IMPACT

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Looking back in time:

Backcasting gives model future credibility

An understanding of the extent and timing of permafrost development in peatlands can be a tool to validate paleoclimate reconstructions using vegetation or faunal ecosystems. Valid paleoclimate reconstructions, or reliable "backcasts" of environmental conditions, can then lend credibility to forecasts of responses to expected climate change.

Stephen Zoltai, a research scientist at the Canadian Forest Service's Northern Forestry Centre in Edmonton, has been looking back in time to find an analog for the predicted warming of 2-3°C by mapping the extent and distribution of permafrost in peatlands 6000 years ago, when summer temperatures over continental North America during the Holocene warm period were 2-4°C higher than at present.

To derive his estimate of permafrost distribution in peatlands 6000 years ago, Zoltai used data collected from coring and sampling of peatlands in west-central Canada over the last 23 years. Applying wetland development processes, especially the relationship between sphagnum development and associated permafrost development in peatlands, and using radiocarbon dates from 117 locations, Zoltai was able to make an ecologically sound estimate of the paleoclimate of permafrost dynamics 6000 years ago. Permafrost initially developed in peatlands farther north than today, indicating that the mean annual temperatures were about 5°C warmer than at present.

"If a model works well back in time to a known climate," Zoltai says, "it has more credibility for predicting unknown scenarios. Permafrost distribution is a tool to complement other tools, like pollen studies, but its big advantage over other models is that it gives us a good regional picture."

Convinced that it's a good approach, but that the accuracy and reliability of the reconstruction of paleoclimatic conditions responsible for the distribution of permafrost in peatlands can be improved with a more complete data base, Zoltai, with bryologist Dr. Dale Vitt of the University of Alberta, is extending the study. Over the next three years, they will add study sites across Canada to obtain a clear picture of permafrost development through time and changing climates on a continental scale.

Message from the Minister of Natural Resources Canada

Canada has an abundance of natural resources, and from this base of wealth we have built a strong and prosperous nation. We have a responsibility for ten per cent of the world's forests. To ensure that our forests are key to future opportunities for jobs and economic growth, as well as the future state of the global environment, we must continue to maintain their health and longevity.

At Natural Resources Canada, we are committed to encouraging progress toward sustainable forest management. The Canadian Forest Service's Climate Change Network provides the essential scientific knowledge to develop policies and management strategies to mitigate the potential effects of climate change.

We will continue to demonstrate our commitment to partnerships as a key approach to environmental issues at the Canadian Forest Service's workshop addressing fire activity in Canada, in Edmonton between April 2 and 4, 1996. The purpose of this event will be to develop a national consensus on the importance of, and possible responses to, increasing fire activity in Canada.

This issue of *Impact* provides a brief look at the important research our scientists are conducting. Their contribution to our knowledge about forests will play a vital role in advancing our knowledge of climate change.

A. Anne McLellan

Natural Resources Canada / Ressources naturelles Canada
Canadian Forest Service / Service canadien des forêts

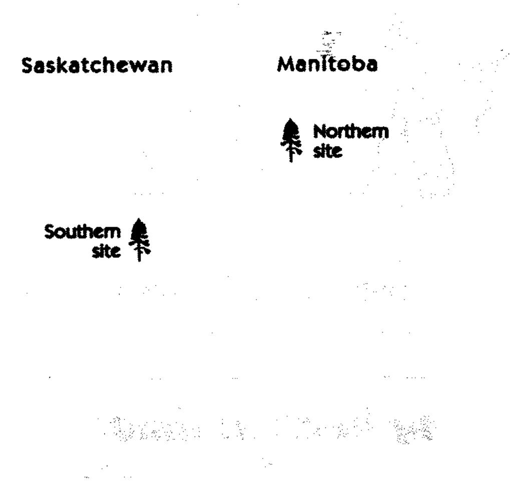
Canada

April showers best for jack pine tree ring growth

Tree-ring analysis of jack pine cores collected in 1994 from two BOREAS (**BOR**eal Ecosystem-Atmosphere Study) sites has yielded some unexpected results. Research scientist Dr. Ian Campbell at the Canadian Forest Service's Northern Forestry Centre in Edmonton says results from the southern jack pine site in Saskatchewan, part of the BOREAS allometry program, were entirely expected, "but we were a little bit surprised by the results from the northern site in Manitoba."

Tree ring width and density data showed spring precipitation to be the most important variable in determining ring width (productivity) at the southern site. Surprisingly, spring precipitation—specifically April rainfall—was also the most important factor determining ring width at the northern site as well.

Dr. Campbell explains that April rainfall promotes rapid melting of the snowpack so the root zone thaws earlier. "If you have abundant April showers, you increase the growing season. The air temperature relationship to ring width turns out to be weaker than we expected at the northern site. The length of root zone frost-free season seems to be the major factor."



Jack pine tree rings from the two BOREAS sites revealed the importance of precipitation for ring growth.

An even more interesting result was the northern site's stronger correlation of ring width with the previous year's weather. At the southern site the growing season is longer and needles have time to contribute to tree growth in the current year. At the northern site, although needle area generated this year is a function of this year's weather, ring width generated this year is a function of the needle area already available from last year. Or, the previous year's needles are responsible for the current year's growth. As Dr. Campbell puts it, "functional needle area is generated last year" at the northern site.

Dr. Campbell's jack pine results were presented in a poster session at the October 1995 BOREAS workshop in Washington, D.C.

Low-cost DendroScan technology gaining international recognition

A low-cost X-ray densitometry system developed by research scientist Dr. Ian Campbell and technician Thierry Varem-Sanders at the Northern Forestry Centre (NoFC) is getting attention in the densitometry world.

The system uses X-rays to measure the density of wood and a scanner to read tree ring widths. DendroScan software developed by Varem-Sanders interprets data from an X-ray machine and a scanner connected to a computer.

Queens University geography professor Dr. Julian Szeics is applying for an NSERC (Natural Sciences and Engineering Research Council) grant to duplicate the NoFC facility, and the precise, efficient yet cost-effective system has already been adopted by Glen MacDonald, a geography professor at the University of California, Los Angeles. "He's building a facility similar to ours," says Dr. Campbell, "and after shopping around, decided to use DendroScan." There are plans to market an instruction manual for setting up a lab such as the one at NoFC, including a disk with the DendroScan software.

Dr. Campbell says they are currently running an international, interlab comparison of systems and techniques that will highlight the strengths and disadvantages of each system. Twelve labs (in Australia, United States, Ireland, France, Germany, Switzerland, Netherlands, and possibly Russia) will analyse cookies from the same three trees. "We're going to compare lab costs, turnaround time, training costs, and the precision and resolution versus costs in time and money of the different techniques each lab is using," says Dr. Campbell. He expects all lab results by the end of the year and will publish the results of the comparison. "This comparison will allow people to match their needs with the type of systems out there. They'll be able to evaluate the tradeoffs—of preassembly versus self-assembly, for example, or precision required versus cost."

The NoFC system cost about $23,000, much less than the less-precise systems available for $110,000.

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RECYCLED PAPER

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Differences in black spruce physiology identified

After five years studying adaptive physiology of black spruce at the Canadian Forest Service's Petawawa National Forestry Institute (PNFI), Dr. Kurt Johnsen and his colleagues in physiological genetics research have identified families that can grow well across a large range of site conditions.

A major component of their work has been physiological assessments of four full-sib families (products of controlled pollination for which both seed and pollen sources are known) on three sites over three growing seasons. The site with the lowest productivity was drier than the other two sites. Two of the families maintained high productivity across all sites (stable), while the other two had high productivity on the two wetter sites (unstable).

Dr. Johnsen and John Major, a PNFI tree physiologist, demonstrated with gas exchange measurements that the stable families had high photosynthetic rates on both wet and dry sites and across years ranging from hot and dry to cool and wet. These family differences were substantiated by Dr. Larry Flanagan of Carleton University using stable carbon isotope discrimination.

"We have been able to identify families that can do well across a large range of site conditions," says Dr. Johnsen. "It's better to have trees that can handle many environmental conditions. Physiological testing allows us to identify these families where field testing by itself, over a finite period, often doesn't."

Besides examining genetic variation in responses to currently important abiotic stresses, such as drought, Dr. Johnsen, in partial collaboration with Dr. John Seiler of Virginia Polytechnic Institute and State University and Dr. Dennis Joyce of the Ontario Ministry of Natural Resources, has studied whether there are important genetic differences in responses to elevated CO_2 levels predicted for the next century. This work, strengthened by the use of field tested, pedigreed material, indicates that trees that are among the best growers under current CO_2 levels are often not among the best under elevated CO_2 conditions.

In the past, physiological genetics research has been hampered by an inability to gather enough reliable data. "Our success has been in large part because we use state of the art technology combined with a judicious choice of pedigreed genetic material," says Dr. Johnsen. Besides novel uses of "off the shelf" gas exchange systems, Major has developed a sophisticated automated, computerized, multichamber steady state system that permits large sample sizes. In parallel, as well as in collaboration with Dr. Martin Lechowicz, Department of Biology, McGill University, and director of the McGill Phytotron growth environments complex, Major has developed procedures to conduct experiments in growth chambers that are programmed to mimic seasonal and diurnal climate and daylength using real weather data. Dr. Flanagan, a plant physiologist and expert in stable isotope research, uses technology that is particularly useful for detecting subtle genetic variation.

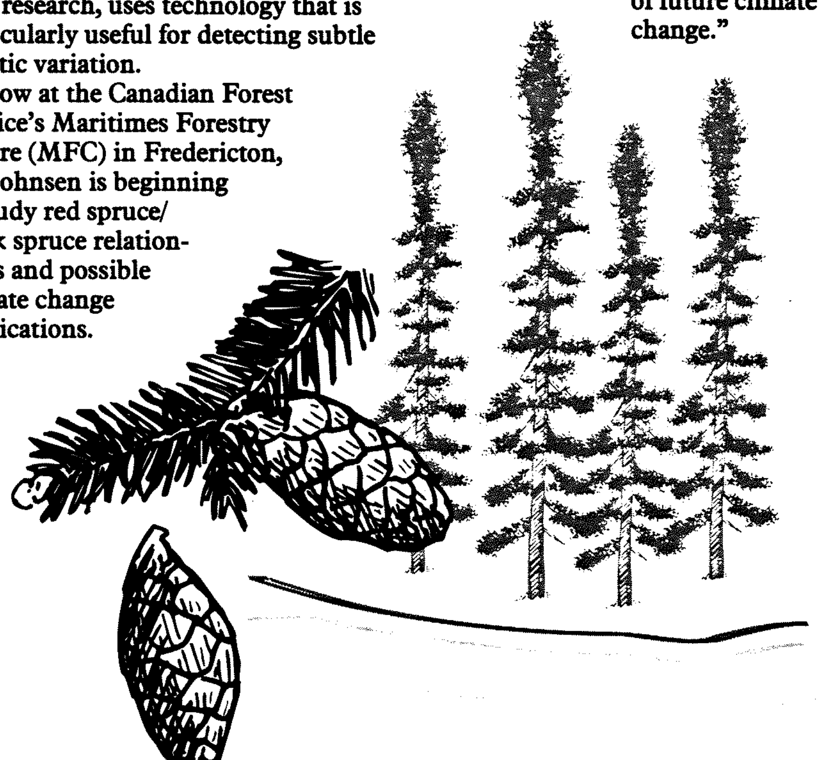
"We have been able to identify families that can do well across a large range of site conditions."

Dr. Kurt Johnsen

Now at the Canadian Forest Service's Maritimes Forestry Centre (MFC) in Fredericton, Dr. Johnsen is beginning to study red spruce/black spruce relationships and possible climate change implications. Unlike transcontinental black spruce, red spruce is a more southern species that is becoming rarer over much of its limited range. The two species overlap over much of red spruce's range and interbreed to a yet unknown extent. Red spruce seems to do better under warmer conditions, so Dr. Johnsen speculates that red spruce germplasm (genes) may be important for future black spruce evolution.

Dr. Johnsen is also involved in work in Mexico, where biodiversity may have a particular impact on forest responses to climate change. As head of the Canadian delegation to the North American Forestry Commission's Forest Genetic Resources Study Group, Dr. Johnsen will complement population genetic studies by Dr. Tom Ledig of the U.S. Forest Service with investigations of the ecophysiological tolerances of Mexican spruces.

In addition, studies with Dr. Judy Loo and Dr. Alex Mosseler, MFC colleagues in the new Canadian Forest Service Biodiversity Network, will examine genetic diversity of rare Mexican tree species using both population and physiological genetic tools. "Ultimately, we are working toward developing and promoting the tools for effective forest tree genetic conservation incorporating the uncertainties of future climate change."



Aspen decline factors diagnosed from tree rings

A large part of the research into climate change and its impact on the northern forest is building better models. Research scientist Dr. Ted Hogg at the Canadian Forest Service's Northern Forestry Centre in Edmonton has been working on an ecophysiological process model for aspen forest. Using tree-ring analysis to test the model, he hopes to gain an understanding of the climate events that have led to the current aspen decline in parts of the southern boreal forest and aspen parkland.

Dr. Hogg is using tree-ring analysis of aspen from a Canadian Forest Service study site in the aspen parkland at the Batoche National Historic Park north of Saskatoon to document the onset and progression of aspen decline and to diagnose the factors causing the decline. Though tree-ring analysis is generally considered more difficult to do for aspen than for conifers, Dr. Hogg has had excellent results and has been able to use tree rings to confirm drought events in daily weather data from 1920 to present. "Drought produces very narrow rings in aspen, and severe drought seems to have a long-lasting effect; reduced growth continues for up to 10 years," Dr. Hogg says.

More significantly, using the DendroScan X-ray densitometry technique developed by fellow research scientist Dr. Ian Campbell and technician Thierry Varem-Sanders, Dr. Hogg can distinguish drought years (high density wood) from years when insect defoliation (low density wood and a paler colour) has had an impact. The tree ring results conform with the insect outbreak history from other data over the study period.

The drought severity of each year is estimated using a Climatic Moisture Index (precipitation minus estimated potential evapotranspiration) developed by Dr. Hogg. He can then compare how the timing of the aspen decline is related to drought years and insect defoliation events throughout the life of the stands. Dr. Hogg thinks that "what actually kills the aspen is a combination of tent caterpillar defoliation with drought."

The computer model Dr. Hogg developed will be used to predict ring growth (changes in forest productivity) in response to various scenarios of climate change. The model is process-based and uses daily weather data, soil water-holding capacity and annual defoliation history to estimate daily transpiration, soil

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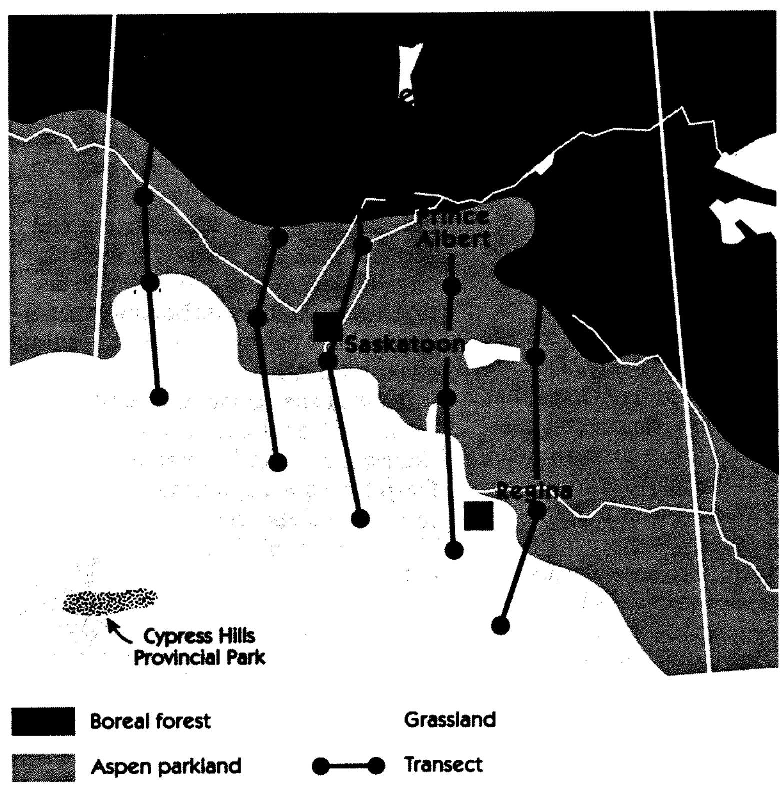
Conifer seedling survival key to tree growth in changed climate

In a warmer, drier future climate, conifer regeneration would be dramatically reduced in the southern boreal forest. Mature, planted conifers, however, can withstand even severe drought once they reach a certain age, suggesting that seedling survival rather than growth of existing trees may be the most important factor for the southern boreal forest if predicted climate changes occur.

In a two-year study, Northern Forestry Centre research scientist Dr. Ted Hogg and Dr. Art Schwarz of the University of Alberta's Canadian Circumpolar Institute surveyed stands of mature (40- to 80-year-old) conifers at 100 sites in Saskatchewan, across a climate gradient from grassland to boreal forest. Because conifers are naturally absent from the drier zones, plantations and shelterbelts were used as study sites. Most sites were abandoned farmsteads, and white spruce was the most commonly encountered species. At each site, any spontaneously regenerating conifer seedlings were surveyed.



Regeneration surveys were conducted on five farms, shelterbelts, or plantations at each site.

Natural regeneration of conifers was good in the boreal forest and northern aspen parkland but almost negligible on the prairies, suggesting that seedlings are sensitive to drought. Dr. Hogg says it appears that the critical stage is the first few weeks

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BOREAS update:

Progress reported, plans made

The BOREAS (**BOR**eal **E**cosystem-**A**tmosphere **S**tudy) field sites in Manitoba and Saskatchewan are deserted now, showing few signs of the bustling activity of the 1994 intensive field campaign. One year after the most extensive in-depth study of the boreal forest ever conducted, the teams of international researchers are back in their offices, busily analyzing mountains of data and writing up their results.

BOREAS field officer Dr. David Halliwell and scientist Dr. Ted Hogg, both of the Canadian Forest Service's Northern Forestry Centre in Edmonton, compared progress with other researchers at the BOREAS Workshop in Washington, D.C., October 17-20, 1995.

"The workshop was encouraging in that people are making progress and slowly getting things resolved," observed Dr. Halliwell, adding that "there's still a lot of data analysis to be done, though."

Future plans

Discussions centered around the remaining holes in data and results and plans for additional field work to be done in the summer of 1996. Project scientists from dozens of participating agencies and universities will be running at least one intensive field campaign, although it will be smaller than the field efforts of 1994. In addition to satellite and aircraft measurements, there will be ongoing measurements of essential meteorological and ecological data.

Poster sessions

At the workshop Dr. Halliwell presented a poster outlining a study that examined the relationship between tree ring growth and climate for two jack pine sites. The study was a joint effort by Northern Forestry Centre researchers Dr. Ian Campbell, Thierry Varum-Sanders, Harjit Grewal, and Dr. Halliwell.

Dr. Hogg presented a poster session on hydroregulation in aspen, describing the results of a study he did with Northern Forestry Centre technician Rick Hurdle. In the study, measurements of sap flow were used to estimate water vapor loss (transpiration) from two aspen forests. They found that transpiration from aspen was remarkably constant over a wide range of weather conditions, both in the boreal forest and aspen parkland. The study results were also presented by Dr. Hogg at a special BOREAS session of the Ecological Society of America in Utah in August 1995.

One of the exciting results from the BOREAS tower and aircraft measurements is that transpiration rates from black spruce and jack pine forests were much lower than the rate from aspen forest. Some researchers even suggested that boreal spruce and pine forests are behaving as a sort of "green desert" because of the low rates of both photosynthesis and transpiration that were observed.

Biometry results

A major Canadian Forest Service commitment to BOREAS was in biometry, providing baseline ecological data on soils, moisture, understory vegetation, woody debris, and tree characteristics. The biometry data have been collected in a series of three file reports entitled BOREAS Biometry and Auxiliary Sites. They will be published in late 1996 by the Northern Forestry Centre.

The first report describes the general setting of the research plots and details site locations using air photo information and topographic and forest cover maps so plots can be relocated. Overstory and understory data are provided in the second report. Included in the overstory data are biomass (weight of trees per unit area) at each site, trees per hectare, and species present, to provide a

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Aspen decline factors diagnosed from tree rings

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moisture, photosynthesis, respiration, and ultimately the relative growth of stem biomass in an aspen stand each year.

"Earlier models considered only tree transpiration, so our model had to be modified for luxuriant understorey and interruptions of grassland." The model Dr. Hogg developed (given the working title of SAP—Simulator of the Aspen Parkland) has already successfully simulated aspen tree ring growth from the Batoche site.

The Batoche work is confirming the importance of drought in controlling the productivity and distribution of the boreal forest and aspen parkland in western Canada. Tree-ring analysis shows that there has been a big drought event every 20 years. Under climate change, Dr. Hogg says, "we could expect these events more frequently, and the aspen parkland would be particularly susceptible."

Dr. Hogg now plans to extend the SAP model to a real forest management situation in the boreal forest near Meadow Lake, Saskatchewan, where aspen dieback has occurred. The study is centred in the Bronson Forest, part of a Forest Management Lease Area operated by Mistik Management, which is participating in the study. Other participants in the study are Northern Forestry Centre research scientist Dr. Stan Navratil (growth and yield assessments) and Dr. Ann Naith, renewable resources professor at the University of Alberta (carbohydrate analysis and regrowth of aspen).

With a better understanding of the combinations (and likely feedback effects) of extreme climate events and insect defoliation episodes that have produced the current state of aspen decline, researchers will be able to assess the ability of aspen to recover from future natural events. That's an important consideration not only for management of commercial forests but because the aspen parkland/boreal forest ecotone is where the first major impacts of climate change would likely occur.

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Some of these Canadian Forest Service climate change studies are linked with other regional, national and international climate change research initiatives, including the Global Energy and Water Exchange Experiment (GEWEX), the Arctic Environmental Strategy (AES), the Boreal Forest Transect Case Study (BFTCS), the Northern Biosphere Observation and Modeling Experiment (NBIOME) and the Boreal Ecosystem–Atmosphere Study (BOREAS).

Conifer seedling survival key to growth

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after germination, but the seedlings remain vulnerable for up to six years.

Tree-ring analysis of the plantations shows that mature trees, however, are able to withstand drought periods. Productivity is reduced in dry years, but all the conifer species looked at in the study (white and blue spruce and jack and Scots pine) seem to be resilient to the effects of prairie droughts. "Even very severe droughts, such as in 1988, which was one of the driest years this century, are not causing long-term damage," Dr. Hogg says. "It's remarkable that these trees seem to be able to hang on, but we don't expect widespread conifer dieback from drought like we see in aspen."

While there wouldn't be widespread mortality of existing conifer stands with future drying of climate, the poor regeneration of conifers in the southern parkland and grassland regions suggests there would be a big impact on the southern boreal forest through massive regeneration failure of conifers in dry areas. Coupled with the potential loss of forest cover that could result from the increase in wildfires that might be associated with climate change, a possible scenario is conversion of conifer forest to aspen and grassland.

The Canada-Saskatchewan Partnership Agreement in Forestry contributed funds for this research project.

BOREAS update: Progress and plans

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picture of forest composition. The third report presents measurements of downed branches, twigs, and other forest floor detritus in addition to soils information such as texture, organic matter content, nutrients, and moisture conditions.

Dr. Halliwell along with Northern Forestry Centre researchers Dr. Mike Apps and Dr. David Price provide an overview of the contents of the three reports and discussion of their methods of analysis in an article entitled "Survey of the forest site characteristics in a transect through the central Canadian boreal forest", which appeared in *Water, Air and Soil Pollution* issue 82 earlier in 1995.