conducted in developing strategies for a sustainable fibre supply and bio-economy under the CFS Program “Developing Sustainable Fibre Solutions” by the Canadian Wood Fibre Centre.

The CWFC’s mission is to provide collaborative scientific solutions supporting the forest sector as the cornerstone of an innovative, prosperous Canadian bio-economy. The forest sector has identified that the CWFC should work on supporting tomorrow’s bio-economy, addressing the quantity and quality of the fibre supply and greater knowledge sharing and technology transfer activities.

Today’s e-Lecture will highlight how the CWFC staff have been conducting woody biomass research since its inception in 2006 and prior to that with CFS and how we are building on that research with collaboration with our many partners to provide up-to-date operational research to provide potential options to a changing climate.

Slide 2

Leading this work for CWFC is Suzanne Wetzel.

Suzanne studied Forestry at the University of Toronto, then went on to complete her PhD at the University of Guelph in tree physiology. She started her career within the Canadian Forest Service at the Petawawa National Research Forest, specializing in ecophysiology of white pine, then later moved to Sault Ste Marie where she concentrated her research on non timber forest products and the bioeconomy. She joined the Fibre Centre at its inception and continues to enjoy exploring how Canada’s forest resources can best be harnessed in support of the bioeconomy.

Slide 3

Thank you Tim, we’ve been working on a collaborative project with industry, CanMetEnergy, and the University of Toronto’s Faculty of Forestry. Our project is mainly focussed on gaining a better understanding of the processes which occur when biomass is stored for extended periods of time...And the major goal of this research is to develop more cost-effective and safer methods for biomass storage in the future.
What is the issue? It is easy to forget that many biological, chemical and physical processes are ongoing when biomass such as a large pile of woodchips is stored. For example, bacterial growth persists in the pile, fungal decomposition is taking place, oxidation reactions are occurring, and gases such as CO2 and methane are being released into the air. These processes, as well as evaporation and condensation of water, can lead to excessive heat building up in the biomass piles, and has led to self-heating fires, major worker safety hazards and degradation of feedstock quality.

Just to give you an idea about how much heat can be produced within a large biomass pile, you can see the heat escaping from this pile of woodchips outside in the extreme cold of winter (-30°C).... Overall, the purpose of our research is to determine how alternative storage practices can potentially reduce the dangers associated with self-heating, improve feedstock quality and better understand the environmental impacts of biomass storage, specifically the amount of greenhouse gases that are released over the life cycle of biomass piles.

What are we doing? In order to tackle these research questions we have been developing mathematical models for the various processes which result in the heating of piles (bacteria growth, oxygen consumption, wood decomposition) and are currently measuring changes in temperature, moisture, bulk density....Our main research site is Pineland Forest Nursery in Manitoba, where we are conducting experiments on two large woodchip piles, one fresh and one which has already been stored outside for over a year. In the lab, woodchip samples from these piles are also being tested for bulk density, moisture content and size distribution.
Findings and Impact:

- Progress has been made on developing instruments to monitor temperatures within the pile in real time, allowing us to overcome the challenges of losing data when temperatures increase to levels that are detrimental to localized loggers.
- Soil sensors have been retrofitted to detect biomass moisture in real time; work is being conducted to improve the calibration.
- A model has been developed to predict biomass temperature but requires more data for calibration, shown in the figure.
- The model has identified parameters, such as moisture content, sugar content, oxygen levels within the pile as parameters that have the largest impact on decomposition and pile temperatures, requires more data to verify results.
- Work has been conducted to raise awareness of the project among other researches, allowing for collaboration of efforts and larger data samples.

Overall, these trials are working towards a monitoring solution, which will lead to improved biomass modeling, the ability to quantify GHG emissions from various types of biomass, and better data on internal pile dynamics, ...all of this will facilitate the path for better management techniques. (**For example, as you can see here (Figure 7), the internal temperature of the biomass piles increases significantly over time... If we are better able to understand the timeframe and parameters of this process, we can then work on best practise pile management approaches**)... This research would be contributing to the bio-economy by facilitating the path to developing a standard that allows individuals, small business, and corporations to manage biomass without investing in expensive monitoring equipment, minimizing the loss of biomass quality due to degradation or complete loss of biomass reserves due to self-ignition.

Thank you/Collaborators: Highlighting our main collaborators: University of Toronto, FP innovations (data and analysis) and braingrid (data collecting equipment) Pineland Forest Nursery (woodchip storage).... Thank you! Overview of CRP outlining the highlights of the CRP and the key research questions.

And now I would like to ask Sally Krigstin of the University of Toronto to explain how their research is expanding on this.
I would like to go back and pick-up from Suzanne’s second slide. And while it is very important from a fire risk and GHG emission mitigation point of view to understand the dynamics of woody biomass degradation, it is also important from an industrial utilization perspective. The storage and subsequent degradation of the woody biomass alters its physical and chemical characteristics that can make it more amenable to specific biorefinery processes which produce biobased chemicals, biomaterials and bioenergy. It is the objective of our work to determine the changes to woody biomass over time and under various storage conditions so that we can model the effects on the biomass in terms of their chemical and physical characteristics that will affect “next stage” of the biorefinery processes.

The growth of the microorganisms within the biomass are the main agent responsible for the degradation of the biomass, although there are other mechanisms which are also affecting degradation such as chemical oxidation reactions. However, the microorganism degradation makes the greatest contribution to the chemical changes which take place in the biomass. In order for the microorganisms within the pile to grow and prosper they need 1. certain temperature, 2. Specific pH, 3. Some require oxygen 4. certain level of moisture and 5. Food. These 5 factors are highly correlated and interdependent and hence cannot be easily managed within a pile.

For example if Food is metabolized by the microorganism for growth or maintenance activities it does so according to the following...chemical reaction...

\[ C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{energy} \]

and as can be seen from the chemical reaction that breakdown of cellulose or glucose in the woody biomass will produce CO2, water and energy. To show the interrelationship between the degradation of the food and the energy produced, you are looking at a graph showing the temperature inside a biomass pile in blue and the ambient outdoor
temperature. It is clear that as soon as the pile was constructed there was a rise in temperature even though the ambient temperature (brown dots) is fairly constant. Even through the cold months of November and December this year, the temperature in the pile remains very high. The increase in temperature also positively impacts the growth rate of the microorganisms, thus sustaining their increasing activity in consuming and degrading the biomass.

Slide 12

This slide shows the moisture content inside the same pile. It is apparent that the moisture generated by the micro-organisms are contributing to higher moisture in the pile as the average moisture content is increasing as seen by the blue dots.

The chart on the bottom left is the original moisture content throughout the pile when it was constructed in August 2017. The average moisture content throughout the entire pile was 59.7%. The physical sample bags that were embedded in the pile on set-up were removed from Trench # 4 in December 2017, and show the same trend, with the moisture content of the biomass increasing in this vertical section increasing from an average of 62% to 66% over the 4 month period. The findings can be seen in the two small bar charts. It is interesting to note that the increase in moisture is predominant in the middle and top of the pile, with the bottom maintaining the original moisture, suggesting that the degradation of the biomass is not consistent throughout the height of the pile. One explanation for this could be that there is limited oxygen at the bottom of the pile because of the high level of material compaction.

Slide 13

Over the 4 month storage the average loss in biomass material was measured to be 7.4% or 1.8% per month. Changes that we might expect to see are 1) a more porous structure due to early loss of hemicelluloses which will provide easier access of enzymes to the cell wall material for further degradation of cellulose and lignin. In addition the lower density of the material due to material loss results in weaker material that will have lower energy requirement for mechanical size reduction. Most “next” stage processing require a particle size reduction step. With continued degradation of the cell wall material we expect to see the amorphous cellulose being degraded before the crystalline cellulose. Since it is the crystalline cellulose we are interested in for the production of nanofibres, the natural degradation may be a processing advantage.
It is clear to see that his research will contribute to the bio-economy in two ways, 1) by providing important characterization information to biorefineries so that they will better be able to adjust their processes to the predicted quality of the incoming material and 2) eventually design the storage phase to optimize the woody biomass quality required by various biorefinery facilities.

Thanks Sally! That is very interesting!

Let’s take a step back and look at the potential of biomass harvesting in the Great Lakes – St. Lawrence. Jeff Fera of the CWFC has been leading this work for the past few years. Jeff, can you bring us up to date on your work?

Slide 14

Thanks! I am now going to talk about my joint research project, “Sustainable biomass harvesting in the Great Lakes – St. Lawrence Forest Region”. This is a project co-led by myself, Jeff Fera, Forest Silviculture Research Officer with the CWFC-NRCan and Dr. Trevor Jones, Hardwood Silviculture Scientist with the Ontario Ministry of Natural Resources and Forestry.

Slide 15

The objective of this research is to understand how forest biomass harvesting can be included as a viable harvesting method under partial harvesting systems while still practicing sustainable forest management. To do this we need to look at the ecological, economic and operational impacts of such a harvest as compared to the normal operational practices. If this can be achieved, it will provide sound and defensible scientific support for policy and guideline development towards best management practices for biomass harvesting in south and central Ontario.

Slide 16

Going beyond the primary interest of the need to supply the bio-economy with fibre, we wanted to go a step further and do a study in the GL-SL forest region, which has not received as much attention as the boreal forest in regards to research studies focussing of biomass harvesting as well as look at the unproductive, unhealthy forest conditions that so many foresters are familiar with and see if we can use the biomass market as an economic
starter to go into these stands and do the necessary silviculture to return these forest back to their original healthy and productive state.

Slide 17

So this study has 4 research sites:

1. Algoma Site – 40 min north of SSM – It is a Uneven aged hardwood stand – Shelterwood cut (regen cut) EST. 2010

2. Nipising Forest – 40 min NE of North Bay, ON, - Uneven aged hardwood stand – Shelterwood (regen) cut EST. 2009

3. Haliburton Forest – Uneven aged hardwood stand – (Selection cut) EST. 2009

4. Petawawa Research Forest – Pine mixed wood site – Shelterwood cut (regen cut) EST. 2012

Slide 18

I’ll jump to some quick interesting results from our study at the PRF, which was 120 hectare degraded pine site, which we implemented a shelterwood, regen harvest under two scenarios:

Tree length system – Trees cut to CFSA standards, tree tops and branches are left within the forest

Full Tree / biomass system - All trees cut down to at least 10 cm DBH, topping and deliming done at roadside.

Small trees, tops and branches then chipped at roadside.

The figure shows the volume of material harvested per meter cubed. There was no statistical difference between the TL and FT methods when it came to merchantable volume in the sawlog material, however, there was a difference in biomass recovered, obviously the biomass system harvested biomass, but also in the small pole and large pole size class. The picture to the right depicts this difference. In the Tree length system, more often than not these smaller standing trees are left standing even though they may have a market for them, in the biomass/full tree harvest, the operators were forced to recover all material which equated to a bump in the small log size class.
Jumping past all of the ecological results we can quickly have a look at some of the economics, which the data for this was driven by our operational time of motion study. So given a 1 fellerbuncher, 2 skidders, 1 slasher and topper chipper scenario, for a sub-contractor putting the extra effort into a biomass harvest can be profitable. Since you are recovering not only the biomass but an increased volume of the small pole log material - the operational data (fuel, maintenance...) was provided by FPInnovations.

And to further this, under the same equipment scenario, the landowner also sees a profit, mostly due to the increase in the small logs and no thanks to the price of biomass material. A large asterisk is around the transportation cost as this was standardised to 100 km. As we all know prices fluctuate and the details here are not to be taken as gospel, but guides as to what might be possible in your forest and to hopefully take some of the trepidation out of the idea of doing a biomass harvest with in a partial harvesting system.

Thank you to our partners and now I would like to ask Paul Hazlett and Jérôme Laganière to show how their work with the CWFC is helping to identify options for help maintain woody biomass supply!

This is a new CWFC project ‘Amending Forest Soils with Wood Ash to Maintain Fibre Supply’

The research questions addressed in this project are, How can we maintain fibre supply under more intensive forest harvesting? and, How can we maintain fibre supply in light of forest health conditions that compromise forest productivity? In this case focusing on beech bark disease.
One part of Canada’s strategy to fight climate change is a movement to renewable energy to reduce fossil fuel usage. Although still a small part of Canada’s renewable energy capacity the contribution of biomass to electricity generation doubled from 2005 to 2015. More complete utilization of tree biomass is one possible source of fuel, however, more intensive harvesting has the potential to decrease soil nutrients and forest productivity, and put a strain on the long-term fibre supply.

Slide 23

Increased intensity of biomass removal is visible in this slide. The larger bunch/pile in the picture is the result of normal harvesting utilization and the smaller bunch signifies the extra volume harvested for biomass.

Slide 24

Beech bark disease is a large problem in Eastern Canada. The dense regrowth following the mortality resulting from Beech Bark Disease limits growth of other tolerant hardwoods and results in reduced site productivity.

Slide 25

Currently 2/3 of the wood ash produced in Canada is landfilled. This varies by province. Quebec has passed a law with a goal of zero landfilling or incineration of organic waste by 2020. Wood ash applications to appropriate sites would return nutrients to soil that were removed during forest harvesting, especially Ca, Mg, K, and P, thereby maintaining soil fertility and ensuring a sustainable supply of wood fibre.

In some of the most productive and highly valued forest areas in Eastern North America (~600K ha in Ontario, alone), for example, an outbreak of beech bark disease is killing mature beech trees; regenerating stands on these sites are often dominated by dense beech thickets, which result in stagnation of forest productivity. Formation of these thickets is particularly problematic on sites where acid rain has reduced soil pH and base cation status. A comprehensive economic and ecologic evaluation of silvicultural solutions to this issue is required. Moreover, this increased abundance of beech is a concern to the forest industry because beech logs produce wood of lower quality than other hardwood species (e.g., sugar maple, yellow birch). It is thought that acidification and nutrient loss has caused changes in tree species composition in favour of beech. Thus, soil applications of wood ash in combination with other treatments such as soil preparation and vegetation control may be a useful tool to
enhance soil pH, restore nutrient levels and promote the competitiveness of other hardwood species on these sites, ultimately sustaining short and long-term forest productivity and improving commercial value.

Social license is essential if the forest sector is to grow the bio-economy. In general, the public has a negative perception of increased utilization of “logging waste”. It will be easier for the public to accept intensive biomass removals if wood ash applications are used as a natural fertilizer to replace the nutrients removed during biomass harvesting.

There are two parts to our approach. The first one addresses the question, Can wood ash applications be used as an innovative silvicultural tool to sustain hardwood forest productivity in light of beech bark disease? Building on existing Beech Bark Disease Project (OMNRF) in Ontario (Porridge Lake) and long-term research trials at Station de recherche forestière de Valcartier in Quebec (Valcartier) we are establishing two new wood ash application experiments. Partners for this research include the Ontario Ministry of Natural Resources and Forestry, Westwind Forest Stewardship, Murray Brothers Lumber, and Resolute Forest Products.

The second part of the approach builds on a Canada wide network of wood ash trials called AshNet to address the questions, Do wood ash applications increase forest growth? What forest and soil types will most benefit from wood ash applications? What application rates are required to increase fibre supply? This is a CFS-led network with collaborators from UNBC, USask, UManitoba, Lakehead, Laurentian, UToronto, Trent, UQAT, TELUQ, OMNRF, Wood Pellet Assn Canada, Ontario Power Generation, Friends of Muskoka Watershed, and FP Innovations. AshNet includes trials in economically important forest regions of BC, Saskatchewan, Manitoba, Ontario and Quebec. These trials cover a range of ash application rates and were established between 1 and 21 years ago. The objective is to report on the effect of wood ash applications on the growth of Canadian forests using the most recent data compiled from AshNet research sites.

And now I would like to ask Jerome to provide more detail to the work that we are involved in!
Beech is a common hardwood species in northeastern America and a progressive expansion over sugar maple has been documented in the last decades. An increase in the abundance of beech in tolerant hardwood stands is often seen as a threat for the forest industry because beech logs rarely have the wood quality required for high value products such as peeling and sawing products. In the light of the beech bark disease, the beech problematic is also very much amplified.

The goal of this project is to assess the effect of mechanical treatment and amendments on the regeneration success of beech vs. sugar maple/yellow birch in thinned stands (in light conditions potentially more favorable for maple/birch). Assess the opportunity of biomass harvesting for bioenergy to initiate a strategy against beech encroachment in Valcartier hardwood forests.

The trial is located at the SRF-Valcartier, near Québec. We selected a stand showing evident signs of maple regeneration failure: ground cover with very little maple seedlings and high density of beech saplings. We established 12 plots in which we applied our different treatments. We have three soil amendment treatments (ash, lime, fertilizer addition), one control and one mechanical treatment applied or not in combination with other treatments. Why we are amending soils? Acid deposition and the consequential reduction in soil pH and calcium availability is one factor potentially responsible for reduced survival and growth of maple seedlings. Why exposing the mineral soil? It’s been documented that maple and birch would benefit from light soil disturbance, but not too much however to avoid beech root sprouting. The light scarification treatment consist in disturbing the surface soil layer, mixing the organic layer within the surface mineral soil and exposing it using a toothed disk mounted on a brushcutter (see pic). Why are we conducting this trial in a thinned stand? Maple and birch tend to be favored by canopy openings relative to beech and we want to see if additional treatments/soil preparation can effectively favor these species over beech. This is a newly established trial (on-going) so unfortunately no results to present today.
Measurements on seedlings (species, stocking, growth, morphology), Soil properties (pH, elemental concentration, etc.), Microbiome (microbial –bacteria and fungi- community structure using metagenomic tools (DNA metabarcoding).

Slide 31

Collaborators from CFS include David Paré, soil science, Sébastien, Fanny, Olivier, Serge of great help in the field and in the lab. Armand Séguin, forest genomics, and Christine Martineau, microbiome genomics. Bernard Ferland is our contact at RFP, who are providing the ash from their biomass boiler.

Thanks Guys!!

As we look at increasing woody biomass utilization in Canada, CWFC staff have been working with several partners to develop tools and options to help with identifying the availability of woody biomass in Canada and to optimize the woody biomass supply chain!

Slide 32

When we speak of woody biomass, we are talking about 3 types of biomass:

Opportunity Biomass: Mill wood waste, urban construction debris and roadside residues created by harvesting operations.

Purpose Grown Biomass: Afforestation and concentrated biomass.

Other Biomass Sources: Silviculture treatments such as thinnings, utility corridors, natural disturbance salvage, and FireSmart operations.

Slide 33

The first step in evaluating the woody biomass potential in Canada was to identify how much was available and where is it located. In partnership with Agriculture and Agri-Food Canada, we developed the Biomass Inventory Mapping and Analysis Tool (BIMAT). The online tool allows anyone to access sustainable inventory information for agriculture crop residues (AAFC) and woody biomass (CWFC).
The user-friendly interface for the user to identify the types of feedstock and the option to select the amount needed or a maximum haul radius for a specific location.

Slide 34

For this example, we are looking for woody biomass only, within a 100km maximum haul radius of Drayton Valley, AB. The reports generated show the amounts and types of woody biomass available spatially.

For anyone looking to do this themselves, I have included the website in the bottom right corner of the slide or you can just use your search engine of choice and enter BIMAT.

Slide 35 shows a summary of the amount of woody biomass available by type for roadside residues and mill wastes for mills with >100,000 cubic metres annual capacity and urban wood waste for centres with greater than 1000 people.

Slide 36

Moving to the next slide, you will see that we are also exploring alternative sources of wood fibre by expanding the forest through short rotation woody crops. With the goal of growth rates at 8 times that of natural forests, we have developed protocols for establishing and managing three types of afforestation plantations.

High yield afforestation plantations are grid-style. hybrid poplar or aspen, plantations established at 11-1600 stems per hectare. The design allows for a single, 16-20 year rotation with an average growth rate of 13-20 m³/ha/yr, producing large diameter stems that can be used for conventional forest products.

Concentrated biomass plantations are hedge-style, hybrid poplar and willow, plantations established at 13-16000 stems per hectare. This design allows for up to seven - 3 year rotations with an average growth rate of 6-10 oven dried tonnes/ha/yr, producing small diameter stems with a high bark to white wood ratio. This limits potential product options to products that allow for a high bark content such as mulch, animal bedding or feedstock for biomass boilers, industrial pellets or renewable natural gas production.

For longer term carbon sequestration options, we have developed the mixedwood afforestation option where tolerant softwoods are planted in high yield afforestation plantations following
crown closure. Depending on the management objectives for the site, the deciduous component can be harvested at year 20 or left on site to fall out through succession creating wild life habitat and eventually result in coarse woody debris in the residual conifer stand that will continue to grow on the site for 60-80 years.

Slide 37

Because there isn’t an infinite amount of $$$ available for investment in purpose grown plantations, we have developed an Afforestation Site Suitability model to identify the sites with a higher growth potential. Using bio-geo climatic information, we have been able to create a model that estimates growth potential of SRWC plantations for almost any location in Canada. In conjunction with our establishment and management protocols, this is an important tool to help adopters in understanding the potential of their investments.

Adding to this, we created a national network of afforestation sites, in collaboration with academia, provincial agencies and individual landowners that includes in excess of 135 sites that are used to validate our establishment and management protocols and the growth trajectories developed by the Site Suitability Model.

Slide 38

As we moved along in our operational research path, and coincidently, as our operational research sites grew older, we transitioned from developing establishment and management protocols to developing and evaluating various harvesting, collection and transportation options with the focus on mid supply chain optimization. Knowing that everything comes down to delivered biomass costs, we conducted operational evaluations across Canada of many options for each phase of the supply chain. An example of one of these operational evaluations included biomass harvesting and baling operations in the Ottawa area, transporting the bales to Timmins, for processing to create large biomass briquettes approximately 10cm in diameter and 40cm in length, and to the Kingston area to create industrial wood pellets.

Moving to Slide 39, you can see that we have incorporated innovative sources, such as utilizing woody biomass from FireSmart and Mountain Pine Beetle Rehabilitation operations using conventional and innovative harvesting options that are suitable for afforestation and natural
forests, such as the Anderson Bio-Baler, Fecon Bio-Harvester and the Gyro-Trac BBS. We have incorporated various processing and trucking options as well.

One thing to keep in mind is that regardless of the type of feedstock you are dealing with, the goal is to deliver the feedstock with physical characteristics that are suitable to the end user’s production facility for the cheapest cost/tonne!

As we heard earlier in Suzanne’s and Sally’s work, we are continuing to evaluate biomass storage options and uses for biomass stored in conventional piles. One new option that we have identified through our work is the potential to reduce transportation costs and long-term storage decomposition using compacted baling technology. Slide 40 shows the results of a 2-year study that we have conducted in the development of the compressed baling system that packages woody biomass into compressed round bales ranging from 650-1200kg per bale depending on pre-packaging moisture content. The compressed baling system was developed initially to create larger payloads to reduce transportation costs.

Through continued research on the baled biomass, it was determined that in the baled medium, the woody biomass could be stored long term, more than 20 months without decomposition, while reducing moisture content and improving the physical characteristics of the biomass over time.

Moving on to Slide 41, you can see that CWFC and the CFS researchers have been working together to develop options for the use of short rotation woody crops for bioremediation purposes. The work being led by Richard Krygier and Martin Blank of the CWFC have led to increased user uptake by industry for utilizing municipal bio-solids and wastewater in addition to remediation of sites impacted from oilsands development.

Slide 42

An example of bringing research to life is the work that we have been conducting on industrial sites such as the revegetation of phospho-gypsum stacks in collaboration with Nutrien (previously Agrium) and the University of Alberta. Nutrien came to us with the objectives of:
1) improving the long-term sustainability, ecosystem diversity, and aesthetic values while reducing long term maintenance costs of the site,
2) provide biomass that could be used for energy production and sequestering carbon, and
3) utilize excess nutrients/water resulting in improved groundwater quality.

Taking advantage of years of short rotation woody crop research, we incorporated all 3 SRWC regimes by;

1) establishing concentrated biomass beds of willow and hybrid poplar on reclaimed storage pond site,
2) establishing high yield afforestation plantations of hybrid poplar on re-engineered phosphor-gypsum stacks, and
3) establishing tolerant conifer (white spruce) in high yield afforestation plantations once sites close canopy.

As we move to Slide 43, I would like to ask Frederic to show how his work at the Universite de Montreal is building on this work.

Slide 43

Hello everyone. I am happy to present to work we are doing to combine biomass production and land rejuvenation. Thanks Tim, indeed our project is in line with the project you just presented.

For several years, we have done studies to increase the productivity of concentrated biomass system using fast-growing willows. In parallel, we have done a lot of project using willows for phytoremediation. Lately, we have decided to combine the two.

I am presenting pictures from 2 experiments in the Montreal area: the first is a former landfill and the 2nd at St-Roch-de-l’Achigan with the company Agroénergie. We also have a great collaboration with the CFWV-NRCan group of Richard Krygier where we are investigating the effect of wastewater on willow wood properties -unfortunately the results are not completed yet.

This is a stem section of 3 year old coppiced willows because understand its properties is at the heart of what we do -our project is to optimized the value stream from this harvested (commercially) biomass.
This is a schematic of the general strategy in my research group, and also and newly funded NSERC Strategic Project Grant (Pitre, Labrecque and Barnabe) and where Richard Krygier is a collaborator. We wish to demonstrate that using willow for bioremediation purposes (cleaning soil and water), and using the biomass for bioenergy and bioproducts, is the key to make this value chain highly profitable.

Our willow biomass is harvested from two main sources, a mature wastewater treatment experiment in the vicinity of Edmonton in Alberta and managed by Richard Krygier and Martin Blank. The others are in Montreal, with willows harvested from contaminated land and just North of the city in Saint-Roch-de-l’Achigan where Agroenergie manages a wastewater experiment.

Of particular interest are phenolic compounds because they have high commercial value as they are being used in medical, nutraceutical, cosmetic and industrial purposes.

Why? It is an educated guess, we know that willows have exceptionally high levels of phenolics. Willow bark has been used in traditional medicine to extract salicylic acid, the active compound of aspirin. So, we suspect that phenolic metabolism in willows is quite active.

This is our working research hypothesis: in response to environmental stressors from the bioremediation process, willows will produce more phytochemicals and these will be beneficial to the conversion processes by reducing inhibitors.

I begin with an example of how, the growing conditions are sufficient to modify wood properties.
This figure presents stem sections of the same willow genotype, of the same age and harvested at the same time, the only difference is the location. Using a stain specific to cellulose we highlighted that the trees from St-Roch (left panels) produce more cellulose in their fibers, significantly more than at the other site (La Pocatière).

Slide 49

This site-specific response was also observed with phytochemical production. We took advantage of a long-term trial that we are maintaining across Quebec, where identical plantations we set-up at four sites with five cultivars of willows. We surveyed several phenolic compounds and I selected here two phenolics: condensed tannins and flavonols.

On the left, I show that for SX67 more than double the amount of tannins were extracted at St-Roch than on any other site. On the right, La Pocatière was the site where we obtained the higher amounts of flavonols.

Slide 50

I use this last slide, to show that both genotype and environment can affect the conversion of biomass for bioethanol production.

First, on the left, we studied the amount of glucose that could be extracted using enzymatic saccharification using 35 European willow genotypes. The all had the same age and were treated the same way. I use this figure to show that the genotypic difference is great and that between the worst and the best, a threefold difference was obtained in the theoretical bioethanol yields. Not all feedstocks are equal.

On the right, the figure shows glucose extracted from three willow genotypes grown in pots or in the field, and mechanically stressed or not. When stressed the willow trees produced significantly more extractable glucose that not-stressed, supporting our research hypothesis.

Thank you for your attention!
Moving forward, we believe that the CWFC has developed a comprehensive package of collaborative operational research to assist end users with research and technology development to position themselves into a thriving bio-economy!

Combining biomass inventory information with operational harvesting and processing research and supply chain optimization enables end users to evaluate a wide range of potential bio-economy options!

Developing establishment and management protocols for Short Rotation Woody Crops for afforestation and bio-remediation and carbon sequestration opportunities provides end users with multiple revenue streams!

Utilizing wood ash could improve soil fertility and forest health, divert materials from landfills and close a loop in the cycling of nutrients making forestry operations and the development of Canada’s bio-economy more sustainable.

Incorporating storage options and real-time pile monitoring methods gives precision data on pile dynamics, leading to development of much better management techniques to minimize loss in biomass quality and quantity

Enhanced physical and chemical biomass characterization can be used to assist in the development and production of commercially viable bio-products.

Thank You!