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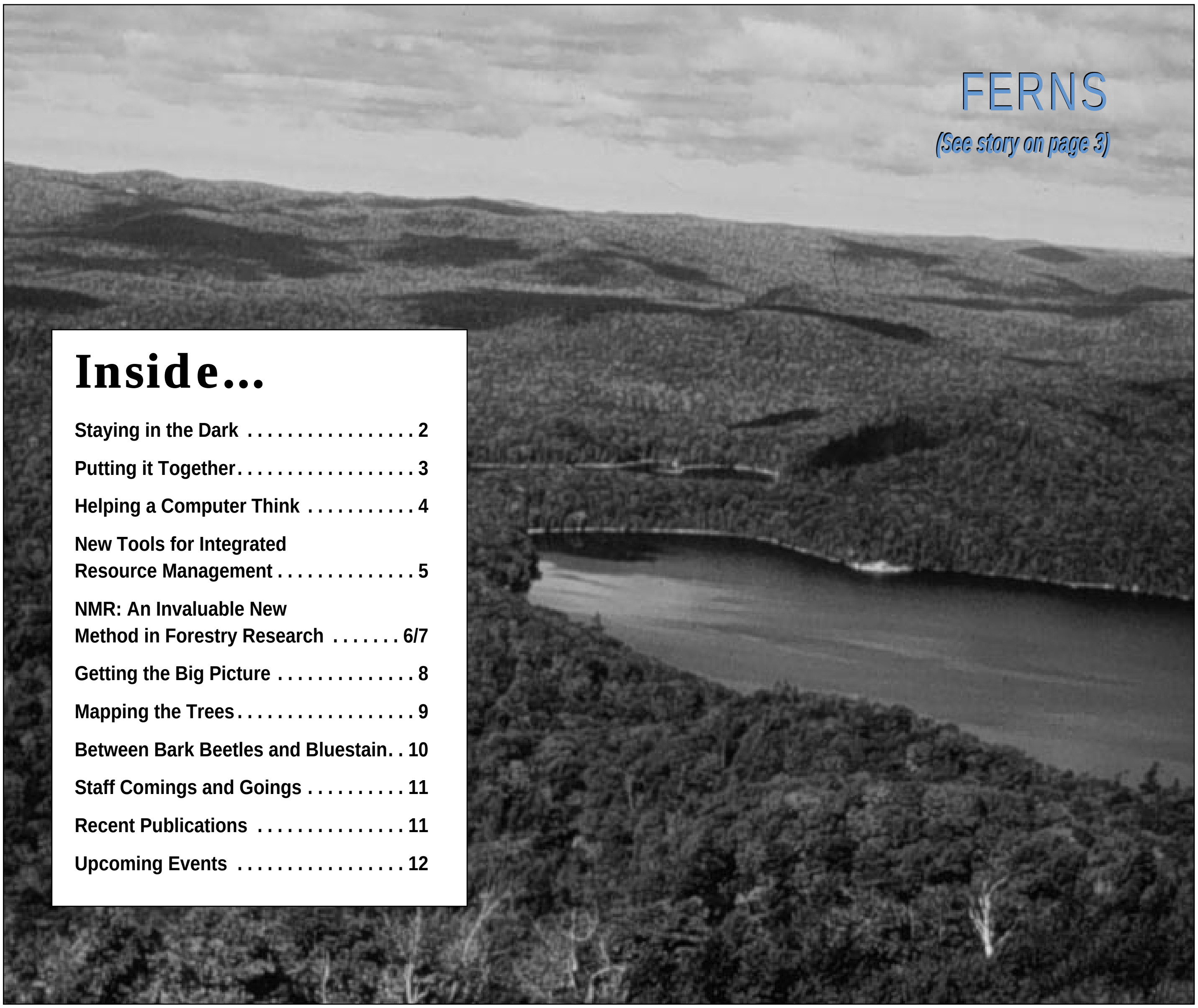

FERNS

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Natural Resources Canada
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Canada

Staying in the Dark:
A mountain hemlock genetic diversity study

"There is a greater need to know more about mountain hemlock, including its germination needs."

The Canadian Forest Service is in the dark when it comes to mountain hemlock seed germination and researchers have discovered that being in the dark is just what the species prefers.

"Although much has been published on the ecology and silviculture of the species (Mountain hemlock: an annotated bibliography, Edwards & Meagher, 1995), we know very little about mountain hemlock seed germination. The tree is considered a minor species in terms of timber value," says Dr. George Edwards, who has worked as a scientist with the Canadian Forest Service for almost 30 years. "However, mountain hemlock serves as a protective cover for watersheds and provides an important wildlife habitat. As logging extends into higher elevations, there is a greater need to know more about it, including its germination needs."

So far, researchers have shed light on one aspect of mountain hemlock seed germination: that the species prefers to be kept in the dark. Studies at the Pacific Forestry Centre revealed that light actually reduces germination. Although only in the preliminary stages, this research has already been applied in the forest industry.

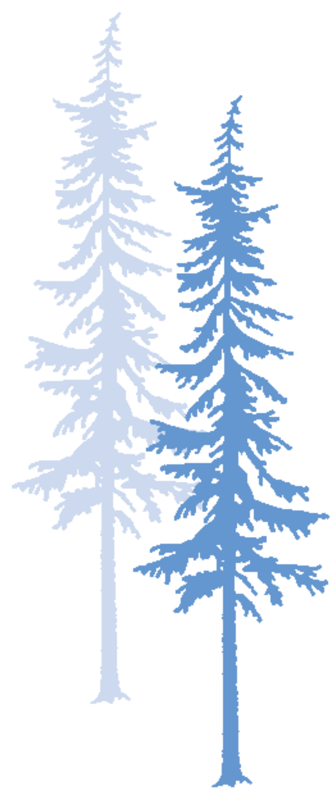
"After discussions with Dr. George Edwards," says Kim Creasey of Western Tree Seeds Ltd. in Blind Bay, B.C., "we tried to see if we could in fact improve the germination capacity and vigour of mountain hemlock by simply stratifying and germinating mountain hemlock in a darkened environment within our cabinet germinator. The result we achieved was that both the germination capacity and vigour proved to be far superior than that of the test set exposed to normal prescribed standards of light."

The research determining that mountain hemlock seeds germinate best in the dark is part of a larger study on the species that focuses on its genetic diversity. Forest inventories usually do not distinguish between western hemlock, mountain hemlock, and other high-elevation species, so it is not known if mountain hemlock is being depleted by current forest practices. Studies will determine if the species varies greatly genetically and how this will affect its ability to adapt to changing environments as well as how readily the species can be moved from one area of its range to another.

"So far, the research suggests that there is little difference between coastal and interior mountain hemlock as far as seed germination is concerned. The seeds from the twenty seedlots that we studied so far have behaved essentially the same. But these are only preliminary results; more experiments with interior sources will give us a clearer picture."

Although it's best for mountain hemlock to be in the dark during seed germination, the Canadian Forest Service is trying to shed light on the germinating process to ensure its future in our forests.

Dr. Edwards can be reached at
gedwards@pfc.cfs.nrcan.gc.ca

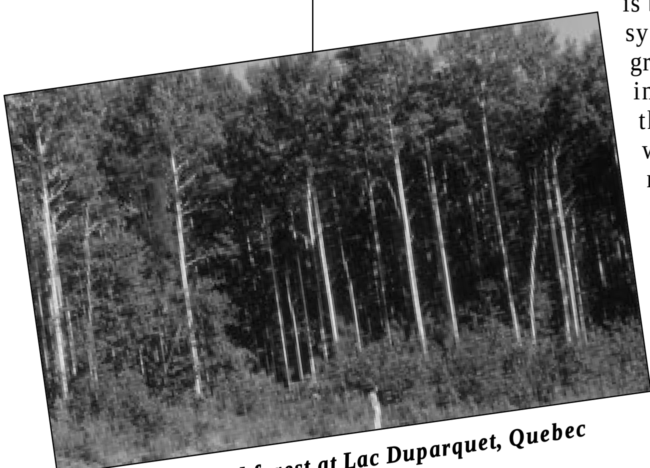


Putting it Together While Keeping it Apart

"FERNS will link researchers...and provide a forum for the exchange of information."

You may think of it as just another humid-loving plant, but FERNS has a different meaning in the Canadian Forest Service.

With forests covering almost one-half of its land mass, and as caretaker of 10% of the world's forests, Canada has a responsibility to secure a sustainable environment not only for itself but for the global community. In this immense country of complex and distinct forest ecosystems, multidisciplinary and multi-partner approaches are essential to research. Across Canada, long-term sustainable forest management and forest ecosystem research sites have been established by federal and provincial governments, universities and industry to address sustainable development issues. The Forest Ecosystem Research Network of Sites (FERNS) is being developed to synthesize and integrate scientific information across these research sites while having each remain autonomous.



Mixedwood forest at Lac Duparquet, Quebec

"FERNS will link researchers working at the various sites and provide a forum for the exchange of information," explains Jim Wood, coordinator of FERNS under the Effects of Forestry Practices Network of the Canadian Forest Service. "It will also provide an important link between researchers and clients. We want to promote these valuable long-term forest management research sites at both the national and international levels." FERNS is open to federal, provincial, university and industrial long-term multidisciplinary research sites that are focused on the study of forest management practices at the stand or watershed levels.

By providing opportunities for comparative and collaborative research, FERNS will promote inter-agency cooperation between governments, universities and industry. It is a means to create a sense of unity among forest ecosystem management researchers throughout Canada and ultimately around the world.

An example of a FERNS site is the Hotchkiss River Silvicultural Study in northwestern Alberta. This project has a planned 20-year series of harvests and surveys to study the effect of innovative silvicultural and harvesting techniques that protect understory white spruce during the harvest of deciduous overstories. It is also a study in how alternative silvicultural and harvesting methods provide post-harvest wind protection and realize the growth potential of residual white spruce. The project also applies new methods to encourage natural regeneration of deciduous trees in stand openings that are created by harvesting.

"FERNS is a great way for the Hotchkiss study to gain a national focus," says Dan MacIsaac, CFS program coordinator for the Hotchkiss River Silvicultural Study (working through the Northern Forestry Centre in Edmonton, Alberta). "The response to FERNS by Hotchkiss partners has been very positive."

Another example of a FERNS site is the Lac Duparquet Research and Teaching Forest located in the heart of the boreal shield ecozone in northeastern Quebec. The research and teaching forest, run by the University of Quebec, is being used as the basis for the development of new silvicultural approaches aimed at maintaining biodiversity and long-term ecosystem productivity under management. About 75% of the 8000 hectare forest is devoted to ecosystem management research while 25% will remain protected for study of long-term natural forest ecosystem dynamics, monitoring, and for compatible, low-impact uses.

FERNS will not only enhance communication between researchers and forest managers within these and other sites across the country, but will preserve the long-term research investments of these sites so they remain accessible throughout the country. This integrated Canada-wide approach is consistent with the new global scientific culture in which archiving and inter-connectivity of data is becoming increasingly essential.

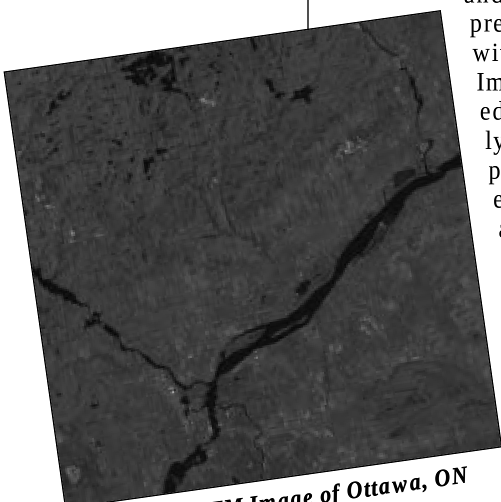
Jim Wood can be reached at
jwood@pfc.cfs.nrcan.gc.ca

Helping a Computer Think

"Image analysis has to be automated if the results are to be promptly and understandably displayed"

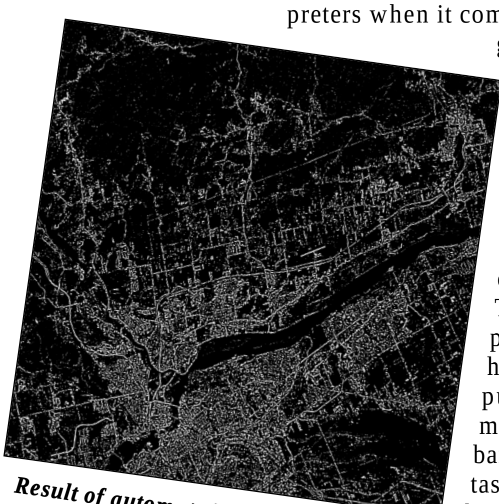
The weather satellite images on the evening newscast show what remote sensing can do," says Canadian Forest Service scientist Dr. Joji Iisaka. "The cloud movements they show are easily understood by everyone. Imagine having similar images of the landscape, showing the changes underway and allowing us to zoom in to localities of interest. We'd be as familiar with the whole province as with our neighbourhood park."

"The problem isn't only getting the images," explains Iisaka, working in the Landscape Management Network. "A growing flood of images flows from new sensing technologies. The problem is analysing, interpreting, and representing. Human interpreters don't have time to deal with 90% of the data collected. Image analysis has to be automated if the results are to be promptly and understandably displayed. Automation becomes even more important as images are analysed to generate an ever-broader range of information on physical and biological change."



Landsat TM Image of Ottawa, ON

The key obstacle to automation, says Iisaka, is the detection and recognition of physical features from spatial patterns. Computers lag far behind human interpreters when it comes to distinguishing roads from streams, dams from bridges, or clearcuts from natural clearings. Tackling the problem of helping computers surmount this barrier is the task Iisaka has brought with him to the Pacific Forestry Centre from the Canadian Centre for Remote Sensing in Ottawa. His specialty is the development of algorithms, mathematical rules and procedures used by computers to perform a task. He uses advanced computing functions for new approaches to image analysis.



Result of automated road feature extraction employing brightness, non-vegetation and line-like features

For example, he has pioneered the innovation of "pixel swapping" in digital images. By shifting an image over itself slightly in eight directions, he uses changes in the pixel values to reveal surface features. These can be point-like (trees, towers, rocks), line-like (roads, power-lines, streams), or area-like (man-made simple shapes like fields or clearcuts, natural irregular shapes like forests and lakes).

His software then applies rules to identify features and to call attention to uncertainties. His method can distinguish the smooth curves of a road from the irregular curves of a stream. When a probable road crosses a probable stream there is a probable bridge. If a stream narrows and there is no road, the bridge is more likely a dam. Iisaka's programs educate the computer to make such distinctions.

The approach also overlays information. For example, a line-like feature that tends to ignore topography is probably a power line. To integrate many kinds of information, including factors that are vaguely distributed and not "crisp", the software incorporates principles of fuzzy logic and combinatory logic. These shortcuts also avoid lengthy computer processing, accelerating results. The goal is to be able to generate interpretations without delay using only the processing attainable in a desktop computer. The approach is being tested on a patch of forest in the Prince George District.

Joji Iisaka's work is enhanced by extensive contacts with scientists in Japan and throughout the Pacific Rim. Currently he is involved in project proposals to use the software in Brazil, for analysis of the Amazon rainforest, and in Indonesia, to track human migratory patterns.

Dr. Iisaka can be reached at
jiisaka@pfc.cfs.nrcan.gc.ca

New Tools for Integrated Resource Management

"Our tools will help managers analyse alternatives."

Forests are increasingly valued and managed for more than their timber resources. To support multiple forest land uses and a variety of users requires an Integrated Resource Management (IRM) approach and new planning tools. Developing those tools is the task of Canadian Forest Service scientist Dr. Robin Quenet and others in the Landscape Management Network.

Historically, forest management has focused on timber. It allocated land resources primarily for timber extraction. This planning approach, when broadly applied, results in a mosaic of single use areas. IRM integrates the sharing of resources among diverse interests and users. As a result, the traditional mosaic of areas with single uses gives way to a mosaic of planning zones integrating and regulating multiple uses.

IRM creates a new world for planners. Instead of enabling a single type of management, planners now must set the stage for a variety of managers. They face a diversity of goals, stakeholder values, and data sets. They have to consider resource conflicts and interactions and foresee how these could be altered by different planning strategies. To test the alternatives, they use computer projections of "possible futures". These techniques not only are data-intensive but also require the integration of many kinds of information from diverse sources. IRM thus places unprecedented demands on information management.

Quenet points to the enormous amount of information contained in the vast number of databases compiled during the long history of resource planning. This information has been collected to very different standards, scales, and projections and is stored in different formats. These incompatibilities make integration difficult. Databases frequently do not have an adequate "data dictionary", the crucial manual that explains how the data are structured, how they interrelate, and how they can be used. These dictionaries, indispensable for sharing data, are becoming more common as stakeholders see the need to work together.

"In developing IRM planning tools," says Quenet, "I've found that the Pacific Forestry Centre provides a wonderful scientific resource. The broad expertise of the staff will greatly assist us in interpreting the interrelationships among data sources."

Quenet's project organizes the data in a way that reveals potential interactions and conflicts in resource use. For example, by relating a proposed cutting sequence to ecological data, participants can envisage how the forest structure would change through the years, and how these changes may affect wildlife habitat. That leads to modifications. "The goal," he says, "is to describe the landscape we'd like to see and then develop management strategies that will achieve it."

Making this information easy to understand and use is particularly important. Quenet points out that a user-friendliness is essential in IRM to support joint decision-making by stakeholders. "Our tools will help managers analyse alternatives," he says. "They will select the strategy they want."

Dr. Quenet can be reached at
rquenet@pfc.cfs.nrcan.gc.ca

Forests are valued for more than their timber resources.

NMR: An Invaluable New

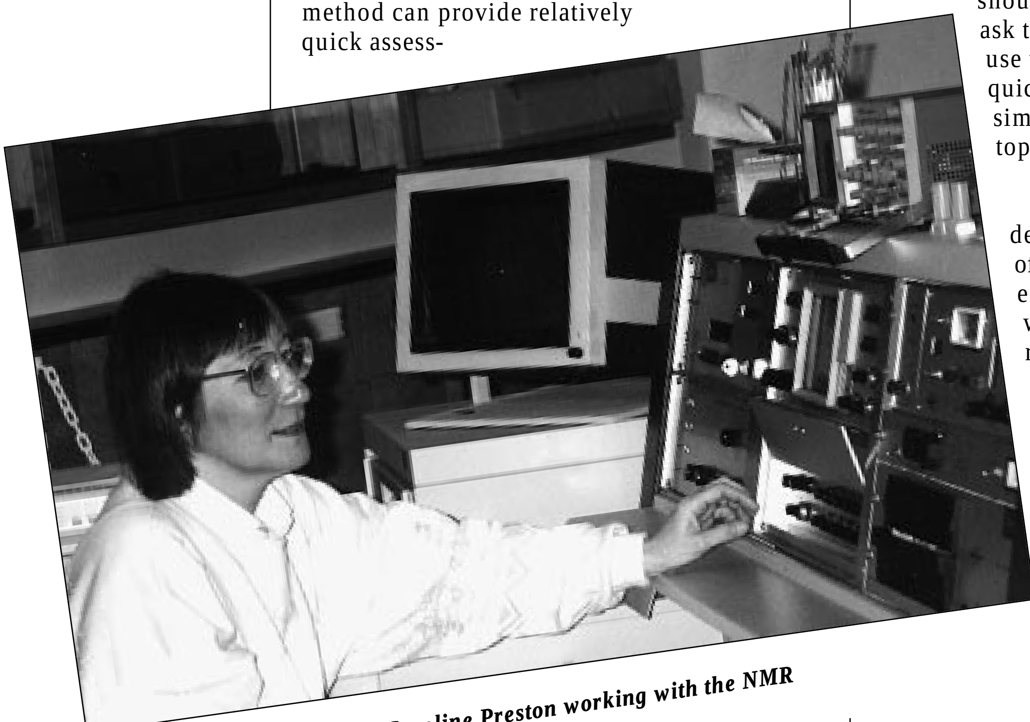
"Unlike current methods, this NMR process is both fast and non-destructive."

Spinning Seeds at a Magic Angle

Not since Jack and the Beanstalk has magic been so associated with seeds.

A nuclear magnetic resonance (NMR) technique using carbon-13 magic angle spinning has been developed to assess the readiness of conifer seeds to germinate. Unlike current methods, this NMR process is both fast and non-destructive.

"Until now there has been no rapid, simple technique for assessing the readiness of conifer seeds to germinate," says Dr. Caroline Preston, research scientist in the Forest Ecosystem Processes Network of the Canadian Forest Service. "We have found that this NMR method can provide relatively quick assessments without the need for extraction, purification or separation of the seed which is normally necessary in germination studies."



Dr. Caroline Preston working with the NMR

The production and planting of seedlings is essential to sustainable forestry. In B.C. alone, at least 600 million seeds including 22 species of conifers must be sown annually. Although seed cost is minimal, germination failure rates range between 1% and 100% and can be very expensive. Traditionally, extra seeds are placed in one container to increase the odds of germination, but these must be removed manually when one of the them germinates, which is time-consuming and costly. Also, such multiple sowings may waste seeds that are scarce. However, the carbon-13 magic angle spinning (the optimal angle at which a solid behaves like a liquid) NMR technique eliminates the need to plant extra seeds. It increases the germination success rate by determining the readiness of the seed to germinate without destroying the seed resource.

"Although not practical for routine applications, the carbon-13 NMR is proving to be an excellent research tool," Preston explains. "It should speed up research and help us ask the right questions. The hope is to use the information to develop a quick test process based on the much simpler technique of using a bench-top proton (1H) NMR."

How is readiness to germinate determined by NMR? "The low rate of respiration of dry seeds increases rapidly as the seeds take up water and, at the same time, reserve materials in the seed begin to break down. During germination of seeds in which lipids are the major reserve (like conifers), there is a reduction in total fats as metabolic activity proceeds. Lipid bodies contain the enzymes required to break down the lipids into fatty acids, which are then processed further by hydrolysis and oxidation." Carbon-13 magic angle spinning NMR provides insight into changes in the lipid components during the germination process well before visible changes occur.

High resolution NMR reveals carbon components in seeds (such as soybeans) that, although they look solid, at the microscopic level have a molecular mobility similar to liquids. But in conifer seeds, microscopic oil droplets are embedded in other components and differences in magnetic susceptibilities cause severe line broadening in NMR spectra. Carbon-13 magic angle spinning at relatively low speeds (500-100Hz) however, has been found to eliminate line broadening in spectra of fruits and tree seeds. Preston and her colleague, Brian Sayer in the Department of Chemistry at McMaster University, found that the NMR method is ideal in determining readiness of seeds to germinate within two days after stratification (a process of subjecting the seed to moisture and chilling to "wake" it from its dormant state). Although application of high resolution carbon-13 NMR to tree seeds has been demonstrated before, this is the first time it has been directly applied to forestry research.

NMR: A 50 Year Old New Idea

Less time-consuming and less destructive thus less expensive and less wasteful. That's what NMR spectroscopy offers forestry research.

Although NMR techniques are used extensively in many areas of research including agriculture, the Pacific Forestry Centre is the only forestry lab in Canada, and possibly in the world, that has exclusive, modern, in-house NMR capability for both solution- and solid-state samples.

Besides seed germination, NMR spectroscopy at the Pacific Forestry Centre is used to characterize carbon-based components and their transformations in litterfall, the forest floor, soil organic matter, and dissolved organic carbon, including the ecological role of tannins. Projects have been carried out in a variety of coastal and interior ecosystems, including the Salal Cedar Hemlock Integrated Research Program (SCHIRP) which investigates problems of nutrient limitation and vegetation competition in cedar-hemlock cutovers.

"We've applied NMR techniques to just about anything available in the forest, from the forest floor to the leaves in the canopy," says Preston. "We have looked at humic substances in the soil and sugars in the wood. We've used the NMR to look at wood rot and studied how needles change when they hit the forest floor. And it's been indispensable to our work with tannins. We can extract and purify our own tannins and use them as standards in our analysis. Also, there is potential to develop rapid tests using the simpler, cheaper benchtop proton (1H) NMR. The application of NMR to forestry research is endless."

Despite its success in helping scientists to understand the nature of the forest and the effects of cultivation, NMR spectroscopy remains an underutilized resource in forestry research. It's a situation Dr. Preston hopes will change as more researchers realize the benefits of NMR.

"I believe there are at least three major areas of forestry research that could greatly benefit from NMR analysis. Besides using it to understand the germination process, nuclear magnetic resonance would be helpful to studies in moisture content, which plays a critical role in all aspects of seed science, technology and trade. As well, the research potential of applying it to cold hardiness is tremendous. By examining a few needles using NMR techniques, one can determine whether a tree is frost hardy or has frost damage in far less the amount of time it takes to examine them by traditional methods."

NMR technology is over 50 years old, but applying NMR methods to forestry is still a new idea. Through the efforts of researchers such as Caroline Preston, it's potential as an effective research tool in the forestry field has not gone unnoticed.

Dr. Preston can be reached at
cpreston@pfc.cfs.nrcan.gc.ca

Getting the Big Picture

"The idea is to find the best balance for forestry given the technology available."

"Everyone wants better information on forests," says Canadian Forest Service scientist Dr. Don Leckie. "Timber companies want more accurate data at lower cost. Governments want greater accountability in forest practices. Tourism and recreational interests are concerned about multiple forest uses and non-timber species. Biologists care about ecology, and environmentalists about sustainability. These demands push far beyond the limits of traditional information-gathering methods."

A most important opportunity is high-resolution imaging. "Forest inventorying is still mainly done by human interpretation of aerial photos," Leckie points out. "Interpreters identify stands of trees and estimate the species. Computers are only used to display interpretations in Geographic Information Systems. We really need computerization throughout, from acquisition of digital images to helping the human interpreters. But to do this properly, we have to be able to count up from individual trees."

This was the goal of the Digital Remote Sensing Project at the Petawawa National Forestry Institute. Leckie was project leader and worked with Dr. François Gougeon, who continues research on individual tree crown recognition at the Pacific Forestry Centre (see page 9). Their project developed image processing and analysis methods with the Multispectral Electro-optical Imaging Scanner (MEIS). The techniques they developed included image enhancement and correction for problems such as aircraft instability and the varying reflective angles of sunlight in different parts of the image.

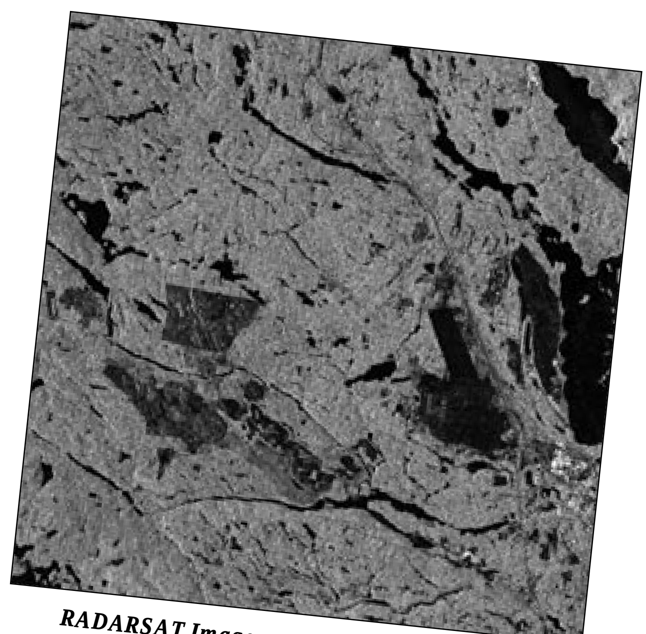
"It's all a matter of balance," says Leckie. "As you go to higher altitudes, the resolution declines but fewer image corrections are needed, so interpretation is easier to automate, and more area can be covered in a single pass. The idea is to find the best balance for forestry given the technology available. MEIS showed how to do that."

Remote sensing is also valuable for disease control in determining the area and extent of infestation. Traditionally, a disease site is examined visually and sketched by observers in low-flying aircraft. Remote sensing with analysis of light spectra can already detect three or four levels of damage at 75% accuracy and is improving all the time. Eventually, remote sensing will be used for disease detection as well as for assessment.

Another of Leckie's interests, radar, is the main Canadian specialty in remote sensing. Canada's original interest was in gathering information on arctic ice conditions, for which radar is well suited. The technology has since been applied to other areas, such as forestry, an application on which Leckie is an authority. Radar has the important advantage of producing images during cloudy weather. In the Amazon and other tropical rainforests, which are under cloud for long periods, radar can be an important means of mapping clearcuts.

Leckie looks forward to new kinds of data from advanced airborne and satellite sensors. But he also values more traditional satellite information. "We have a real treasure in 25 years worth of Landsat data at 30 metres resolution, which is wonderful for showing long-term changes in forest patterns." Using this resource, he has compiled a video which dramatically portrays the progress and regrowth of clearcuts.

Dr. Leckie can be reached at
dleckie@pfc.cfs.nrcan.gc.ca



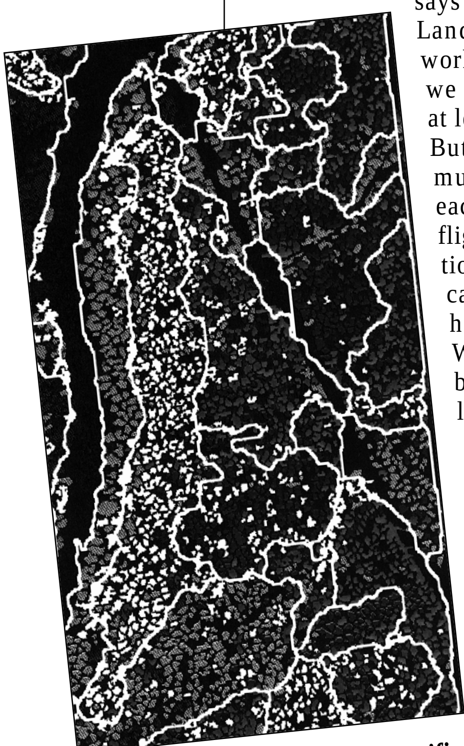
RADARSAT Image, acquired April 5, 1997, of Petawawa Research Forest, Canadian Forces Base Petawawa and surrounding area.

Mapping the Trees

"Each improvement in spactial resolution brings a need for new analytical techniques."

Airborne remote sensing technology now enables forest analysts to distinguish individual tree crowns. This opens the possibility of replacing forest stand estimates with precise measurements. But with millions of trees to be counted, such measurements could only be done by computers, which do not yet have anything like human capabilities for pattern recognition. Canadian Forest Service scientist Dr. François Gougeon has taken on the challenge of developing software to enable computers to automate the analysis of tree data in digital images.

"Each improvement in spatial resolution brings a need for new analytical techniques," says Gougeon, working in the Landscape Management Network. "To see individual trees, we need a spatial resolution of at least one metre per pixel. But we also have to cover as much ground as possible with each flight line to reduce flight costs and image correction. As sensors improve we can get that resolution from higher and higher altitudes. Within a year, we'll almost be able to get it from a satellite."



The individual tree crown classification of the Nahmint Lake species trial area in the central forest of Vancouver Island, B.C.

François Gougeon came to the Pacific Forestry Centre from the Petawawa National Forestry Institute, where he began developing automated image analysis with Dr. Don Leckie (see page 8) and others. His approach, presented in a suite of computer programs, has three stages.

The first stage is to delineate individual tree crowns using shading patterns. Seen from above, a sunlit coniferous crown may be distinguished from its neighbours by margins of shadow. The shadows are wider when the sensor looks towards the sun, because the shadowed sides of trees are more visible. When the sensor looks the other way, in the same direction as the sun's rays, it sees mainly the sunlit sides and fewer shadows. The computer has to be taught how to recognize similar crowns among the changes in sunlit shapes from one side of the image to the other. Sloping terrain similarly changes lighting patterns. The new programs try to account for these and other factors to show individual trees with counts, density, coverage, and gaps.

The second stage is to identify the species of each crown from the "spectral signature" of the light reflected from its leaves. The computer has to learn to take account of the colour differences caused by the different angles of reflection across the image. The result is a species count and distribution. A current challenge is to improve the validity of spectral identification and the transferability of spectral signatures between images.

In the third stage, the crowns, artificially coloured by species, are grouped into stands judged uniform in species composition. This information can then be linked with traditional inventories residing on Geographic Information Systems for presentation and analysis.

Tests comparing the results with actual tree counts on the ground show that the new software is already at least as accurate as human interpretations in relatively flat terrain. Further development and tests are steadily improving performance on irregular topography. In the softwood forests covering much of B.C., the regularity and separation of tree crowns assists automated identification.

While Gougeon eagerly awaits data from the new earth observation satellites to be launched in 1998, he also sees a complementary role for aircraft images. A satellite's biweekly passage may coincide with a cloudy day. But aircraft can be sent immediately for updates of changing situations. Airborne imaging with very high resolution will be especially important for information on regeneration, disease propagation, and other local circumstances requiring close monitoring.

Dr. Gougeon can be reached at
fgougeon@pfc.cfs.nrcan.gc.ca

The Brotherhood Between Bark Beetles and Bluestain

"Core to the weakening of the tree is the partnership between the insect and the fungus."

It's the epitome of the codependent relationship: the bluestain fungus depends on the beetle to get it into a tree and the mountain pine beetle depends on the fungus to keep it in the tree. This relationship is the most serious threat to mature pines in western Canada.

"The mountain pine beetle is usually the first of a succession of insects to invade mature pines, most often lodgepole pines in B.C.," says Dr. Les Safranyik, research scientist in the Pest Management Methods Network of the Canadian Forest Service. "A number of other phloem feeding insects and wood borers infest the trees as well, but only after they have been killed or weakened by the mountain pine beetle. Core to the weakening of the tree is the partnership between the insect and the fungus."

Mountain pine beetles carry spores of bluestain in the mycangium

The mountain pine beetle carries bluestain fungi while it chews into the phloem or inner bark. Other insects also carry bluestain fungi, but mountain pine beetles have specialized structures called mycangia which carry spores of bluestain. The bluestain fungi are specialized as well in that they produce sticky spores which adhere to the body surface of the mountain pine beetle. Thus, the fungi get into the tree where the spores germinate quickly and penetrate tree cells. Normally, the tree will "flush out" the insect by releasing a flow of primary (preformed) resin into the egg gallery or secondary resin formed in the cells adjacent to and in response to the injury. But the bluestain fungi kill these cells so resinosis is no longer a threat to the beetle, thus host colonization is secured.

Soon after boring into the bark, female beetles produce and release chemical attractants (pheromone) which trigger a massive beetle attack on the tree. After mating, the female burrows up the stem in the inner bark region, laying eggs along the sides of the egg gallery. About two weeks later, the eggs hatch and the larvae mine galleries circumferentially, in the inner bark that is colonized by the bluestain fungi. When mature, these larvae pupate in chambers that are lined with the fungi, which the young beetles feed on to complete their maturation. Then the adult beetle leaves the tree, carrying the fungi to other trees not only in the mycangium, but on their bodies.

"Bluestain fungi kills cells quickly radially and vertically in the bole," adds Dr. Ralph Nevill, also a research scientist at the Pacific Forestry Centre, "but circumferential spread is enhanced by beetle larvae that mine their way outward, thereby transporting the bluestain throughout the tree."

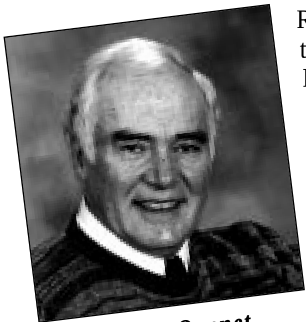
The fungus seems to benefit the beetle not only in the process of weakening the tree but by supporting the insect nutritionally as well. Studies have shown that when deprived of the fungus, adult mountain pine beetles do not attain their normal black or dark brown colour.

"There seems to be a nutritional role in primary bark beetles (those that attack apparently healthy trees like mountain pine beetles) as well as in secondary beetles (those that attack weakened trees or enter the tree after the primary beetles)," says Nevill. "The secondary bark beetles also carry bluestain fungi, although it is different from the one introduced by the primary beetle. We are not certain, but we suspect this may also be for nutritional reasons."

Such questions are only the beginning of the research needed to fully understand the mountain pine bark beetle's symbiotic relationship with the bluestain fungus. And that relationship appears to be a key to curbing the loss of pine trees.

For more information, please contact jsafranyik@pfc.cfs.nrcan.gc.ca or ranevill@pfc.cfs.nrcan.gc.ca.

Staff Comings and Goings


Robin Quenet

Robin Quenet

Robin has returned to the Pacific Forestry Centre to work as a research scientist in the Integrated Resource Management section of the Landscape Management Network. *(See page 5.)*

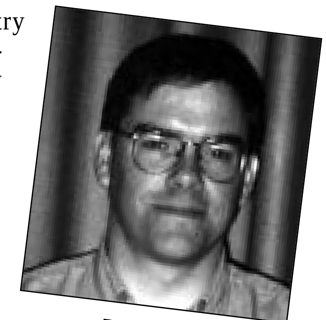
Bill Wagner

Bill has arrived at the Pacific Forestry Centre to work as the Model Forest coordinator. The Model Forests Program stretches across Canada and throughout the world, promoting the creation of partnerships to implement and test sustainable forestry practices. Bill is the coordinator for two of the Model Forest sites: the McGregor Model Forest near Prince George, B.C. and the Long Beach Model Forest which hugs the west coast of Vancouver Island. Bill is a registered professional forester who has worked as a timber supply analyst for the B.C. Ministry of Forests as well as the USDA Forest Service. He has also owned and operated a forest consulting company.


Bill Wagner

Dave Hill

Dave has come to the Pacific Forestry Centre to assist the lead scientist of the Digital Remote Sensing Project and other team members in planning, conducting and reporting investigations on the use of remote sensing technology for forest resource monitoring and assessment *(see page 8).* While working in the private sector, Dave has developed applications for the Compact Airborne Spectrographic Imager (CASI). He has also worked for the B.C. Ministry of Forests, providing imagery for the province's Forestry Update Program.


Dave Hill

Recent Publications

Yew Big Bud Mite
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Upcoming Events

1997 Western International Forest Disease Work Conference
September 15 - 19, 1997
Prince George, B.C.

The 1997 Western International Forest Disease Work Conference promises to be an interesting conference in a location highly conducive to discussions on a wide variety of forestry and land use related issues. The conference will include topics such as boreal disturbance ecology, mixedwood management, and forest health. For further information contact the program chair, Dr. Kathy Lewis at (250) 960-6659 or LEWIS@UNBC.EDU.

Part Cuts '97: Meeting Multiple Objectives by Partial Cutting: Research and Equipment Demonstration
September 24 - 25, 1997
Cranbrook, B.C.

This workshop is designed to increase familiarity with partial cutting procedures and considerations. Topics to be explored include relating machinery operations to equipment productivity and residual stand requirements; maintaining windfirmness and forest health of the residual stand; and biodiversity considerations in partially cut stands. Field trips will demonstrate several equipment types and their productivity, methods for removing smaller diameter trees, and the manufacture of value-added products. For more information, contact the BC Forestry Continuing Studies Network at (250) 365-7292.

Fire and Ecosystem Restoration in Dry Interior Forests in Southern BC
September 29 - October 2, 1997
Fort Steele, B.C.

This symposium includes renowned scientists speaking on fire ecology and ecosystem management, and the ecological impacts of current management practices. There will be presentations incorporating fire ecology issues into operational and higher level planning processes, plus discussions on risk management. Presentations will alternate with field tours where participants can see actual fire ecology projects. For more information, contact the BC Forestry Continuing Studies Network at (250) 365-7292 ext. 357.

Structure, Processes and Diversity in Successional Forests of Coastal British Columbia
February 17 - 19, 1998
Victoria, B.C.

The main purpose of this workshop is to share findings from recent studies in forest types of coastal B.C. on the effects of converting old-growth forests to managed forests, how various ecosystem attributes change during stand succession and the extent to which they are restored as forests mature. Topics will include: changes in stand structure and composition; site carbon and nutrient balance; and species diversity focusing especially on those species with low dispersal capabilities. For more information contact the Canadian Forest Service at (250) 363-0737 or check http://www.pfc.cfs.nrcan.gc.ca

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Editor: Joanne Stone
Layout: Jennifer Adsett
Writers:
Joanne Stone
Larry MacDonald

For further information:
Phone: (250) 363-0606
Fax: (250) 363-6006
Email: jstone@pfc.cfs.nrcan.gc.ca

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