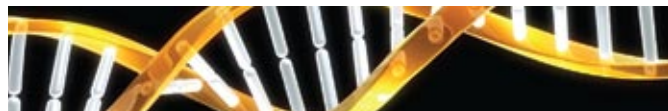


GENOMICS SPRUCING UP OUR FORESTS AND GROWING HUGE BENEFITS!

1. FOREST GENOMICS—USHERING IN A NEW ERA OF PROGRESS FOR THE CANADIAN FOREST INDUSTRY



Genomics has launched a technological revolution in a wide range of sectors. In forestry, for example, it is providing tangible solutions for current issues affecting the Canadian forest industry. These include:

- The growing demand for forestry products, but declining resource availability; the productivity of trees planted must be increased (more wood in less time).
- Growing social pressure to increase protected areas; harvested forest land area must be reduced.
- Industrial competitiveness that creates a need for value-added products based on higher yield trees (more wood, bigger and better quality).
- New environmental conditions brought about by climate change; more trees that are better adapted to climate change requirements.

Forest genomics provides answers to these problems by encouraging the reforestation of wooded areas with fast-growing, high-yield species that deliver superior wood quality and show better adaptation to the new environmental conditions. This result is achieved through new tree breeding techniques that are faster and less costly than traditional methods. Genetic improvement, used in Québec and Canada for more than 40 years now, helps to increase tree productivity by creating new, higher performance varieties through species selection and genetic crossing (classic hybridization), without recourse to GMOs.



The black spruce, white spruce, jack pine and Norway spruce are the species most often used in genetic improvement programs. Spruce has major commercial value, supplying the lumber and pulp and paper industries with quality fibre. In Québec, 72 percent of the 115 million trees planted

every year are spruce, while in Canada, they represent 61 percent of the 622 million seedlings reforested annually (National Forestry Database 1990-2008, Canadian Council of Forest Ministers, Government of Canada: <http://nfdp.ccfm.org>).

As **figure 1** shows, traditional breeding methods are much slower than genomics when it comes to selecting the best trees for reforestation. Genomics, on the other hand, uses cutting-edge diagnostic tools (DNA biochips) that lead to more rapid and accurate identification of desirable traits in species used for reforestation.

2. SOCIO-ECONOMIC AND ENVIRONMENTAL BENEFITS OF FOREST GENOMICS

2.1. FOREST GENOMICS—THE ANSWER TO SUSTAINABILITY AND COMPETITIVENESS IN CANADA'S FOREST INDUSTRY

The forest industry has long been at the forefront of the Canadian economy. It creates more than 375,000 direct jobs and generates annual revenue of over \$82 billion. In Québec alone, it generates 150,000 direct jobs and \$12 billion in annual revenue. This industry, which is currently in crisis, must ensure its sustainability and survival in a highly competitive environment. A country like Brazil, for example, where it takes a mere 7 to 10 years for a eucalyptus tree to grow, has its eyes on markets currently serviced by Canada's spruce forests where 60 to 80 years are required to reach maturity.



In the short term (3 to 5 years), forest genomics allows intensive, high-yield, efficient reforestation. In the medium term (5 to 10 years), it has the potential to increase forest regeneration (silviculture) and forest resource availability in Québec and in Canada. Finally, over the longer term (10 to 20 years), forest genomics will help supply the industry with top-performing raw materials, in terms of both quality and quantity. These multiple benefits will mean improved profitability and added value for Canadian forest manufacturers, giving them a competitive edge. In addition to attracting private and public investments and qualified workers, the advances made as a result of forest genomics will also serve to increase significantly Québec's and Canada's visibility.

TRADITIONAL METHOD: 15-20 years

Selection of top performing trees—at maturity stage—based on desirable physical traits (**Phenotype**) passed down to descendants

SELECTION TOOL: PROGENY TESTING

GENOMICS METHOD: 1-2 years

Selection of top performing trees—at the seedling stage—based on genes (**Genotype**) determining the desirable physical traits

SELECTION TOOL: DNA BIOCHIPS

Figure 1. Comparison of time required to select top performing trees using the traditional breeding method vs. the genomics method. Recourse to genomics tools (DNA biochips) allows the selection of trees—as early as the seedling stage—that boast a wood quality, rate of growth and adaptation for optimal reforestation. With this method, selection is more rapid and less costly.



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2.2. FOREST GENOMICS—SUPPORTING THE SUSTAINABLE DEVELOPMENT OF FORESTS



As for sustainable development, groups like the Québec Intensive Silviculture Network (RLQ), which promotes, at a regional level, the concept of intensive tree farming, rely heavily on the contribution of forest genomics as a way of regenerating our forests.

The genomics-based selection of trees with increased adaptability to the new environmental conditions (climate, soil) also holds major potential for addressing the impact of climate change. A species' ability to adapt to given climate conditions can, in fact, be optimized through genomics. For instance, certain species are better at absorbing CO₂, a genetic trait on which we can capitalize thanks to genomics. Given the boreal forest's carbon sequestration capacity—up to 175 metric tons of carbon per hectare compared to about 30 tons for corn—accelerating the rate of reforestation may just well represent one of the solutions to mitigate the impact of global warming. Finally, forests also clearly hold greater promise for conversion into bio-fuels when compared to corn.

3. ARBOREA, AN INNOVATIVE GÉNOME QUÉBEC-FUNDED FOREST GENOMICS PROJECT MAKING CANADA A LEADER IN THE FIELD



The Arborea project is a good example of a success story in forest genomics. Spearheaded by two Laval University researchers, John MacKay and Jean Bousquet, this major genomics project on white spruce is funded by Génome Québec, Genome Canada, public partners (Québec Ministry of Natural Resources and Wildlife) and private investors (FPInnovations). It brings together 60 researchers from more than six universities and research centres in Canada and abroad and has attracted to Québec \$23 million in investments.

Since its inception, Arborea, in collaboration with researchers from British Columbia, has sequenced more than 25,000 of the white spruce's 30,000 genes. Of this number, some 20 to 30 genes are involved in growth and 5 to 10 in wood density. The identification of genetic biomarkers linked to variations in these desirable traits for reforestation (growth, density and adaptability) have led to the development of DNA biochips that will be used for the timely identification of top performing trees. In addition, one Arborea researcher, Nancy Gélinas, has evaluated the economic benefits and feasibility of using these tools by assessing the productivity gains resulting from traditional breeding methods compared

FOR MORE INFORMATION ON THE ARBOREA PROJECT:

Visit the Arborea Website: www.arborea.ca

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to the genomics approach, the market value of white spruce based on its diameter and the related ecological benefits from carbon sequestration and the optimization of biodiversity.

The assessment of the productivity gains (shown in **table 1**) indicated that genomics reduces the time needed for white spruce plantations to reach their maximum output and increases economic benefits (in dollars per hectare) compared to the traditional approach.

Table 1: Yield of a white spruce plantation on top quality soil having undergone silviculture treatments: comparing various breeding approaches

	Age at which maximum output of a plantation is reached	Present value ¹ of benefits (in dollars per hectare)
Non-improved trees	38 years	\$471.00/ha
Improved trees: traditional approach ²	35 years	\$600.00/ha
Improved trees: genomics approach ²	33 years	\$712.00/ha

¹Present value at a rate of 7%. ²Based on a plantation scenario of a 10% increase in wood volume. Source: Petrinovic J, Gélinas N and Beaulieu J. 2009 Benefits of using genetically improved white spruce in Québec: The forest landowner's viewpoint. *Forestry Chronicle* 85(4): 538-547.

Finally, Arborea has evaluated the perception of the public and of professionals interested in the application of genomics to forestry. This assessment is critical. If the general public and interested parties (researchers, forest industry, decision makers, silviculturists and environmental groups, etc.) are not on board with the application of genomics to forestry, our research and investment efforts are all in vain. This information is also useful for determining the best way to communicate this knowledge to the various stakeholders, thus increasing their support for genomics applications in forestry (Nancy Gélinas, 2009).