branch lines

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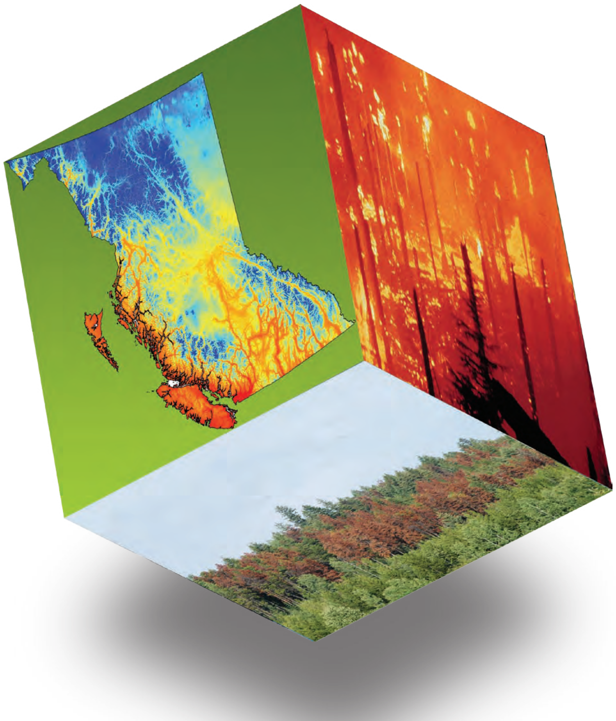
Future forest ecosystems

Ecological and management stresses (e.g. climate change, wildfire, insect attack) are seriously impacting the forests of British Columbia. In December, 2005, British Columbia's Chief Forester, Jim Snetsinger, held a symposium to evaluate the current forest management paradigm and to determine how we can prepare to manage our forests in light of these changes. Four researchers from UBC's Faculty of Forestry were invited to contribute to this two-day event hosted by the University of Northern British Columbia in Prince George. Dr. Rob Kozak (page 2) opened the discussions with a paper that provided a global context for envisioning future forest conditions. Dr. Suzanne Simard (page 4) provided a review of some of the unintended effects that reforestation and harvest practices have had on ecosystem patterns and processes across multiple scales in BC. One of her themes, that "diversity begets resilience", was underscored with examples throughout the conference. Dr. Sally Aitken's presentation (page 6) focused on the need to consider changing how we select species and seed sources for reforestation in anticipation of future stresses such as climate change. Finally, Dr. Bruce Larson provided closing comments for the first day by suggesting that continuous planning is the best approach to dealing with changing needs, objectives and ecological stresses. This suite of presentations provided some provocative ideas that we are sharing with our readers in this issue of Branch Lines.



Also in this issue we continue to describe the Faculty's research that relates to the mountain pine beetle (MPB) and its impacts. We highlight Dr. John McLean's trials testing the effects of nitrogen fertilization; Dr. Kathy Martin's research on the impacts of the MPB on wildlife ecology, particularly cavity-nesting birds and mammals; and Dr. Markus Weiler's studies of MPB impacts on hydrological cycles in watersheds.

Your feedback is always welcomed.

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The future of BC's forests – a global context

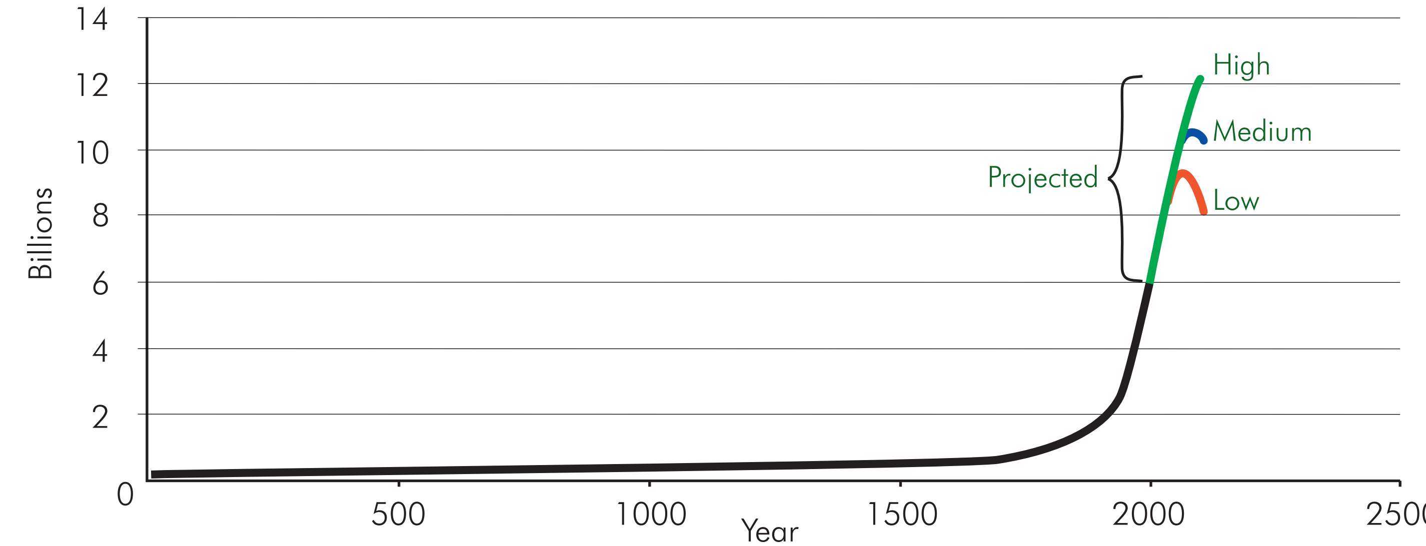
Some of the key objectives of the recent BC Ministry of Forests and Range Symposium on Future Forest Ecosystems were to "identify the current and future conditions of British Columbia's forests", to "review our current forest management paradigm", and to "determine potential improvements [to it] in light of forecasted changes." Given that any discussion of future forest conditions must be inextricably tied to concepts of sustainability and sustainable development, I would suggest that this is a logical starting point for such a lofty dialectic.

We are all familiar with the constructs of sustainable development, the most common refrain originating in the Brundtland Report, Our Common Future (everybody repeat after me): "…development that meets the needs of the present without compromising the ability of future generations to meet their own needs." In forestry, we tend to talk about sustainability in tangible, bite-sized scales that make sense to us – sustainable forest management of individual stands and landscape units. Yet globally, are we sustainable? Let's look at some of the facts.

First and foremost, human population is growing at an explosive rate, tracking towards infinity, and while many of our precepts and notions about our planet may be wrong, we are pretty sure that it cannot support an infinite number of people. A breakdown will have to occur in one form or the other as population levels exceed earth's carrying capacity. And not only is population growing at an alarming rate, but so too is the rate at which we consume resources that are becoming more and more scarce. Simply put, we are not living within our means. Worldwide, we are taking from nature faster than we are putting it back, and this is only exacerbated by the looming forces of globalization. Yet the reality is that population growth and its twin, consumption, hardly ever appear on the sustainability agenda. This is cause for major concern as each subsequent generation will be forced to make tougher and tougher choices with fewer and fewer options. The time to react is now and not when it's too late, but the paradox here is that our society no longer seems to be made up of ***citizens***. Rather, we have become ***consumers*** with no real responsibilities other than the need to meet our increasingly voracious consumer appetites. In short, we have become complacent and seem to lack the resolve to make things better…

Or have we?

Now, I'm not so naïve to believe that all of the world's woes can be single-handedly be tackled with solutions rooted in forestry (no pun intended). And yet I am optimistic. Forests and, by proxy, forestry professionals, clearly have important roles to play with respect to global sustainability. We know that forests cover a huge portion of this planet, providing bountiful goods and services to society as a whole, including food, shelter, medicine, and energy. Forest ecosystems are important repositories for biodiversity and genetic resources and they provide an important regulatory function with respect to climate, water, erosion, and so on. But more importantly, I think that forestry professionals are really well positioned to take a leadership role on many matters related to sustainability by putting forward bold and innovative programs that capture the complexity of forest ecosystems and the needs of communities that depend on them. Why is this? Because, in many ways, foresters are miles ahead of the curve in thinking about these sorts of issues. Who else deals with such complex spatial and temporal scales? What other sectors try to balance a myriad of social, environmental, and economic needs day in and day out? And who else must deal with uncertainty, tradeoffs, and varying futures in the way that foresters do?



Global population (historic and projected)

Source: Bongaarts and Blatao (2000), Durand (1974), Haub (1995), McEvedy and Jones (1978), Nielsen (2005)

Maybe now is the time for the forestry community to catalyze the proverbial "paradigm shift" that we've been hearing about for years. But before we can pretend to undertake something so consequential, we probably need to agree on a strategic vision for BC's forests. If there is an outcome from the Symposium on Future Forest Ecosystems, I would hope that it is about developing such a vision and that it revolves around creating a ***sustainable*** future by managing forests for a wide variety of present and future services. What will this vision look like? Well, in many ways, that's up to forest practitioners and researchers like you and I. But given that we have no clue how and in what form society will value forest goods and services over the next rotation cycle, I think that the most prudent approach would be to manage for long-term and healthy ecosystems consisting of a variety of species, stand types, and ages.

We may also want revisit our current strategy of managing our forests with the *defacto* assumption that their optimal use is in the commodity production of logs, lumber, panels, and pulp and paper. If BC does continue down this path, it's difficult to imagine that we will be able to remain globally competitive, especially in light of globalization and the "wall of wood" that is coming on line from the southern hemisphere. This raises a number of questions related to the production of alternative goods and services from BC's forests. How can we give rise to a meaningful value-added wood products sector as a means of creating more wealth and employment for every cubic metre of wood cut? Are there opportunities for non-timber goods and services ranging from recreation to carbon sequestration to salal? And if we take a more holistic and balanced approach to the production of goods and services, who should have the social license to manage our forests?

These are all tough questions, especially when they are underpinned by the salient need to balance an assortment of ecological, social, and economic values in a manner that is truly sustainable. But they need to be posed and, again, I think that forest professionals are up to the challenge. ***Now*** is the time to create a strategic and sustainable vision for BC's forests and for forestry professionals to lead the charge with bold, forward-thinking, conservation-minded initiatives that serve to maintain the long-term health of forests and the communities that depend upon them.

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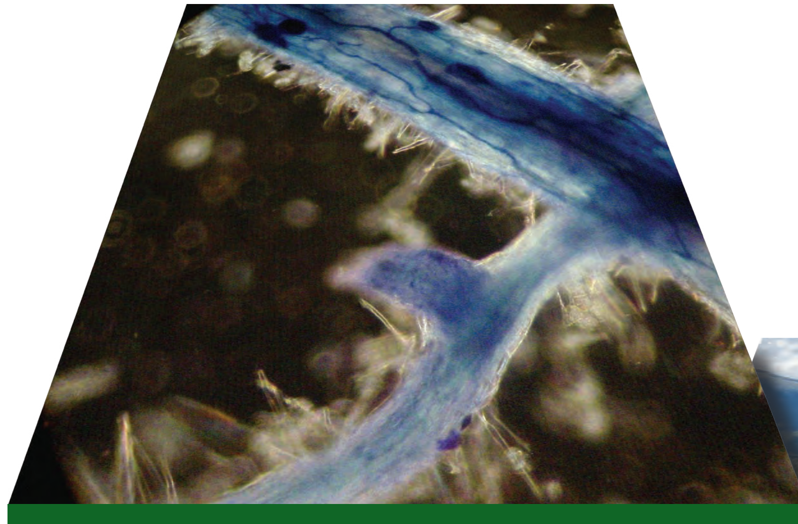
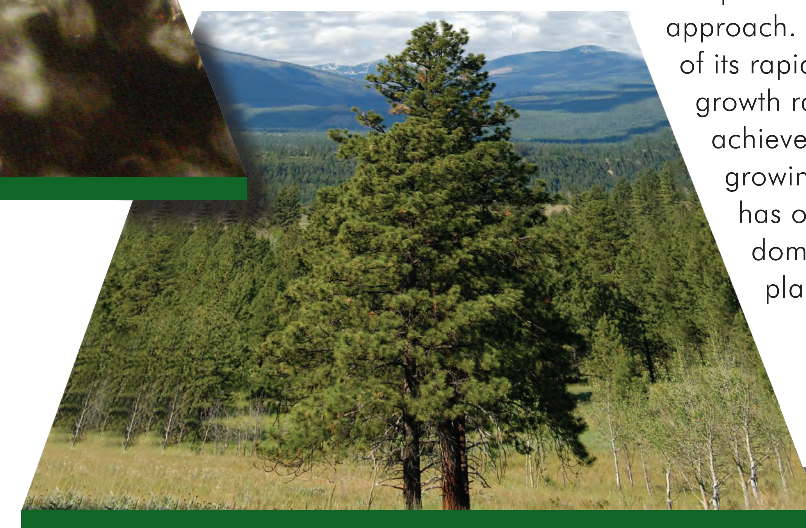
Changes in ecosystem processes and management

British Columbia forests are undergoing rapid change due to a warming climate and large-scale disturbances, and this has been exacerbated by management policies and practices resulting in forest simplification. Increasingly, ecologists point to evidence that simplification compromises ecosystem resilience, and trends in our forests may bode poorly for their ability to respond to stresses brought by a rapidly changing climate. A shift in the provincial management vision, from one driven by lumber and pulp commodity markets to one more strongly based on ecosystem conservation, is necessary to maintain diversity and bolster resilience.





Free-growing reforestation policy, introduced to address poorly stocked plantations and promote rapid conifer growth, combined with forest density rules, have driven a management pathway recently characterized by clearcutting, planting to few conifer species, brushing for reduced weed competition, and conifer spacing. Some interesting trends have arisen following widespread application of this approach. First, because of its rapid juvenile height growth rate ensuring early achievement of free-growing, lodgepole pine has overwhelmingly dominated the provincial planting program.

Second, brushing and spacing have increased asymptotically at considerable expense. Third, young southern-interior wet-belt forests have tended to change from predominantly mixed species to leading in either lodgepole pine or Douglas-fir. Along with these simplifying trends, brushing effectiveness at improving conifer productivity has been questionable. In all but the broadleaf complexes, our research group has found that brushing effects on conifer productivity were marginal to non-existent. Where birch has been weeded, conifer growth has increased, but mortality has also increased due to Armillaria root disease. There are several other potential ecosystem costs of birch removal, including: reduced forest structural diversity; lowered populations of Armillaria-antagonistic rhizosphere bacteria; reduced mycorrhizal diversity and carbon transfer to Douglas-fir; and reduced Douglas-fir productivity over the long term due to loss of N-rich birch litter inputs.

Harvesting practices have also affected patterns and processes at higher scales, and these have the potential to feed back to forest-scale patterns. Historical harvesting practices, for example, have generally reduced forest patch and landscape complexity. Using remote sensing, scientists have found that the rate of harvest has helped change BC high-elevation forests from a net sink to a net source of atmospheric CO_2. The provincial harvest, particularly with beetle salvage, will likely contribute to rising CO_2 levels over the next century. Climate change is already affecting disturbance regimes across BC. The massive mountain pine beetle outbreak, which is expanding northward, upward, and into younger stands, has resulted from a warmer winter climate and an expansive range of lodgepole pine. For cavity nesters, the beetle outbreak has been a boon, at least in the short term. Dr. Kathy Martin (UBC) has found that forest decline associated with bark beetles, combined with warmer winter temperatures, has resulted in higher population densities of cavity-nesting birds in the south Chilcotin. However, beetle salvage harvest has reduced nest sites and cavity nester densities four years after harvest. For hydrological cycles, large harvests encompassing 50-100% of a watershed area, such as is occurring with some beetle salvage, are predicted by Dr. Rita Winkler (MOF) and Dr. Younes Alila (UBC) to increase daily peak water flows by 25-50%.

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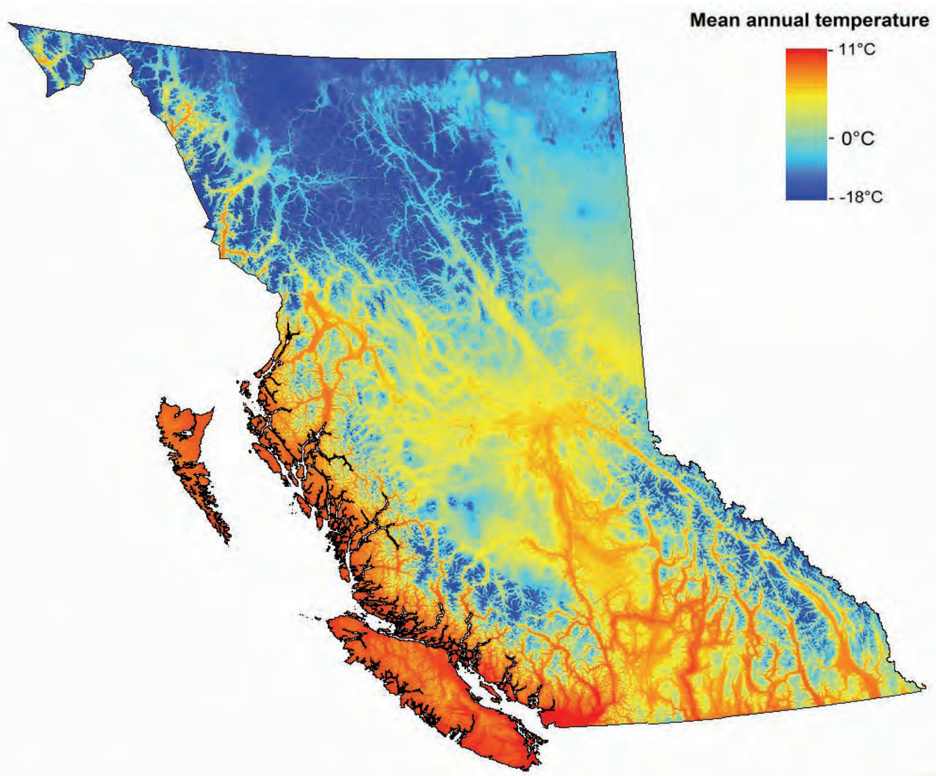
Species and genetic selections in a changing climate

With the predictions of rapid climate change this century, we need to consider changing how we select species and seed sources for reforestation in anticipation of future environments. By combining a regional climate model (e.g., ClimateBC - www.genetics.forestry.ubc.ca/cfgc/climate-models.html) with the current geographic range of a species, the 'climatic envelope' of a species can be determined. Using various climate change scenarios, it is possible to predict the future location of a species' climatic envelope. Predictions like these indicate that the climate in the Peace River region of Northeastern BC could support ponderosa pine by 2080.



Current mean annual temperatures (British Columbia)

However, such rapid species migration is not possible unless facilitated by humans. While climatic envelope shifts are easy to predict, they are based on many assumptions and extrapolations and do not account for limits to migration such as seed production and dispersal, disturbance regimes, competitive interactions, pests and pathogens, and geographic barriers.

Relationships between climate, survival and growth, and the limits to species ranges need to be better understood for all species in order to plan reforestation for the future. Possible range limitations include abiotic factors causing seedling damage or mortality (e.g., frost, drought), interspecific competition, low species densities (causing low pollination success or the introduction of maladapted genes through pollen flow) or growing season restrictions on seed production. If frost injury to seedlings is a current limitation, we will need to be more cautious about planting a species into colder climates than if the range is limited by seed production or maturation. There are no compelling reasons to use exotics given our wealth of native tree species, but we should start exploring opportunities for northern range expansion of southern species such as western larch, ponderosa pine and western white pine.

With uncertainty around environmental conditions and a shifting target over time, 'smart' species mixtures may reduce risk. However, if planting density is high and climate changes after crown closure, species mixes may not reduce risk if one species is excluded early in stand development or if the species do not overlap much in climatic envelopes. Species with wider climatic ranges may be safer bets, but more narrowly adapted species offer greater stand and landscape level diversity. Minor species components in mixed plantings may be a good way to operationally test species beyond their current ranges. Stand models could also be used to model mixed stands in changing environments and evaluate factors such as planting density and effectiveness of intimate mixtures of species versus group plantings. Natural regeneration, green-tree retention, and active use or tolerance of broadleaves will contribute to diversity and stand resilience.

Provenance (seed source) selection, seed transfer and breeding are all tools for dealing with climate change. Current seed-transfer guidelines are based on the use of relatively local seed for reforestation within Seed Planning Units but favour movement of seed from warmer collection sites. Seed orchards, containing trees selected as good parents in tree breeding programs, may serve new geographic areas in the future, and seed demands will change geographically with climate change. Provenances vary in response to temperature, and have different optimal temperature limits and ranges at which growth is highest. For lodgepole it appears that productivity will increase with an increase in mean annual temperature of 2°C. This increase can further be enhanced through better matching of optimal provenances or seed orchard seedlots to planting environments rather than by using current seed transfer guidelines. If the climate warms by 4°C, productivity will decline substantially but the losses could be mitigated in some geographic areas by optimizing provenance or seedlot selection.

Uncertainties around future climates and species ranges should make conserving genetic resources a high priority. Of particular genetic value for the future adaptation of species and the use of those species by humans are isolated populations at the margins of species ranges. These populations are likely to contain unique genetic combinations not found elsewhere in the species range, and thus may be adapted to different climates.

Climate change is quickly becoming a reality for forestry in BC. Many major biological responses, like the Mountain Pine Beetle epidemic, could be waiting in the wings. It's time to start considering how best to modify policies and practices for reforestation in these uncertain times to build diversity and resilience into our future forests.

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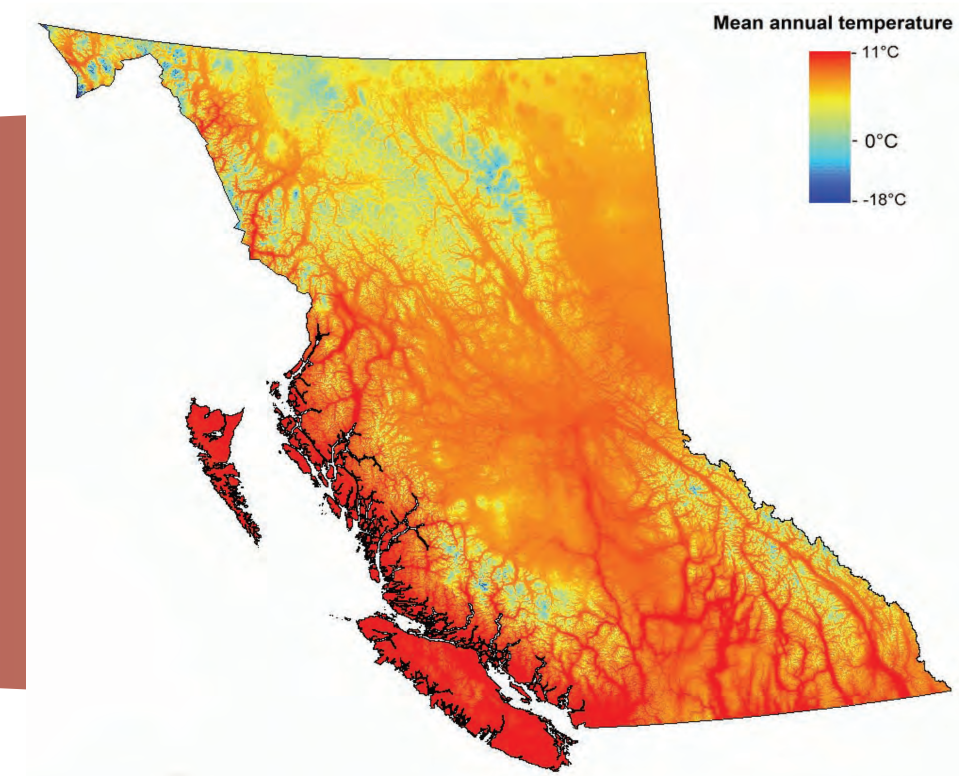


Projected mean annual temperatures for 2085

Alternative management paradigms and their ability to respond to changes

The essence of the meeting and workshops was to consider alternative management paradigms. Although there are many interpretations of what a paradigm is, the concept was first popularized in the late 1960s by Kuhn in *The Structure of Scientific Revolutions*. He described a paradigm as a set of beliefs, theories, or a world view that is unquestioningly accepted and has become established as "truth." We should consider what paradigm for BC forest management is unquestioningly accepted.

Given that there may, or may not, be a paradigm for our management, we can consider historical approaches to forest management. The first approach is what I will refer to as the "don't worry about it" approach. An example was the coppice system in early English history. As firewood was needed stems were cut down and new sprouts appeared. Whatever grew was accepted as the new crop. Another example was the German's land reorganization when farmers were given long narrow strips of forest. The strips went up and down slopes and it was assumed that there was an equality of site productivity.

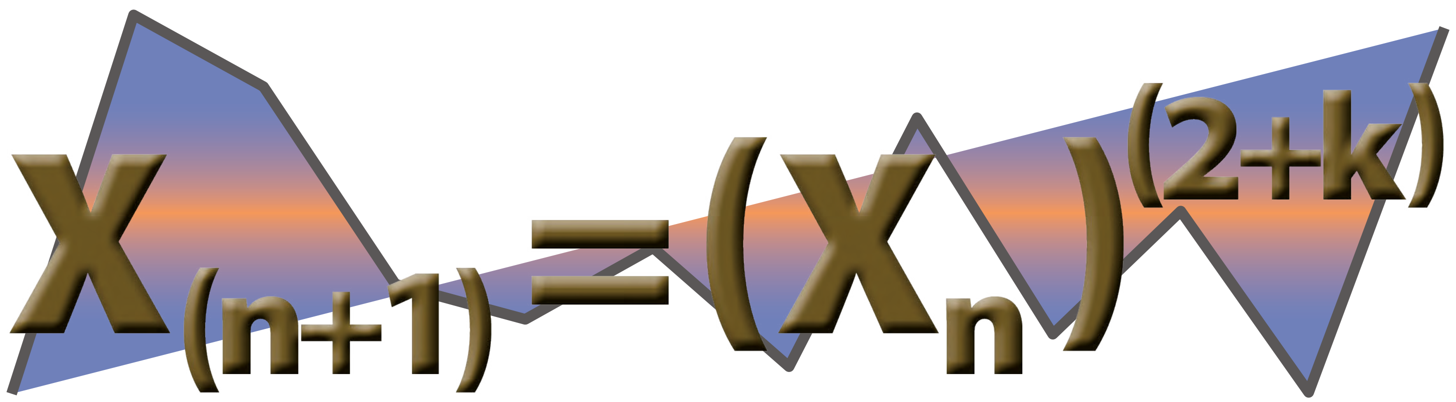
A second approach is non-declining evenflow. This assumes a steady and consistent flow of output. It is usually thought of as non-declining after a preliminary calibration period (such as conversion of old growth to second growth). Non-declining evenflow has become accepted as a basic premise of sustainable forestry.

The third approach is to maximize a single objective with constraints. This was first made popular by Faustman during the last part of the 19th century. He introduced the concept of maximizing net present value (NPV). Later constraints such as minimum wood flow and wildlife habitat were added. With the popularization of linear programming in the 1960s this approach came to dominate management in North America.

The fourth approach is to balance multiple objectives on the same forest. This approach gained wider acceptance as different social groups became dissatisfied with maximization of wood volume or NPV. These two outputs were easily quantifiable and usable in linear programs. Other objectives were added as constraints to the solution. We have struggled with this approach because the number of objectives seems endless and there is great debate over the quantification of many of these objectives and their weighting.

The fifth approach is to manage for ecosystems. This approach can be either ecosystem management which focuses directly on the natural range of variability, or ecosystem-based management if outputs directly consider societal needs, such as timber.

Much has been made of the *zoning* approach involving areas of intensive management, preserves, and extensive management. This looks remarkably like the "don't worry about it" approach. Many variables (such as biodiversity) are relegated to the unmanaged preserves and what will happen will happen. There is nothing wrong with this approach which is a variation of the first approach.



$$X_{(n+1)} = (X_n)^{(2+k)}$$

Mandlebrot set example for k = -1.9

Current discussions assume that sustainable means steady and predictable. This is actually just an extension of the non-declining evenflow approach.

A look at chaos theory shows that it is easy to produce mathematical expressions that will never go to zero, but will appear to be completely unpredictable. A good example is the famous Mandelbrot Sets. Mandelbrot showed that a recursive equation could generate an infinite series of values. This series could be considered sustainable because they varied around an average value. For some coefficients the series of values are quite steady and can be reproduced by a normal non-recursive mathematical function. For other coefficients the series are "chaotic" and unpredictable because they cannot be reproduced by a normal function. These chaotic solutions are very unsteady and unpredictable, but can be considered sustainable because they still vary around an average number.

In other words, absolute sustainability may be very erratic and have unsteady flows of fibre. Sustainability and stability are very different and may, or may not, occur at the same time. Attempts at creating stability ***reduce*** our ability to respond to change.

Planning is essential, but our best approach is probably a system of continuous planning so that we can incorporate our changing needs, objectives, and the environmental conditions such as disturbances. Planning must not only embrace the ideals of adaptive management, but also those of continuous quality improvement.

To take a systems approach to our management we need to consider the patterns and qualities of the system as a whole and forego our reductionist training that we have carefully honed for use in other approaches to management. We also have to be constantly reminded of the conservation of risk and be prepared to live in a world of increasing uncertainty.

It is questionable whether we are managing under a new paradigm, although ecosystem management might qualify. We have to look carefully at our approach or mix of approaches and develop a planning scheme to best address our needs.

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Wildlife biodiversity and MPB in interior forests

In our study of forest wildlife populations in the Cariboo-Chilcotin forests near Williams Lake, recent tree decay has increased drastically, mostly due to a mountain pine beetle (MPB) attack. Forest conditions have changed from ten years ago when more than 90% of the mature conifer trees were healthy to less than 50% of trees remaining healthy in 2004. Much public concern and research has focused on containing the spread of beetles, cutting beetle-killed trees expeditiously and developing markets for this wood (see the September 2005 issue of Branch Lines). However the mixed forests of interior BC support rich communities of forest wildlife including over 172 species of birds. Cavity nesters comprise one special group of over 40 wildlife species that require a tree hole (cavity) for reproduction and survival. Many of these species such as woodpeckers, nuthatches and chickadees nest in unhealthy aspen but feed on invertebrates that live in conifers. Our research monitors the impacts of insect outbreaks and beetle management activities on forest wildlife ecology, particularly cavity-nesting birds and mammals.

Insect outbreaks may have significant impacts on biodiversity in forest ecosystems by altering food availability or habitat suitability for birds. Conifer bark beetle and budworm outbreaks increase the food available for breeding birds, and bark beetle larvae are also a major food for woodpeckers in winter. Thus, an increase in beetle densities may increase population density, breeding success and/or winter survival of forest wildlife species. In our long-term study near Williams Lake, most of the resident woodpecker species have increased since 1999. As

continued overleaf

well, densities of nesting mountain chickadees have tripled and doubled for red-breasted nuthatches. Increased numbers of woodpeckers to excavate cavities may have allowed these small cavity-nesting species to increase as they are often considered to be limited by the availability of cavities for nesting. The recent mild winters also may have increased survival for some species.

Forest birds help to maintain forest health by reducing survival of injurious insects. Many birds feed on MPB and contribute to the regulation of bark beetle populations at endemic and post-epidemic levels. Birds feed on beetles directly, and indirectly increase the death of bark beetles by thinning bark, dislodging beetle broods, and increasing opportunities for parasitism of beetle broods by other insects. Some birds feed on adult MPB during flight before these beetles can infect the next generation of trees. Many MPB bird predators are year-round residents associated with mature forests (e.g. large dead or decaying trees with cavities), and may show negative responses to aggressive beetle management. It may be critical for the long-term health of forests to maintain roosting, nesting, and feeding habitats required by these beetle predators.

What patterns can we expect as the MPB epidemic runs its course? In the southern United States, forest wildlife species showed a 'boom and bust' relationship with the southern MPB. Initially woodpecker densities increased with MPB abundance, then declined as bark beetles saturated the habitat. Our wildlife research in interior BC indicates that 41 of 99 bird species have shown significant changes in abundance since 1995; with 21 species showing significant increases in abundance and 20 species showing significant declines. Most resident cavity-nesters increased with increasing MPB densities, but on one site with beetle salvage activities, abundance of cavity nesters decreased. In 2005, we also noted a 50% decrease in densities of nuthatches that may indicate a decline in habitat quality. We will continue to examine effects of the MPB and habitat change until the end of the outbreak to ensure that there are sufficient resources to maintain wildlife populations on the working landscape after beetle attack and beetle management activities.

Female hairy woodpecker

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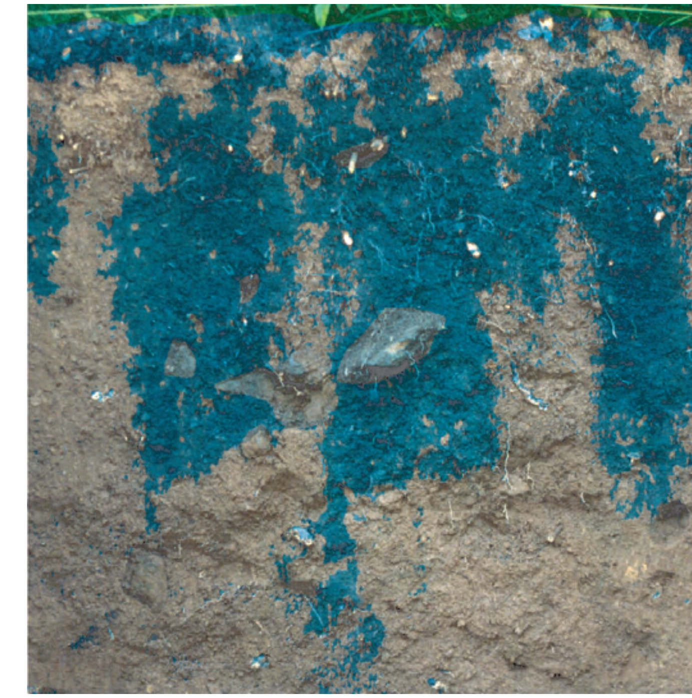
MPB impacts on watershed hydrology

Forest hydrology focuses on the effect of forest management on the hydrological cycle in watersheds. In the past, water quantity and quality were mostly affected by clear-cutting and road construction. Currently, the mountain pine beetle epidemic creates new challenges for forest hydrologists in BC. The first of these challenges is to detect the hydrological changes due to forest management and forest disturbance. Changes may be clearly detected at the stand level since the loss of forest cover is directly related to an increase of rainfall, snow accumulation and snow melt, a decrease in evapotranspiration and changes in soil moisture. However, detecting changes at the watershed scale (everything from small headwaters to several 100 km^2 basins) is a much bigger challenge, particularly when watersheds consist of complicated mosaics of various runoff generation processes. These processes regulate whether and how fast an area contributes to stream flow. Therefore, a certain hydrological change at the stand level does not necessarily transform into a similar change at the watershed scale. The hydrological sensitivity of a particular location and its connectivity to the stream must be known in order to predict changes at the watershed scale. Changes in stream water quality (e.g. nitrate) can be especially severe after dieback when whole trees remain on the site. In addition, after dieback there is a strong decrease in water and nutrient uptake which may result in excess nitrification and nitrate leaching to the stream.

In UBC's Water Tracer Lab, we are combining hydrological models and field-based approaches to improve the prediction of impacts of disturbances such as the mountain pine beetle epidemic on watershed hydrology. We are using natural and isotope tracer methods to detect changes in flow pathways and alterations in the contribution of various runoff generation processes. We monitor the tracers with wireless sensor networks and use the results to map hydrologically-sensitive areas that require particular attention by forest managers. This new methodology allows us to better understand the cumulative changes in a watershed and the implications for the susceptibility of stream water quality.



Water and a blue food dye is sprinkled on a forest soil and a soil profile excavated. The pattern of infiltrating water is visualized using image analysis methods.

Another emerging field that we are currently working on is the identification of uncertainties in hydrological modelling. Models cannot fully represent the complexity of nature. The process descriptions in models, and the measured data (climate and streamflow) used to constrain hydrological models, are uncertain. Therefore, simulation results of any hydrological models used to predict impacts of the mountain pine beetle epidemic will also be uncertain. To assess and predict these uncertainties, we are using new techniques (such as stochastic models and Monte Carlo simulations) only recently made available for hydrological studies. The impacts of change in a watershed cannot be assessed without adequately quantifying the uncertainty in streamflow simulations.

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Will nitrogen fertilization of mature lodgepole pine stands help them withstand MPB attack?

Fertilization of trees on nitrogen-poor soils increases tree vigour, improving the natural defence within the tree and increasing the tree's ability to produce defensive compounds. There are two distinct reactions of a lodgepole pine tree when it is attacked by a mountain pine beetle. The immediate response is to release a lot of resin in an attempt to "pitch out" the attacking beetles. The second response is a dynamic wound reaction by which the tree synthesizes defensive compounds in the immediate area of attack to protect it against the beetle and the symbiotic blue-stain fungus that the beetle transports from its previous host tree.

To examine interactions between the MPB and fertilized mature stands of lodgepole pine, we established four plots in the Cascades Forest District near Merritt in 2004. Two of the plots were fertilized with urea. We measured and stem-mapped each tree. At the end of the summer of 2004 we recorded each tree that had been attacked by the MPB in the two N-fertilized plots as well as in two unfertilized (control) plots. All trees were re-assessed in the fall of 2005. To our surprise, several trees in the fertilized plots that had been attacked by mountain pine beetle in 2004 still had green foliage. On closer inspection it was noted that many of the 2004 attacks had been pitched out in the fertilized trees.

Foliage and phloem samples indicated that there had been some increase in the concentrations of nitrogen. Grass and herbs also showed the benefit of the fertilizer. A larger replicated trial will be initiated in 2006 to test the possibility that we can reduce the impact of mountain pine beetle by fertilizing mature lodgepole pine stands.

This study was carried out by students Sam Coggins and Angela Gomm with guidance from Drs. Gordon Weetman and John McLean.

For further information contact Dr. John McLean (Department of Forest Sciences) at 604-822-3360 or john.mclean@ubc.ca.

Faculty research talks

In the fall we began a new series of lunch time faculty research talks. The first presentation was given in October by Dr. Sally Aitken. Sally's talk was entitled ***Gene conservation*** and addressed such questions as adaptations to climate change, the importance of peripheral populations for evolution and conservation, and finding markers for local adaptation. In November, Dr. Thomas Maness talked about his views on sustainability with a presentation entitled ***Sustainability: For whom and for what?*** The series opens in 2006 with our first talk of the year by Dr. John Richardson on January 20. John's presentation is entitled ***A stream runs through it: Interactions between aquatic ecosystems, forests and forestry.*** Dr. Phil Evans will be the second speaker with his February 10 talk on ***Tales of wood – Tales of wonder: Structure, function, performance and perfection in nature's wonder material.*** On March 16 Dr. Val LeMay will be speaking on ***The problem of scaling: From leaves to landscapes.*** Further information on upcoming talks and highlights of past talks can be found at www.forestry.ubc.ca/research/talks.html

Newsletter Production

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