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RESEARCH AT THE LAURENTIAN FORESTRY CENTRE OF NATURAL RESOURCES CANADA

Forest Biomass

Canada

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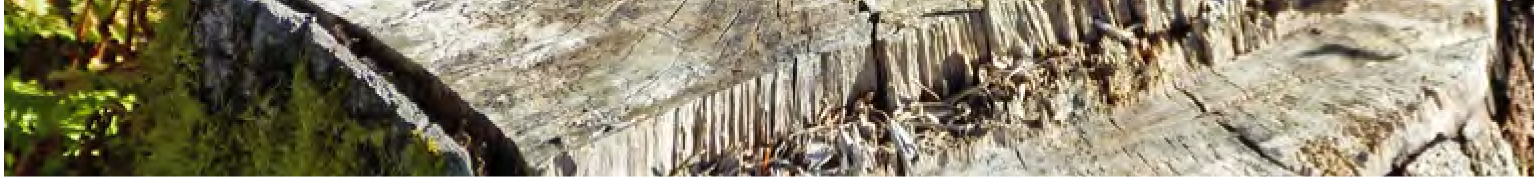


Forest Biomass

FROM BIOMASS TO BIOECONOMY

Over the past few years, the interest in forest biomass has grown quickly. This organic matter, of which there is an abundant supply in Canada's forests, is the basic material for bioenergy, biofuels and other bioproducts that could help reduce our dependence on fossil fuels. The use of forest biomass therefore is a key component of the burgeoning global bioeconomy.

To help governments implement their strategies for increased use of forest biomass, researchers at the Laurentian Forestry Centre of the Canadian Forest Service (CFS–LFC) are conducting research activities that include a range of biomass-related topics such as quantification, characterization, mapping and sustainable development.

"Through partnerships with experts from the government, university and industry communities, the CFS–LFC has built a solid multidisciplinary research program that covers the entire value chain."

– Vincent Roy, Research Director, Forest Ecosystems

In theory, the term "forest biomass" refers to any organic matter derived from trees and plants, including tree trunks, branches, bark, needles, leaves, crowns, stumps and roots. However, in practice, forest biomass refers to trees or parts of trees that are not used by the traditional wood processing industries (sawing, veneering, pulp and paper). In other words, the term refers to the residual biomass resulting from forest harvesting operations.

WHY IS THERE AN INCREASED INTEREST IN FOREST BIOMASS?

In the early 1970s, the oil crisis and soaring prices for fossil fuels spurred a search for renewable energy resources. Unused forest residue quickly became an interesting alternative.

Since then, some of the reasons for the increased interest in forest biomass have been the rising global demand for energy, dwindling oil supplies, the soaring costs of existing energy supplies, climate change and the downturn in the forest industry. Long considered simply as forest and industrial residue, forest biomass has now become appealing for economic and ecological reasons.

The harvesting and sale of forest biomass and bioproducts could become a new source of income for the forest industry, which seeks to diversify its markets. In addition, the use of forest biomass to produce energy could promote a reduction in greenhouse gas emissions.

A renewable energy source

In Canada, the pulp and paper industry is already using forest biomass in the form of industrial residue to meet about 62% of its energy requirements. This biomass is primarily used as fuel for industrial boilers and co-generation plants that produce electricity and heat.

Bioenergy production helps to diversify the uses made of forest products, reduce energy costs and increase the willingness of the forest sector to reduce greenhouse gas emissions.

Biomass is considered to be a sustainable and renewable energy resource and an interesting alternative to fossil fuels. Together with geothermal and solar energy, forest biomass accounts for 7% of Canada's total energy consumption in the residential, commercial and industrial sectors.

Heating with forest biomass

Several projects involving the setting up of small heating plants supplied with forest biomass have recently been undertaken in Quebec because the technology for converting biomass into heat is simple and highly efficient. For example, the fuel used to heat the Amqui and Mont-Joli hospitals (Lower St. Lawrence region, Quebec) is wood chips mostly obtained from harvesting residue. These types of initiatives promote reductions in greenhouse gas emissions and create local jobs. They are good examples of enhanced uses for forest biomass.

A source of bioproducts

Biomass can be processed into various bioproducts, including:

- solid fuel products, such as green firelogs as well as wood pellets and chips for home furnaces and institutional heating plants;
- biofuels, such as cellulosic ethanol;
- industrial chemical bioproducts, including lignin by-products used to replace part or all of the petroleum-based glues used to manufacture glued-laminated wood products;
- pharmaceutical and personal hygiene products;
- textiles.

Where does forest biomass come from?

In Canada, the supply of residual forest biomass for the bioeconomy comes primarily from four sources.

1- **Primary** biomass	Traditional forest management by-products: • Commercial cutting residue (crowns, branches or noncommercial trees) • Trees and branches left behind during stand thinning, brush cutting or pruning • Trees affected by natural disturbances (fire, insect outbreaks and windthrow)
2- **Secondary** biomass	Industrial process by-products: • Bark • Sawdust • Wood shavings • Wood chips • Spent pulping liquor (cooking liquor resulting from the pulp and paper-making process)
3- **Tertiary** biomass	Construction and renovation project residue Demolition operation residue
4- **Quaternary** biomass	Trees produced in short-rotation plantations (intensive silviculture)

AN ABUNDANT AND AVAILABLE RESOURCE

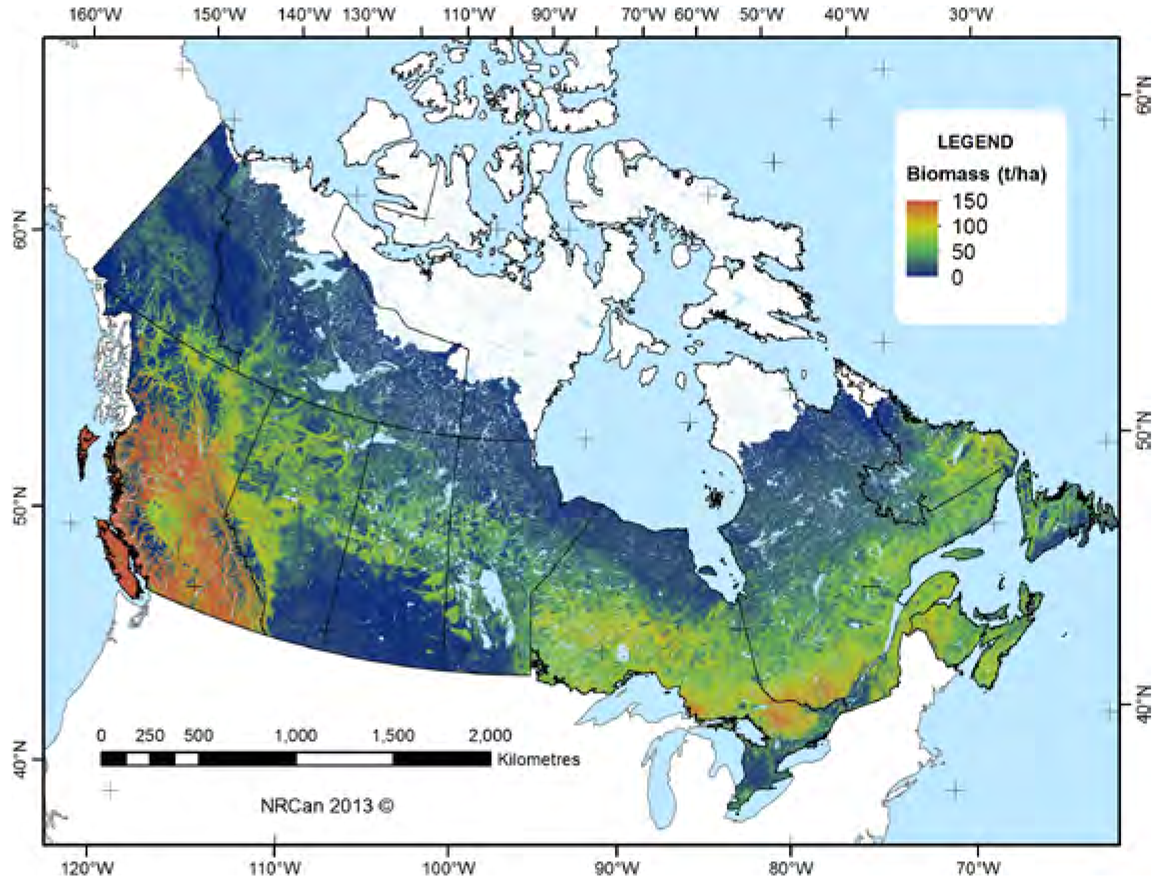
Given that Canada is home to 10% of the world's forests and has great forest biomass production potential, how much forest biomass is available to develop a bioenergy industry? And where can it be found?

In Canada, the amount of secondary biomass in factories is fairly easy to estimate. These available quantities already supply several plants manufacturing wood pellets intended mainly for export. However, in some regions (particularly in Eastern Canada), secondary biomass is used almost entirely to manufacture forest products, such as pulp and paper and particle boards, or to produce energy for use in the factories themselves. The development of the bioeconomy in the years to come will therefore depend partly on supplies of biomass obtained directly from forests. However, it is a fairly complex task to estimate the quantity of biomass that can be obtained from this source.

To address this concern, CFS–LFC researchers have developed tools to estimate volumes of biomass per tree component (trunk, branch, bark and foliage) and per species at the tree and stand levels. This information is then used to determine stand potential for the production of traditional and nontraditional forest products, including biomass for energy purposes. These calculation tools, which include nutrient concentration databases, can be used to draw up carbon and nutrient budgets based on various harvesting methods, which can then be used to assess the environmental sustainability of biomass harvesting practices. These tools, which are valid for the dominant species in Canadian forests, are available online (https://apps-scf-cfs.rncan.gc.ca/calc/en/calculateur-calculator).

Biomass mapping

A team of CFS–LFC researchers is working on including these biomass data in a new series of national maps of forest attributes. These maps provide information on several forest attributes, including the composition, height and age of stands, and provide very good estimates of the quantities of biomass available in a given area. The 2001 base map has an average resolution of 6.25 ha (250 m x 250 m pixels) that can meet strategic analysis requirements at the regional and national levels. The researchers are using sample data from the National Forest Inventory that cover 1% of the country's territory and are developing methods for spatial extrapolation from remote sensing imagery (MODIS 250) to cover the remaining 99%. This map is being updated for 2011 using LANDSAT images. Upon completion, it will have a finer resolution of 0.09 ha (30 m x 30 m pixels) that will increase the mapping accuracy of available biomass at stand level.



CFS–LFC researchers are also developing annual forest biomass monitoring methods that include, among other techniques, satellite monitoring.

"Our maps make it possible to do much more than simply compile a forest biomass inventory. We assess their use in order to test harvesting methods and measure the contribution of this organic material to the forest value chain."

– André Beaudoin, research scientist

Planting of biomass

There has been considerable progress made in the field of short-rotation intensive culture, a relatively recent form of silviculture, in North America and Europe over the past 20 years. It consists of high-density plantations that are harvested in cycles ranging from 3 to 25 years and that produce a high density of post-cutting stump residue. Fast-growing species, such as willow and hybrid poplar, are preferred in order to produce large amounts of biomass over a short period.

Research projects are underway at the CFS–LFC in order to expand our knowledge of short-rotation crops used for energy production purposes. In particular, researchers are assessing how to optimize the spacing between trees in order to increase the amount of biomass produced per hectare. They are also studying the impact of plantation composition on biomass yield.

Fire!

Dead wood that is not recovered following natural disturbances is another major potential source of forest biomass in Canada. A few years after forest fires and insect outbreaks occur in a given area, dead trees often cannot be used for any purpose because of their overly poor quality for the production of traditional wood products.

CFS–LFC researchers are using chronological maps of salvage logging and post-natural-disturbance follow-up activities in order to quantify the biomass available after a fire. However, the unforeseeable nature of forest fires and insect outbreaks makes it difficult to measure the potential for disturbance-generated biomass. In addition, there are challenges with harvesting this biomass, such as the need to build road networks to gain access to the resource.

Lastly, burnt wood has an important ecological function in forests in that it becomes a habitat and food source for insects. What will be the impact of harvesting dead trees on sites affected by fire, windthrow and insect outbreaks? CFS–LFC researchers and industry stakeholders are working in partnership to study these aspects in order to provide a scientific basis for the guidelines that managers will establish as a framework for the sustainable harvesting of disturbance-generated biomass.

"The use of disturbance-generated wood as a source of biomass for bioenergy production could become one of the pillars of Canada's bioeconomy. In British Columbia, a wood pellet manufacturing industry has sprung up because of the supply of trees infested by the mountain pine beetle, an insect pest ravaging Western Canada's pine forests."

– Evelyne Thiffault, research scientist

SUSTAINABLE HARVESTING

As soon as it became clear that forest biomass was a viable alternative to fossil fuels, the scientific community was asked to evaluate the potential impact of forest biomass harvesting. In 1978, CFS-LFC researchers participated in the Energy from the Forest (ENFOR) program in order to develop tools for determining acceptable and sustainable levels for the extraction of organic matter and nutrients. In the past few years, they have established permanent experimental protocols for monitoring the environmental effects of forest biomass harvesting.

In collaboration with European researchers, particularly in Germany and the Netherlands, CFS-LFC scientists carried out an in-depth analysis of knowledge and knowledge gaps related to the environmental risks of biomass extraction for energy purposes from boreal and temperate forests. The study focused on three types of harvested biomass: cutting residue, wood salvaged after natural disturbances, and roundwood. They demonstrated that the use of forest biomass for energy purposes is not generally an issue.

In Quebec, university and government researchers are gathering scientific data to be used in the drafting of guidelines adapted to a variety of conditions in Canadian forests. Effective, credible indicators are being developed to ensure that biomass is harvested sustainably and to help Canada export solid biomass and liquid biofuels to international markets.

"Forest biomass should be harvested in such a way that forest biodiversity and productivity are maintained and forest soil and water quality are preserved."

– Pierre Bernier, research scientist

...to preserve soil productivity

Because biomass acts as a fertilizer in forests by providing organic matter and essential nutrients for plant growth, research projects aim to predict the effects of biomass harvesting on site productivity, particularly through the use of experimental forest monitoring protocols and of nutrient budgets.

Researchers at the CFS–LFC, the Université du Québec à Montréal and the Université du Québec en Abitibi–Témiscamingue have developed a model for annually assessing the effects of a negative nutrient balance resulting from a decrease in biomass, depending on the harvesting method used, for the five main tree species in boreal forests. According to this study, whole-tree harvesting causes a greater nutrient loss than stem-only harvesting, but the magnitude of the loss varies considerably depending on the species.

It has been shown in other CFS–LFC studies that sites deficient in organic matter and minerals are extremely sensitive to biomass extraction and the risk of productivity loss. This is particularly true of jack pine stands on sandy, dry soil. The researchers found that it was necessary to adapt biomass harvesting to site fertility. For example, using soil texture as a sensitivity indicator is a viable, easy-to-use option.

"It has been demonstrated that controlled biomass harvesting generally has little impact on the soil of most sites."

– David Paré, research scientist

...to maintain biodiversity

Mould, arthropods (including insects) and bacteria are present in forest floor litter. These tiny soil dwellers are highly beneficial to the ecosystem in that they degrade organic matter and ensure the circulation of nutrients.

When forest biomass is removed, these organisms are deprived of a potential source of food and shelter. In the long term, the numbers of some species may decline, including those responsible for recycling nutrients. Consequently, tree growth could suffer if fewer nutrients are available in the forest floor litter.

How much biomass can we harvest without disturbing forest biodiversity? To answer that question, CFS–LFC researchers are studying some species of beetles that are known to be good indicators of forest disturbances because of their sensitivity to changes in soil composition and structure. The goal of a research project under way in the Forêt Montmorency is to analyze forest biodiversity over several years, depending on the site and the biomass harvesting method used. The research team is working with ecologists, taxonomists, statisticians, soil specialists and molecular biologists to identify the best indicator species for various biodiversity levels.

"It is important to conduct long-term studies in various types of ecosystems in order to accurately identify the effects of biomass harvesting on the biodiversity of forest floor litter fauna."

– Jan Klimaszewski, research scientist

CARBON DEBT?

Is a bioenergy project based on forest biomass necessarily carbon neutral? At equal efficiency and per unit of energy produced, CO_2 emissions are higher for forest biomass than for fossil fuels. In fact, organic matter contains less energy per unit of carbon than petroleum products and natural gas.

However, compared with fossil fuels, biomass can "pay back" greenhouse gas emissions when it is harvested from sustainably managed forests. The trees grow back and resume their carbon sequestration role. Moreover, if not used, cutting residue and industrial waste end up decomposing naturally and emitting CO_2.

Once the CO_2 debt is paid off, the benefit for the atmosphere increases from year to year. The challenge is to know when the benefits will occur and to what extent. To answer this question, CFS–LFC researchers have analyzed the data obtained from a Canadian network of towers that continually measure CO_2 exchanges between forest ecosystems and the atmosphere. They estimated the payback time for surplus emissions according to the biomass source. The payback time will be relatively short for fast-growing forests where trees quickly resume their carbon sequestration role or if the bioenergy is produced from cutting residue.

Carbon debt payback time per biomass source

Less than 10 years: Post-consumption residue, industrial waste, cutting residue that decompose quickly and biomass produced in short-rotation plantations
Between 10 and 20 years: Wood salvaged after natural disturbances, stumps and large-diameter stems from noncommercial species left behind on cutting sites
Several decades: Standing green trees

CFS–LFC researchers are carrying out other projects to obtain a better understanding of the carbon debt repayment process. The ultimate objective is to determine the best way to use biomass as a renewable energy source to generate maximum benefits for the environment.

AN INDUSTRY TO BE DEVELOPED

The scientific community has been accumulating knowledge on forest biomass and forest biomass harvesting for several years. However, several issues remain to be dealt with to ensure the sustainability of the bioeconomy, provide a scientific basis for promoting the eco-friendly reputation of biomass, and provide access to markets for forest biomass. These issues include the following:

- Obtaining access to various biomass supply sources is vitally important for the expansion of bioenergy projects and the promotion of energy independence in the regions.
- Researchers must develop scientific biomass harvesting indicators and study the effects of biomass harvesting over 5-, 10- and 15-years periods.
- Technologies for the enhanced use of biomass still need to be developed.
- The biomass supply chain requires a new network of partners and a new mentality in order to make use of what was considered a waste product until recently.
- For sustainable environmental certification purposes, ecological research must include social organization and governance aspects as well as an energy conversion technical component.

"Biomass research should combine the scientific activities of researchers in several specialized fields."

– Louis De Grandpré, research scientist