IMPACT

Canadian Forests and Climate Change

Number 2 February 1993

Role of forests in carbon budget examined

Forests are huge, ever changing pools of carbon. They absorb carbon dioxide from the atmosphere, convert it to carbohydrates, of which carbon is an essential ingredient, and store it. Some is stored in the roots, some in the leaves, branches, and trunk. When trees grow, when they become diseased, when they die, or when they are killed by fire, the carbon they contain is redistributed. Some is released back into the atmosphere but, even through fire, only a small portion of the tree biomass is released to the atmosphere immediately. The rest ends up on the forest floor and in the soil and subsequently decomposes over a long time period. The whole process is called the carbon cycle, and the soils of northern forests play an important role in this cycle.

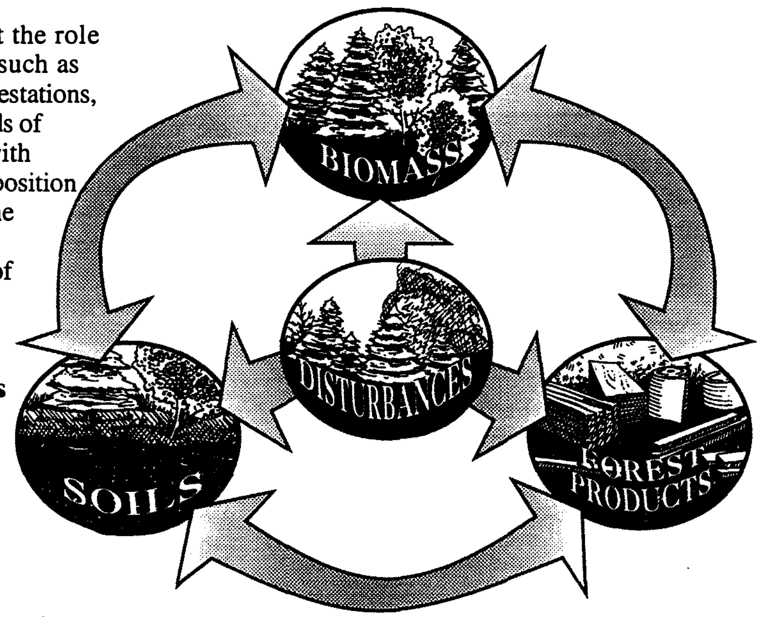
Man has interfered with the natural carbon cycle by pumping huge amounts of carbon dioxide into the air through the burning of fossil fuel and through the deforestation of tropical rain forests. There are indications that temperate and northern forests play an important role in the absorption of carbon dioxide and storage of carbon. Do Canadian forests actually act as an increasing storage container for carbon—a carbon sink?

This is just one question being looked at by researchers involved in a three-phase study on the role of Canadian forests in the global carbon budget.

"This is probably the first and only comprehensive analysis done of the entire forest at the national level," explained Dr. Mike Apps, team leader for Forestry Canada's climate change research team. "For the first time, we've taken into account the role that disturbances such as wildfire, insect infestations, and various methods of harvesting, along with growth and decomposition processes play in the carbon balance."

The first phase of the study, which is now complete, involved more than two dozen scientists from Forestry Canada, various universities, and industry. Its purpose was to identify the current (1986) role of the entire Canadian forest resource in sequestering carbon. For 1986, Canadian forests acted as a weak net sink of carbon which means they absorbed more carbon than they released into the atmosphere. This result was found even after accounting for carbon release due to fire, insects, decomposition, and other disturbances such as harvesting.

"A significant part of the net sink (approximately 21 million tonnes) was found to be in forest products, that is, carbon contained in things like wood building materials and wood products such as paper and furniture," he explained. "This is interesting because this forest product pool can be directly managed. It implies opportunities for significantly increasing Canada's net sink."



The carbon budget cycle, adapted from the cover of *The carbon budget of the Canadian forest sector: Phase 1.*

On the other hand, forest fires and other disturbances can greatly change the carbon distribution in forests. If there is an increase in the frequency and severity of fire and insect infestations, northern forests could become a source of carbon rather than a sink.

"The big concern is that the forest will change, and probably quite rapidly, in a changing climate," said Dr. Apps. "In the prairie region, the southern edge of the boreal forest will be under increasing drought stress. In the north, the forest may not be able to migrate north as fast as changes in the climatic conditions occur. Soil conditions, seed

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Forestry Canada Forêts Canada

CANADA'S GREEN PLAN

Canada

The missing carbon sink: where has it gone?

If forests do function as the missing sink, responsibility for their wise management takes on something of a global responsibility.

– Dr. Mike Apps

Scientists around the world are scratching their heads wondering where it has gone. After all, what goes up must come down, right? Since the industrial revolution, mankind has been putting more and more carbon dioxide into the atmosphere through the burning of fossil fuels and the clearing of forests for other purposes. Presently we put approximately six gigatonnes, that's 6,000,000,000,000 kilograms, of extra carbon into the atmosphere every year through our use of fossil fuel. An additional one to two gigatonnes are effectively added to the atmosphere each year through deforestation, primarily in the tropics.

Of course, all of the carbon we put into the atmosphere doesn't stay there. About one-half of this extra carbon stays in the atmosphere—the rest is absorbed from the atmosphere by the additional growth of green plants through the process of photosynthesis. What puzzles scientists is the fact that the current estimation procedures cannot account for all of the carbon being absorbed by the ocean and the terrestrial biosphere.

Controversial topic

Currently, an excess of 1-2 gigatonnes is unexplained and there is hot debate (pun intended!) as to where this goes. This unaccounted for carbon, often referred to as "the missing sink", is one of the controversial topics of current scientific research.

Why? First, we are not talking about a small amount of carbon. The six gigatonnes emitted annually through fossil fuel burning is equivalent to completely burning all of Canada's forests every two years! The missing sink is about the same as the amount of carbon contained in the biomass of Canada's boreal forest west of Ontario, which we estimate to be about 1.9 gigatonnes. However, when spread out over the surface of the earth, it is a very small quantity (approximately 7 grams per square meter per year) to be detected as additional material on top of the 1,000 to 4,000 grams already there—the problem is really like that of the needle in the haystack.

Second, and this is the real reason driving the search for the missing sink, atmospheric carbon dioxide plays a central role in the greenhouse effect. The build-up of carbon dioxide in the atmosphere because of human activity (from about 280 parts per million before the industrial revolution to more than 360 parts per million today) is the primary cause of concern when it comes to global climate change. The point is that the missing sink (and the oceanic uptake) of carbon dioxide has slowed the build-up of this important greenhouse gas in the atmosphere by about 50 per cent from what it would be otherwise. In other words, the mysterious missing sink may be delaying the onset of global warming in a significant way.

The scientists' real problem is that since they cannot yet explain it, can they be sure that the sink will continue in the future?

Recently, the research world's interest has shifted to northern forest systems. There are at least three reasons for this. First, a paper published in the prestigious journal *Science* by Tans et al. in 1990 suggested that the missing sink had to be in the temperate and boreal forest zone. Heated debate has raged since the publication of this paper, particularly with oceanographers who argue that the missing sink is in the oceans. The current consensus expressed at a recent Intergovernmental Panel on Climate Change Workshop seems to be a compromise, with both the oceans and the northern forests presently contributing to the missing sink.

The second reason for interest in these northern systems is due to the large quantities of carbon contained by these forests and the concern that if the climate does warm up, these forests may become sources, rather than sinks, of atmospheric carbon.

Third, many of the industrialized nations of the world, including Canada, either contain or adjoin these forests and depend upon them for a wide range of economic and social values. The global carbon cycle and potential global warming therefore may be a double-edged sword. If forests do function as the missing sink, responsibility for their wise management takes on something of a global responsibility. At the same time their management as a national resource is of critical interest to these countries. Balancing these environmental considerations with socio-economic ones (sustainable development) requires a good understanding of the part played by these forests in regulating the global climate (the carbon cycle is a particularly important example) and how they might respond to changes in the climate.

- by Dr. Mike Apps

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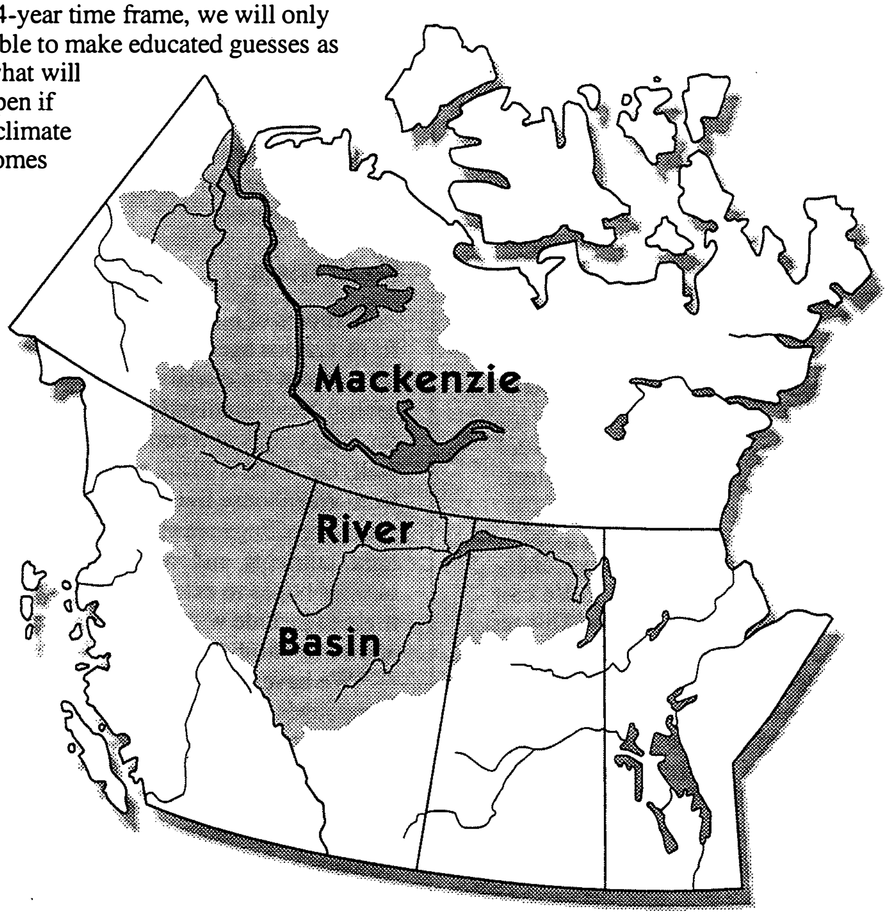
Mackenzie River Basin subject of impact study

Until recently, the area has been largely unstudied. Now, under Canada's Green Plan, the Canadian Climate Centre of the Atmospheric Environment Service is coordinating a multi-disciplinary study to assess the current conditions of the Mackenzie River Basin.

The multi-faceted Mackenzie Basin impact study (the Socioeconomic Impacts of Global Warming on the Mackenzie River Basin) will not provide definitive answers on the effects of global warming on the basin but will provide a benchmark for the future, according to Forestry Canada climatologist Ross Benton.

"Due to the nature of the study, plus the 4-year time frame, we will only be able to make educated guesses as to what will happen if the climate becomes warmer," he explained. "We do know that the north will be more affected than the south. We are especially concerned about the effects of warmer winter conditions and drought on forest health and productivity."



The Mackenzie River Basin encompasses one-quarter of the land mass of Canada and includes the area north of Hinton, Alberta, northern Saskatchewan, the northeast corner of British Columbia, the southeastern and northern Yukon, and a large portion of the western Northwest Territories. This includes the major rivers and lakes that drain into the Mackenzie such as the Peace, Liard, and Athabasca rivers and Great Slave Lake.

Until recently, the area has been largely unstudied. Now, under Canada's Green Plan, the Canadian Climate Centre of the Atmospheric Environment Service is coordinating a multi-disciplinary study to assess the current conditions of the Mackenzie River Basin.

The study, to be completed in 1996, includes components on agriculture, settlement patterns, energy, transportation, national defence, forestry, land use, and the socio-economic impact on the area. A number of groups across Canada, including various government departments, universities, industry, and native organizations, are involved.

Forestry component

Mr. Benton is coordinating the forestry sector component. This study covers a very broad range of forest types, landscape, and a range of forest sector concerns.

He has recruited a group of 18 researchers from several universities, Forestry Canada's Pacific Forestry Centre, and the B.C. Forest Service to collect data on five forestry sub-components of the study. These include development of a comprehensive forestry data base for the area, investigating the effects of forestry disturbances, assessing the implication for forestry growth and yield, investigation of implications for stand dynamics, and an economics modelling component.

"I am collating all the current information on the forest sector such as forest cover, soil types, climate, topography, where industry is located, and the economic factors at work in the area. This will result in an integrated forest sector data base," Mr. Benton said.

Information from the other sub-components will be added to the data base which will then be fed into a forest economics model. "This model will provide projections on future yield and an estimate of the future forest economy," he said. "Our forest sector data will then be combined with data from all the other components to give an overall economic snapshot of present and possible future conditions in the Mackenzie River Basin."

The predictive aspects of the study will involve the input of new climatic variables, such as temperature and precipitation, in order to develop projections on future growth and yield. These predictions will then be input into an overall Input/Output economic model containing all the data. The resulting information will be used to summarize and study the socioeconomic impacts to the Mackenzie River Basin and provide general indications of what will happen in the region under global warming.

Changes in climate will produce stress on ecosystems

"This means that the plant material will decompose at a different rate on the forest floor, and will smell and taste different to wildlife and to insects. In essence, the whole ecosystem is affected."

–Dr. Brian Titus

Studying the effects of climate-induced stress on ecosystems will provide scientists with important clues about what will happen in the boreal forest under a changing climatic regime.

Dr. Brian Titus, a research scientist at the Newfoundland Forestry Centre, says that all plants experience some degree of stress as a result of limitations in temperature, light, nutrient availability, and soil moisture content. However, these stresses will become more noticeable, especially at the present boundaries of ecosystems, if the overall climate changes.

"We assume these stresses will produce plant matter with different concentrations of organic secondary compounds," he explained. "This means that the plant material will decompose at a different rate on the forest floor, and will smell and taste different to wildlife and to insects. In essence, the whole ecosystem is affected."

Stress due to environmental factors may thus affect the distribution of wildlife as well as change some fundamental processes in the soil such as nutrient availability. If scientists can find out how the concentration of these compounds, such as terpenes (fragrant compounds) and tannins, are changing in indicator species, they will be able to monitor ecosystems to discover which ones are under increasing or decreasing amounts of stress.

Field trials

Samples of black spruce and balsam fir of various ages and sizes are being taken from field trials in western and central Newfoundland and are analyzed for their compound concentrations. As well, Dr. Titus is using plant material from greenhouse trials in which black spruce seedlings are stressed in terms of light, nutrients, and moisture. In the future, he hopes to extend the greenhouse trials to include white birch, balsam fir, and some shrub species.

"We have found that some secondary compounds in balsam fir increase and others decrease, depending on the nitrogen levels in the foliage and twigs," he said. "Perhaps most importantly, tannin concentrations increase with decreasing nitrogen."

He explained that healthy nutritious foliage is low in tannins, while nutrient-stressed foliage can have up to twice the tannin content. "A decrease in soil nitrogen availability because of altered rainfall and temperature will likely result in increased tannin concentrations in balsam fir and hence decreased palatability for moose. The question is—will this lead to a subtle change in moose browsing habitat?"

Continued on page 5 . . .

Weather affects growth of sugar maples

During cold, dark winters people spend time indoors. Trees are not so lucky. They have to endure the cold, the harsh winds, and variable snow cover conditions. In 1981, after a particularly severe winter, sugar maples in Quebec showed signs of severe stress and many began to die. Since the sugar maple is an important species to the economy, a number of studies were initiated to find the cause of sugar maple dieback.

Scientists were not sure if the cause was weather related or due to acid rain. Generally, it is felt that changes in the variability of weather and the frequency of extreme events is the culprit. Under a changed climatic regime, it is likely there will be an increase in episodes of extreme weather events, including high temperatures, that cause winter thawing and refreezing as well as summer droughts.

At the Laurentian Forestry Centre, research scientist Dr. Gilles Robitaille, forest engineer Robert Boutin, and others are studying how climatic extremes affect the growth and metabolism of sugar maple roots and the chemistry of the soil solution from which the roots obtain nutrients. Two specific stresses they are looking at are drought and cold.

In the Duchasnay Experimental Forest, 40 kilometres northwest of Quebec City, sugar maples are being tested to see what effect cold, drought, and lack of snow cover will have on the trees.

"The tree roots are affected when subjected to cold," said Dr. Robitaille. "The trees develop dieback symptoms. The next growing season some of the trees either don't grow or they grow very little."

Discovering the effect of drought on the trees has been more difficult because the growing season of 1991, the year the study began, was very dry. "We couldn't distinguish between the drought trees and the control trees as clearly."

Dr. Robitaille collected leaves from the trees throughout the frost free season and is now attempting to discover signs of drought stress through studying the amount of growth hormone, abscissic acid (ABA), in the leaves. Normally, the amount of the acid increases with drought stress. ABA is a growth regulator that affects carbon dioxide exchange through stomatal regulation and causes reduced leaf growth.

"Using an ABA test is a good marker for testing stress, especially drought," he explained. "We can obtain results very quickly. This test could be used when testing for stress in other geographical locations such as along the boreal transect.

"For now, this experiment is unique to North America and it will maintain Forestry Canada at the forefront of research on the effects of climate change on forest productivity."

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Changes

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Tannins are also thought to be involved in decreasing nitrogen availability in the soil. Consequently, site productivity may also be affected if climate change leads to a decrease in soil nutrient availability.

If it can be shown which secondary compounds increase or decrease with changes in stress, Dr. Titus would like to see analysis for these compounds included in the regular sampling of permanent ARNEWS (Acid Rain National Early Warning System) and FIDS (Forest Insect and Disease Survey) plots already established across the country, in order to monitor the levels of stress experienced by various plants.

"We need a more comprehensive and quantitative monitoring system for forest health," he said. "Sampling regularly for secondary compounds may provide data that will complement the present subjective assessments of the condition of plants. This may help us to sense not only the direction of change, but perhaps even which key climatic variable is driving the change."

The organic analyses for this study are being undertaken by Dr. Caroline Preston from Forestry Canada's Pacific and Yukon Region, and Dr. Bob Helleur, who works in the chemistry department at the Memorial University of Newfoundland.

This is one of three studies being undertaken by the Forest Decline Network under the Forestry Canada Climate Change Initiative. The other studies are being undertaken by Dr. Roger Cox at the MFC (winter thaw effects on birch), and Dr. Gilles Robitaille at the LFC (sugar maple decline). All three researchers collaborate and exchange ideas as well as samples for testing and organic analyses, and together hope to come to a greater understanding of how both weather extremes and small changes in regional climate will affect forest productivity and various ecological processes.

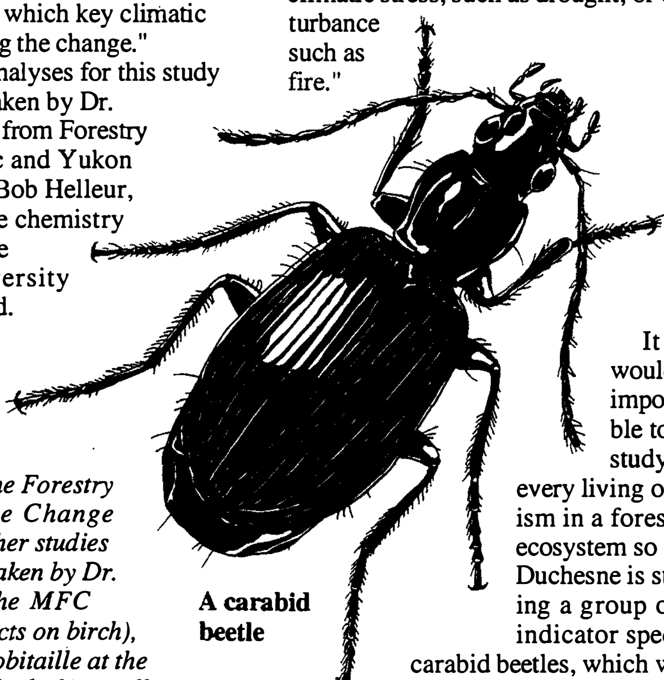
Organisms important indicators of changing climate

"Insects that eat fungi and other insects will tell you a great deal about what is happening in a particular ecosystem."

– Dr. Luc Duchesne

Climate change will most likely affect the species biodiversity of our forests, according to Forestry Canada researcher, Dr. Luc Duchesne. Dr. Duchesne, a fire ecologist at the Petawawa National Forestry Institute (PNFI), is trying to determine how the assemblage of various organisms from large species of wildlife to small micro-organisms in the soil will be affected by forest disturbances.

"It's important to know what happens to the biodiversity of forests because biodiversity controls the productivity and stability of forest ecosystems," he explained. "What we don't know is the mechanics of what happens to the living communities after a climatic stress, such as drought, or disturbance such as fire."



A carabid beetle

It would be impossible to study every living organism in a forest ecosystem so Dr. Duchesne is studying a group of indicator species, carabid beetles, which will provide the kind of information he needs. "Insects that eat fungi and other insects will tell you a great deal about what is happening in a particular ecosystem. They are easily affected by changes in their environment."

His experiments involve comparing a burned-over jack pine site with an untouched jack pine site at the southern edge of the boreal forest. The two sites are in the vicinity of Prince Albert, Saskatchewan. Dr. Duchesne is studying the occurrence of carabid beetles and the rate of decomposition at the two sites. Studying the rate of decomposition is critical in forest sites because it indicates how fast nutrients are transferred from the forest litter to organisms.

Effect of disturbances

"The one site was burned two years ago by a natural fire," he said. "The interesting thing is the site did not regenerate back to jack pine following the fire, although there is evidence that seeds were released in the area. This is a rare phenomenon. It is thought that it may occur frequently as a result of global warming."

Dr. Duchesne has been collecting data at the two sites since September 1991 and suspects that hot, dry weather following the fire may have affected seed germination. However, it's not something that can be proved directly because a number of other factors come into play.

"The number of seeds released, the viability of the seeds, the soil conditions, competition at the site—these and other factors must be eliminated before one can say weather conditions are responsible."

The data collected to date does show increased biodiversity at the burned-over site. "The data suggests that if there is global warming and if we allow fire to run its course through ecosystems, the biodiversity of the area will be altered," explained Dr. Duchesne. "However, we do not have enough data to say exactly what that change will be."

The effect of disturbances on forest biodiversity has not been widely studied in the past so this study is laying the groundwork for future work in this area. To increase the level of understanding of this phenomenon in other ecosystems, other studies are also in progress at PNFI.

Study looks at jack pine growth under changed environmental conditions

Jack pine is an important species in the boreal forest. It often grows in areas that are nutrient-poor and well-drained. These areas will tend to become more problematic under a warmer and drier climate scenario.

Studying how jack pine grows under a changed environmental regime (chemical and physical factors) will help scientists predict how forests will react if global warming occurs.

Jack pine is an important species in the boreal forest. It often grows in areas that are nutrient-poor and well-drained. These areas will tend to become more problematic under a warmer and drier climate scenario.

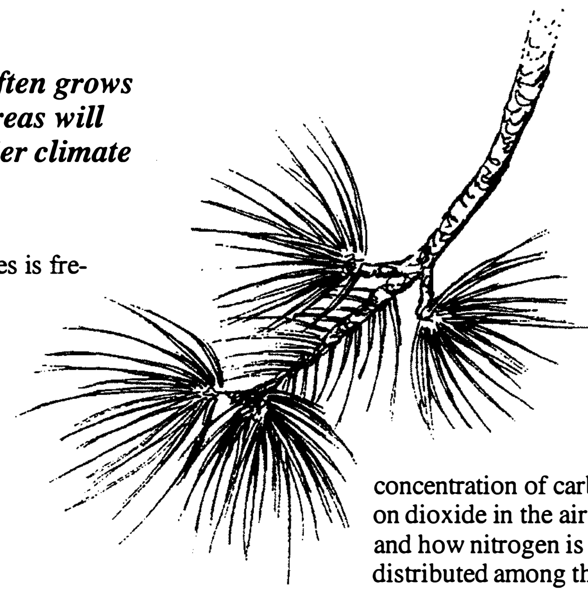
"The kind of knowledge we will gain, from understanding the physiology of these trees, will give us a truer picture of what process models are attempting to predict—how forests will grow in the future," said Dr. Gary Hogan, a research scientist based in Forestry Canada's Ontario Region.

The study will concentrate on two factors—how jack pine will respond to elevated carbon dioxide in the air and how the trees are affected by the level of nitrogen in the soil.

Carbon dioxide is fixed by the plants (converted to carbohydrates) and is used to produce roots and new shoots. Under the higher carbon dioxide concentration, the rate of production of roots and shoots may be altered as well as the relative distribution of biomass between these two compartments. If the growth of shoots is favored over that of roots, the trees may become less drought resistant.

"This could alter the range of conditions under which jack pine could be successful," said Dr. Hogan. "The level of nitrogen in the soil is also an important factor because both elements (carbon and nitrogen) interact. We are looking at the nitrogen concentration in the soil and the rate at which it is available to the seedlings."

Dr. Hogan and his associate, Dr. Weixing Tan, are especially interested in how these interactions will affect the regeneration of jack pine seedlings in the field, because the species is frequently transplanted into a hostile environment where it is susceptible to drought.



In some of the cutovers, nitrogen availability is limited and it is suspected that a tree's ability to respond to carbon dioxide may be limited by nitrogen availability.

Dr. Hogan and Dr. Tan are running a series of experiments, each 100 days in length, in two environmentally controlled chambers. Data is collected every two weeks.

"We want to see what happens aboveground and underground with the higher concentration of carbon dioxide in the air, and how nitrogen is distributed among the seedlings," said Dr. Hogan. "We started in August and haven't run into any major problems yet."

This study is jointly funded by Forestry Canada's Climate Change Initiative and the LRTAP (Long Range Transport of Air Pollutants) program.

Tree respiration rates affected by climate change

Scientists are very concerned what effects climate change will have on forest growth. Research scientist Dr. Mike Lavigne, from the Maritimes Forestry Centre, is studying how tree respiration is affected by a changing climate.

"We know that photosynthesis minus tree respiration equals forest growth," said Dr. Lavigne. "This simple model of forest growth illustrates that any effects of climate change on respiration will impact on tree growth."

It is somewhat complicated to make accurate estimates of respiration in trees. Dr. Lavigne has had to develop an apparatus that will provide the data he needs. At present he is field testing this apparatus on four separate balsam fir sites in western Newfoundland. The data he is collecting is taken from small sections of trees. This data then needs to be scaled up to estimate the annual respiration of stands of trees.

"I'll have the respiration system fully operational by 1994 for the BOREAS experiment," he said. "I am trying to establish temperature response curves for different species. I am also trying to establish how these temperature response curves change in response to global climate change. Once these relationships are established they can be fit into forest growth models to predict forest growth under a different climate."

Dr. Lavigne will be measuring tree respiration in spruce and pine trees at the northern and southern BOREAS locations. This data will be used by other Forestry Canada researchers involved in forest growth models, particularly Dr. Mike Apps and Dr. Ted Hogg. "My data about respiration will be an important part of their modelling efforts," he said.

International BOREAS project will greatly benefit Canada

Team selection

This past summer the International Peer Review Committee faced the daunting task of screening proposed activities for BOREAS (Boreal Ecosystem Atmosphere Study). More than 220 scientific proposals were submitted by scientists from around the world; approximately 50 of these were from Canada. They were competing for the opportunity to participate in the experiment, which will take place in western Canada's boreal forest in 1993-95.

The peer review panel was comprised of two dozen international experts appointed by the sponsoring agencies from Canada and the U.S. Armed with written reviews (up to 6 per proposal) solicited from the larger science community, the expert panel ranked the proposals on the basis of their scientific merit and compliance with BOREAS objectives.

"The overall quality of the proposals was very high and this made the week-long peer review a very demanding process," said Dr. Mike Apps, who is a member of the BOREAS executive committee.

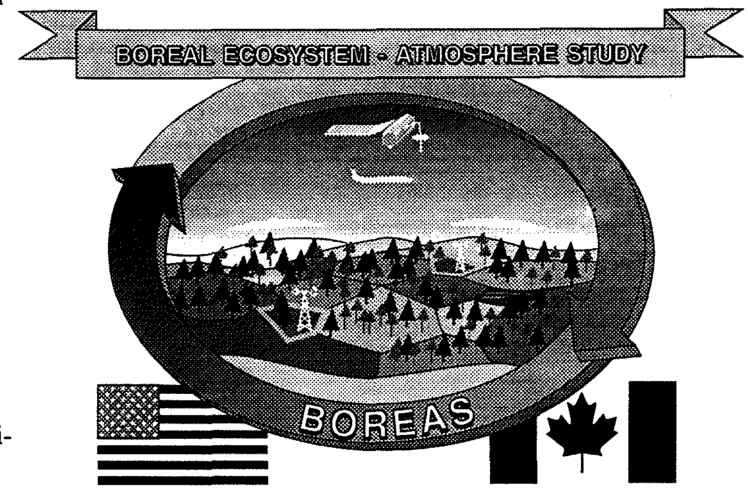
The committee sat as observers during the reviews to prepare themselves for the equally daunting task of putting together a viable project from the highest ranked proposals.

"One of the challenges facing the committee was to match the BOREAS program needs and budget requests with available resources," he explained. "The fact that each of the 220 proposals has price tags ranging from $50 thousand to over $2 million gives perspective to this challenge."

Canadian proposals fared very well in the peer review in relation to the overall review. The highly ranked proposals from Canadian university scientists were bundled into an NSERC (Natural Sciences and Engineering Research Council) Collaborative Special Projects grant submission by Dr. Hank Margolis from the University of Laval, with the assistance of the BOREAS executive committee. In early November, NSERC announced that it would contribute $4.75 million to the project over 4 years.

Some 30 university scientists from more than a dozen universities across the country, together with their post doctoral fellows and graduate students, will be supported in BOREAS activities by this grant. The team was greatly encouraged by the warm response from NSERC. It was noted that, to date, the BOREAS proposal was the only "truly integrated multidisciplinary" proposal it has received.

Projects from Canadian government scientists were subjected to the same peer review with funding at the discretion of the sponsoring departments (not from NSERC). Three Forestry Canada teams have already been selected, two from NoFC (principal investigators Dr. Mike Apps and Dr. Ted Hogg) and one from PNFI (Dr. Murray Strome). Co-investigators include scientists from PNFI (Dr. Margaret Penner), MFC (Dr. Mike Lavigne), PFC (Dr. David Goodenough) or GLFC (Brian Stocks), and NoFC (Dr. Ian Campbell, Rick Hurdle, Thierry Varem, Harjit Grewal, and Dr. Dave Price).



How does BOREAS run?

The eight-member BOREAS executive (four U.S. and four Canadian scientists) is presently responsible for day-to-day direction of BOREAS activities. This function is carried out by staff in the U.S. BOREAS Program office (at NASA's Goddard Space Flight Center in Maryland) and the Canadian BOREAS Secretariat, which has "nodes" in Ottawa (Canadian Centre for Remote Sensing, lead agency), Winnipeg (Atmospheric Environment Service) and Edmonton (Forestry Canada).

In Edmonton, for example, the function of BOREAS field officer is carried out by Joe Niederleitner reporting to Dr. Apps. Members of the BOREAS executive committee are Dr. Piers Sellers, Dr. Joseph Cihlar, Dr. Barry Goodison, Dr. Hank Margolis, Dr. Forrest Hall, Dr. Allan Nelson, Dr. Dennis Baldocchi, and Dr. Apps.

The BOREAS Executive Committee has also continued to provide scientific direction for the project. It provides a scientific and technical advisory function for the BOREAS Coordinating Committee (BCC), to which it reports. The BCC is comprised of senior managers in the sponsoring agencies on both sides of the border. Dr. Dave Brand, Director of Environment in Forestry Canada Headquarters, acts as our departmental representative on this committee.

It is the BCC that made the final choice of BOREAS Science Team members. From this team a third leadership body, the Science Steering Group, has been formed. This broader-based group will monitor and guide the BOREAS science program as it unfolds.

"Things are definitely shaping up for a world-class science experiment in BOREAS," said Dr. Apps. "As one scientist was overheard to say at the Peer Review Panel meeting—BOREAS is big science. For the last few years attention has been focused on the tropical forests. Now it is the boreal forest's turn."

"A number of the world's best scientists will be working in Canada's mid-continental boreal forest and the information, data, and new insights developed will greatly benefit Canada. We can feel good that Forestry Canada continues to play a central role in this important international project."

-Dr. M. Apps and Joe Niederleitner

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Sault Ste. Marie, Ontario P6A 5M7

Regional climate model
Mr. Brian Stocks

Effects of enriched CO_2 on plant growth
Dr. Gary Hogan

Petawawa National Forestry Institute (PNFI)

P.O. Box 2000
Chalk River, Ontario K0J 1J0

Forest floor dynamics
Dr. Mike Weber

Crown development model
Dr. Margaret Penner

Microflora of litter
Dr. Luc Duchesne

Forest Pest Management Institute (FPMI)

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1219 Queen Street East
Sault Ste. Marie, Ontario P6A 5M7

Forest insect responses
Dr. Richard Fleming

Quebec Region

Laurentian Forestry Centre (LFC)
P.O. Box 3800
1055 du P.E.P.S.
Sainte-Foy, Quebec G1V 4C7

Sugar maple decline
Dr. Gilles Robitaille

Maritimes Region

Maritimes Forestry Centre (MFC)
P.O. Box 4000
Regent Street
Fredericton, New Brunswick E3B 5P7

Hardwood dieback
Dr. Roger Cox

Crown development model

Woody tissue respiration
Dr. Mike Lavigne

Newfoundland and Labrador Region

Newfoundland Forestry Centre (NeFC)
Building 304, Pleasantville
P.O. Box 6028
St John's, Newfoundland A1C 5X8

Stress indicators
Dr. Brian Titus

Some of these Forestry Canada 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).

Role of forests in carbon budget examined

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dispersal and other ecological factors may act to delay migration. The net result, over the next 100 years, may be both a smaller forest area and a younger forest containing less carbon. Older parts of the forest will be less suited to the prevailing climatic conditions and will be less productive."

Dr. Apps is concerned that under those circumstances both the stored carbon and the actual production of the forest will be reduced—at least over the next 100 years. The northern forest becoming a carbon source rather than a sink in this situation is a very real possibility.

Phase 2 of the study, now underway, is looking at how forest management and forest sector policy can affect the carbon budget. An improved understanding of the forest's role in the global climate system will help to guide development of wise forest management policies, he said.

"We hope to investigate how the rate of carbon dioxide increase in the global atmosphere can be reduced through reforestation, altered fire protection strategies, energy conservation, increased recycling, and substitution of fossil fuel energy by bioenergy."

"Vigorous, young forest stands grow faster than mature old growth forests and therefore absorb carbon dioxide at a higher rate. The carbon contained in these young stands, however, is considerably less. Forest management, therefore, holds some promise for reducing atmospheric carbon dioxide but will require us to look carefully at what we do with the harvested material."

Approximately 7 billion tonnes of carbon is released into the atmosphere each year through man's activity. Dr. Apps emphasized that while good forestry can temporarily help, the real solution to the carbon dioxide problem and global warming lies primarily in the conservative and more efficient use of fossil fuels.

Phase 3 will involve studying the forest response and future carbon budgets for different climate scenarios. Information gained would provide indications as to what may happen to Canada's forests under different climatic conditions and how we should change our forest practices.

"We don't have all the knowledge and data to be absolutely certain how the forest will respond but we do have some pretty good indications." he said. "I think that over the next few years our Forestry Canada team, working with other scientists across the country, will make some real breakthroughs."