CFS CANADIAN FOREST SERVICE

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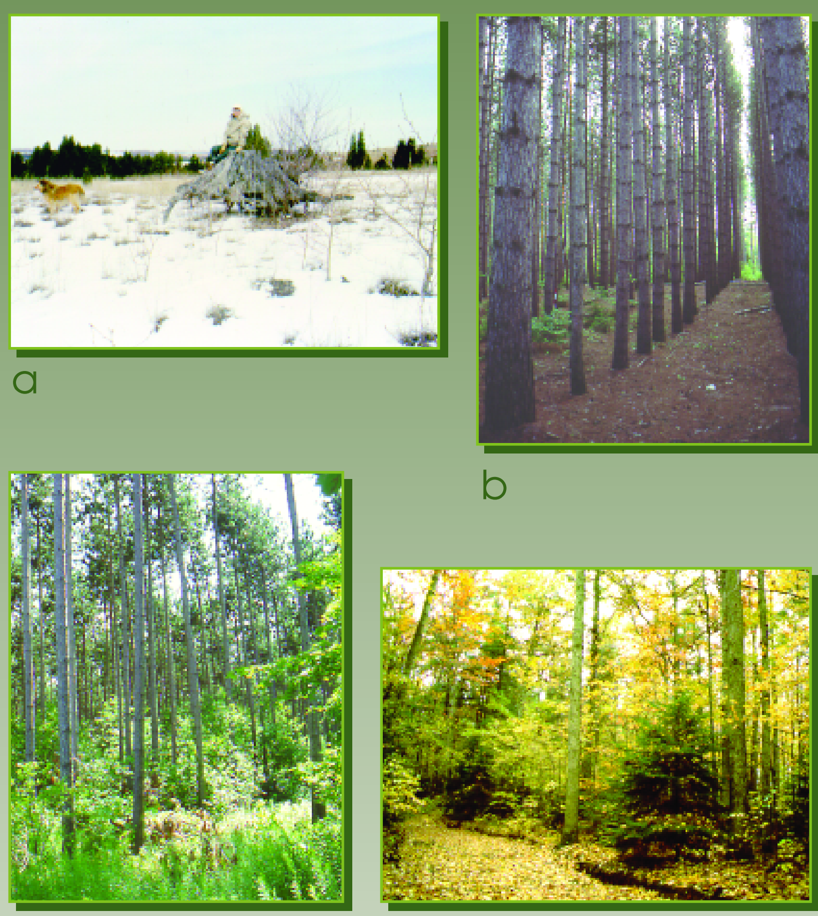
Recovery of Native Biodiversity under Forest Plantations

The role of planted forests (e.g., native species adapted to the forest regions of interest) and forest plantations (e.g., usually monocultures, often using exotic tree species) in biodiversity conservation is a controversial issue. There is no single or simple answer to the question: Are forest plantations good or bad for maintaining biodiversity? In general, people perceive aesthetic advantages to natural forests, and view plantations in a negative light. Rows of tall, straight trees with very little structural and compositional diversity are often neither aesthetically pleasing, interesting, nor are they particularly rich in biodiversity. Clearly, if mature forests composed of rare, late-successional species mixtures are replaced by single-species conifer plantations, forest biodiversity will experience a serious, although not necessarily permanent, setback. However, there are also many examples where planted forests and plantations can benefit biodiversity conservation by connecting natural forest patches on the landscape; thereby facilitating dispersal and gene flow among smaller, isolated populations that might otherwise not survive in a highly fragmented landscape. Plantations can serve as nurse crops, allowing shade-adapted, late-successional species to develop. They can also protect riparian habitats, restore the ecology of degraded sites, and improve the quality of water, air, and soil.

Extensive areas of eastern Canada – once dominated by biologically rich, late-successional, temperate-zone, mixedwood and hardwood forests were cleared for agriculture during the period of European settlement from 1700 to 1900. Some of the resulting desertification can still be seen today. Figure a shows an old eastern white pine (*Pinus strobus*) stump with its root system exposed after severe wind erosion following deforestation. Such erosion has occurred over large areas of



Natural succession from bare land (a) to pine plantations (b and c) succeeded by pre-settlement, late-successional forest types (d).

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On the Track of the Past of Our Conifers

During the Pleistocene, North America was subjected to several glaciations. The last one reached its maximum about 18 000 years ago and the ice sheet covered almost all the Canadian territory. Hence, most species were confined to areas south of the ice front. From these locations, they have spread northwards to build up a set of populations that together now form their natural range. Historical biogeography attempts to unravel the spatio-temporal dynamics of natural populations. Inferences about the past were traditionally made from the analysis of the fossil record. Since the last decades, phylogeography, an extension of biogeography science, takes also into account the geographic distribution of genetic variation to establish the species past history.

Molecular markers, especially cytoplasmic (mitochondrial and chloroplastic) markers, are powerful phylogeographical tools for testing hypotheses about the existence of more or less isolated glacial refugia and of postglacial colonization routes. Extant populations derived from genetically distinct refugia are likely to conserve a genetic imprint after postglacial expansion. By comparing imprints from diverse species, one can infer the number of different glacial refugia and the postglacial colonization history.

In *Pinaceae* (most conifers), mitochondrial DNA is maternally inherited and dispersed through seeds exclusively, whereas nuclear and chloroplast DNAs are dispersed through both seeds and pollen. It follows that gene flow should be reduced for mitochondrial DNA markers and the imprints of ancient genetic structures established at the time of glacial periods should still be visible in the modern structures.

Over the last two years, we carried out phylogeographical studies of a few major boreal forest tree species using polymorphic mitochondrial DNA markers that were developed in our laboratories. The mitochondrial genome is the least polymorphic among the three genomes present in plants and this feature is a major obstacle to identify markers showing variation within species. But our intensive genome sampling efforts were rewarded by the discovery of highly informative markers.

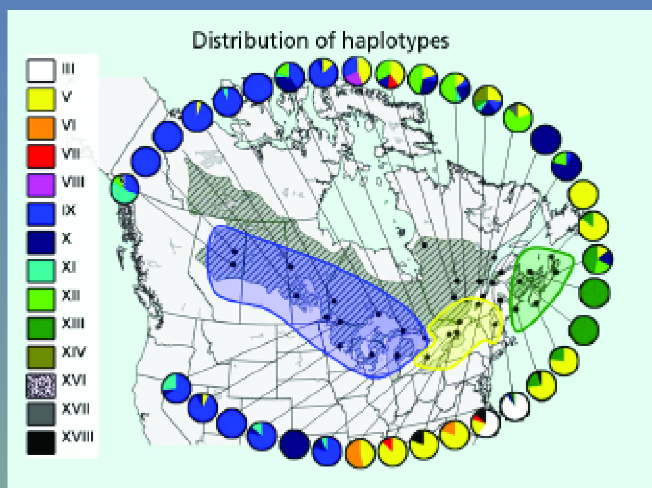

Fig. 1. Geographical distribution of mitochondrial DNA mitotypes in jack pine populations and groups of populations presumably originating from distinct glacial populations.

Fig. 2. Glacial populations (circles) and postglacial colonization routes inferred for jack pine from fossils and mitochondrial DNA data.

By examining the modern population structure of jack pine (***Pinus banksiana***) mitochondrial DNA diversity along its natural range (Fig. 1), we could delineate three relatively homogeneous groups of populations presumably representative of genetically distinct glacial populations. The first one (dominated by the blue mitotypes) covers the region extending from Lake Huron to the Yukon. The second one (dominated by the yellow mitotype and its close allies) is located in the southeast and mainly gather populations located in eastern Ontario and south of the St. Lawrence River in Québec. The third group (dominated by green mitotypes) is located in the Maritimes. A last distinct group could also be observed in central Quebec (north of the St. Lawrence River), which harbours a higher level of genetic diversity within populations and a lower degree of population differentiation than other groups. Such pattern indicates that this region is a zone of contact between the migration fronts of the three ancestral populations colonizing the three other zones.

The available fossil record and the strong population structure high-lighted by our study made it possible to put forward hypotheses regarding the number and the location of populations and refugia for jack pine during the last glacial maximum (Fig. 2). Because of the startling differences between western and southeastern populations, one hypothesis is that there was a glacial population located west of

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Technology Transfer and Forest Health, Getting the Research Out There

Natural Resources Canada's Canadian Forest Service (CFS) has been active in forest health and biodiversity research since 1899. What makes CFS remarkable as a research organization is its ability to get the data and the knowledge generated by the research out to forest management practitioners. Many organizations do great research that helps answer questions about our forested ecosystem, but what matters is getting the research transferred in a timely manner to those who need the information, the technology, and the tools that are developed through application of the research.

A broad view of technology transfer is taken within the CFS. In the university and business communities, technology transfer refers primarily to protection of a technology and its subsequent transfer through licensing. At CFS, our technology transfer may be better referred to as knowledge transfer: getting the information off the lab bench and out of the scientific paper into the field. This can be accomplished through various mechanisms, including seminars, workshops, field tours, technology and information notes, articles in the industry press, and traditional protection and licensing. The idea is to match the transfer method to the technology and the needs of a potential user. If the research deals with improved thinning methods to increase the disease resistance of a certain tree species, potential users may be forest managers on public and private lands. In such a case, patenting and licensing the information would be neither effective nor appropriate for getting the information to potential users because such information cannot be protected by patent, and it is unlikely the target group of users would take out a licence. Furthermore, it would be practically impossible to enforce the licence. However, having a seminar with a field trip to a demonstration area would much more effectively transfer the learning that was gained as result of doing the research to the intended users.

Patents can be very useful when dealing with a technology that needs further development by a manufacturer, before manufacturing. If the technology is destined to be delivered by a third party, through a machine, computer program, or formulation, then protection and licensing make sense. Any third party planning to get involved in creating a technology will need some assurance of exclusivity. One type of technology that lends itself very well to this approach would be a chemical formulation for pest management. The fabrication, sales, and distribution of a pest management formulation is best done through a private-sector third party. The best way to attract a possible licensee is to offer the opportunity to make and sell a product with the assurance that it cannot legally be copied by a competitor.

Abietiv™, a virus used to control balsam fir sawfly, was developed by CFS - Atlantic and licensed by Forest Protection Limited.

The form of intellectual property protection depends on the technology. A chemical or machine is easily patented, whereas software is not. Software is normally protected through copyright. The protection of naturally occurring viruses used in pest management cannot be easily patented either, but they do require registration to be used in Canada or the US. The registration process is long and costly. Through licensing, a company obtains the possibility of using a formulation (that CFS has registered) while maintaining competitive advantage. Also, a prior registration may be an attractive incentive if the area of use of the formulation is very limited, and the cost of applying for and maintaining a patent is perhaps not justified. In some cases, simple protection of a trade name through Trade Mark registration is sufficient to interest a commercial entity.

The CFS has been involved with the protection and licensing of technologies for the last 15 years or more. The main reason for licensing technology has not been to generate revenue, but rather to add value to the research that we do and the knowledge that we generate as part of our mandate to support the competitiveness of the forest sector. One of our longest running licences is for the Luminoc® insect trap. The licensee, Comlab Inc. in Quebec City, manufactures and sells Luminoc®, which is a patented technology. Another technology that was collaboratively developed by the CFS and industry is ***Chondrostereum purpureum***. This fungus is used as a biological control agent for deciduous plants. The technology was developed in collaboration with Mycologics Inc., a small University of Victoria start-up company that is currently negotiating a license for the technology.

Researchers at the CFS - Atlantic Forestry Centre discovered a naturally occurring virus that is able to control the balsam fir sawfly. Because of the very limited market for this product (this pest is currently a problem only in Newfoundland and Labrador), a patent was not justified. Thus, a licence for the registration of Abietiv™ was negotiated with Forest Protection Limited (FPL), which possessed the necessary experience in aerial spraying to offer Abietiv™ to their clientele.

The transfer of CFS technology is directly related to our mission to improve the sustainable management of Canada's forests. By transferring the technology through various means, forest managers are able to gain access to new tools to improve the state of our forests. The CFS's efforts in research and technology transfer have ensured that Canadians, including our clients, receive practical value and benefit, leading to a healthy forest and a strong forest sector.

Joseph Anawati,
Headquarters, Canadian Forest Service

Potential Decrease in Forest Site Productivity Caused by Whole-tree and Biomass Harvesting

A recent survey found that most waste biomass (sawdust, shavings, and bark) from forest manufacturing in Canada is already being used for energy production. Thus, speculation that forest biomass could support an increased portion of the nation's energy requirements, means that waste residues from forest harvesting (FH) sites would have to be used.

Machine harvesting systems vary across Canada, with less expensive full-tree (FT) methods predominating in central and western Canada, whereas cut-to-length (CTL) harvesting is the primary method in the Maritimes. In Ontario and the west, large amounts of FT nutrient-rich harvesting waste, previously burned at the roadside, is now viewed as easily accessible biomass fuel that could be used to supply large, permanent (Dynamotive Canada) and small, mobile, truck-mounted "fast pyrolysis" plants, which can produce cheaply transported "bio oil." This bio oil is the first step in converting bulky biomass into liquid fuel.

In Sweden and Finland, CTL methods, which randomly distribute harvest residues and the plant nutrients contained in them, are the main FH method. Taxation, designed to conserve expensive fossil fuels and to satisfy Kyoto greenhouse gas emission commitments, encourages the collection of nutrient-rich harvest waste residues to fuel huge (500–700 Mw) combined heat and power (CHP) plants in Finland. This has led to the development and widespread use of bundling machines to bale unmerchantable wood and high-nutrient tops, branches, and thinnings for efficient handling and transport out of the forest. The removal of harvesting slash from cut blocks also decreases the cost of site preparation for planting.

Forest biomass from New Brunswick is already being marketed to CHP plants in Maine, and bark is exported to a pellet plant in Nova Scotia. Pulp and paper mill closures have forced a reduction in prices paid for wood. Furthermore, with the advent of a $0.01 per kilowatt hour federal Renewable Power Production Incentive (RPPI), there is increasing interest in the use of biomass for electricity, heat, and liquid motor fuel.

The slash bundling machines from Europe are being demonstrated and advertised in North America. Two bundles of harvesting slash have the energy equivalent of about one barrel of oil or 170 m^3 of natural gas. When bundling machines are operating at peak efficiency, the processing cost of a barrel of oil equivalent (BOE) of forest biomass from a CTL site can be as low as $12–$14. As non-renewable energy scarcity continues to escalate prices for conventional fossil energy, there will be increasing pressure to collect harvesting residues, which have a much higher nutrient content than wood removed for pulp, saw timber, and veneer.

Studying soil solutions after forest harvest.

There is abundant historical evidence that the gathering of nutrient-rich foliage from European forest floors, used as livestock bedding and then spread on agricultural fields in periods before commercial fertilizers were available, caused serious changes in tree species composition, decreased biodiversity and forest growth, and increased soil acidification and nutrient depletion. Coordinated, large-scale studies in New Zealand and the United States 25 years ago, dealing with various levels of biomass removal from FH sites, substantiated these earlier observations concerning forest soil impoverishment in Europe. Recent research results from Finland, showing 8–12% declines in growth rates of rotations of pine and spruce that follow FT harvest, indicate that removing nutrient-rich slash from many forest sites would not be sustainable. Studies in the Maritimes raise concerns, about the maintenance of long-term productivity on a few poor sites, connected with calcium removal by even stem-only harvesting (with nutrient-rich bark attached), but FT methods have been flagged as problematic on many site types because of the significant removals of calcium, nitrogen, and potassium in the small branches with high bark to wood ratios and the attached foliage. Acid rain can cause nutrient depletion on poor sites in the absence of any harvesting, and this depletion is exacerbated by planting shallow-rooted conifers whose foliage is very acidic. Although some operations in northern Europe let forest harvest residues dry out for several months before they are gathered and moved off site, so that much of the nutrient-rich foliage falls to the ground, to date there are no guidelines anywhere in Canada for minimizing the risk of reducing long-term site productivity by biomass removal. Protestations by proponents of harvesting waste collection, that nutrient removals can be remedied by addition of chemical fertilizers, neglect the prohibitive increase in fertilizer costs as the price of non-renewable energy increases and its availability decreases.

In contrast to the obvious problems of nutrient removals with FT harvesting methods and slash bundling, CTL methods distribute tops and branches, which shield the soil from direct sunlight after harvest. Excessive heating, rapid microbial decomposition, and nutrient leaching out of the root zone occur until early successional non-crop vegetation has become established on FT harvested sites. Soil heating, as a result of the removal of harvesting slash, has been found to penetrate deep into the soil profile. Alternative harvesting methods, which limit the size of canopy openings to a width of less than two tree lengths, lessen the severity of post-harvest soil heating.

Overall, our recommendation is that more expensive CTL harvesting methods should be increasingly adopted across Canada, especially on nutrient-poor sites, in the interest of maintaining long-term site productivity. Great caution should be applied to forest harvesting that removes anything other than stem wood.

Taumey Mahendrappa and
Peter Salonius
Atlantic Forestry Centre

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central Ontario. Many of these areas were planted with red pine (***Pinus resinosa***) from 1910 through the Depression era of the 1930s to protect sites from further wind erosion. As these pine plantations matured, many were abandoned as a wood supply for the pulp and paper industry because red pine is poorly suited to paper making. These abandoned plantations provided a canopy cover or "nurse crop" for the reestablishment of native biodiversity. Enough small patches of residual native forest remained in some areas to provide the necessary seed sources for the natural restoration of the original forest cover types. Natural succession under red pine plantations has provided a wonderful, albeit serendipitous, example of our ability to restore, over relatively short periods of 60–80 years, some of our most valuable and increasingly rare, late-successional, native forest types, many of which are currently experiencing widespread decline in population numbers and population sizes. With purposeful thinning, natural succession can be promoted and accelerated to speed the recovery of these original forest types. Eventually, hardwood species (e.g., sugar maple (***Acer saccharum***), American beech (***Fagus grandifolia***), yellow birch (***Betula alleghaniensis***), hickories (***Carya spp.***), black cherry (***Prunus serotina***), white ash (***Fraxinus americana***), etc.) and shade-tolerant conifers (e.g., red spruce (***Picea rubens***) and hemlock (***Tsuga canadensis***)), which are difficult to establish on cleared areas, will begin to encroach on and ultimately dominate these pine plantations.

Red pine was widely used as a plantation species during the early years of forest management in Canada because it was very easy to grow, plant, and establish in large-scale plantations on very dry, harsh, impoverished sites. During the 1960s and 1970s, much research activity, aimed at reestablishing some of our most commercially valuable, long-lived, shade-tolerant trees, showed how difficult and expensive it was to establish shade-adapted, late-successional tree species on open, exposed sites that had been cleared of forest. A much more efficient approach may be to establish a nurse crop of red pine, poplars (***Populus spp.***), or willows (***Salix spp.***) near remaining native seed sources of these shade-tolerant species or to plant these species directly under existing plantations. The series of photographs on page 1 shows the process of natural succession from barren, highly wind-eroded, former agricultural sites to the establishment of a red pine plantation, followed by encroachment of an array of native, shade-tolerant hardwood species similar to those that dominated forest cover before European settlement. These original, pre-settlement, pre-deforestation forest types are among the richest sources of biodiversity that we have in the eastern temperate zone of North America, and also provide a variety of commercially valuable wood.

Tree plantations can be managed for multiple purposes, including biodiversity conservation, yet also fulfill society's need for wood fiber. It is not necessary to copy the agricultural model, whereby we destroy all potentially competing life forms under a tree plantation in order to maximize wood production. Forest plantations provide an important silvicultural "tool" for managing natural succession to restore long-lived, shade-adapted trees of late-successional forest types. These forests regenerate naturally through gap-replacement dynamics, and are self-perpetuating in the absence of catastrophic stand-replacing disturbances, such as the wildfires that dominate Canada's boreal forests. Forest sector expertise in plantation forestry can play a vital role in the protection and conservation of declining, late-successional forests. These forests and their associated biodiversity are especially vulnerable to such forestry practices as clearcutting, and the drive toward shorter forest harvest rotations.

A. Mosseler
Atlantic Forestry Centre

Tree Seed Symposium July 18-21, 2006 Fredericton, New Brunswick

Recent Advances in Seed Physiology and Technology

The Tree Seed Physiology and Technology Working Group 2.09.00 of the International Union of Forestry Research Organizations will hold its next symposium July 18-July 21, 2006 in Fredericton, New Brunswick, Canada. The IUFRO Seed Physiology and Technology Working Group is an open group and welcomes all interested people to attend.

The goal of the symposium is to discuss forest tree seed problems and their solutions, and for the exchange of information on all aspects of forest tree seed physiology and biotechnology.

For more information, visit the Tree Seed Symposium website at http://www.tss2006.org

Forum on "Conservation of Forest Genetic Resources: Challenges, Issues and Solutions" - July 28-29, 2006, Charlottetown, PEI

This Forum brings together researchers and practitioners working in the area of forest gene conservation. The focus will be on a proposed structure and function of a national program to conserve forest genetic resources. For more information, contact Dale Simpson at (506) 452-3530 or via email at dsimpson@nrcan.gc.ca.

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the Appalachian Mountains in the United States, which was genetically distinct from another one located east of the mountain range. During the extended glacial periods, the northern part of the Appalachia would have been glaciated, limiting gene exchange between both populations. Such a physical barrier would have allowed their genetic diversity to drift in different directions and becomes distinct. A similar pattern was found for black spruce. Because of the genetic distinctiveness of jack pine Maritimes populations, we also hypothesize that a third glacial population was presumably located on the unglaciated northeastern coastal area in Canada. This hypothesis is also supported by botanists and entomologists who consider the existence of this refuge essential to explain the present-day distribution of arctic and boreal species in northeastern Nova Scotia.

Recommendations

Canada has made international commitments to conservation and sustainable use of biological diversity through several international conventions. To ensure that we make sustainable use of our forest genetic resources, we first must know better the origins and extent of this diversity, and how it is spatially organized. This information will help us identify potential threats to our forest genetic resources, whether they are from forestry practices or climate change. Based on the results obtained, we hypothesize that extant populations derived from glacial populations that were located either on the unglaciated coast in Canada (mitotypes XII and XIII) or east of the Appalachia in United States (mitotypes III and V) are probably better adapted to maritime conditions. Given their likely isolation from other glacial populations, such adaptation might be unique. Thus, unless there is strong evidence against this hypothesis, we recommend that any seed source movement between the Maritimes and the regions west of the province of Quebec and vice versa should be avoided. Moreover, in situ conservation decisions should also take into account the phylogeographical structure delineated. Thus, we recommend protecting populations in each of the three regions because they originate from genetically distinct glacial populations.

For further information, read:

Godbout, J., Jaramillo-Correa, J.P., Beaulieu, J. and Bousquet, J. 2005. *A mitochondrial DNA minisatellite reveals the postglacial history of jack pine (Pinus banksiana), a broad-range North American conifer*. Molecular Ecology 14: 3497-3512.

Jaramillo-Correa, J.P., Beaulieu, J. and Bousquet, J. 2004. *Variation in mitochondrial DNA reveals multiple distant glacial refugia in black spruce (Picea mariana), a transcontinental North American conifer*. Molecular Ecology 13: 2735-2747.

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