LANDSCAPES, GENOMICS & TRANSGENIC CONIFER FORESTS

A Nicholas Environmental Leadership Forum • November 17–19, 2004 • Durham, North Carolina
Nicholas School of the Environment & Earth Sciences • Duke University
EXECUTIVE SUMMARY

- On November 17-19, 2004, the Nicholas School of the Environment and Earth Sciences hosted a forum entitled Landscapes, Genomics and Transgenic Conifer Forests to deliberate the pros and cons of transgenic conifers.
- Over 75 international, national and local attendees were present, including venture capitalists, biotechnology firms, timber corporations, state and federal government officials, academicians and environmental groups.
- Gene discovery and genetic transformation for conifers centers on DNA constructs influencing wood quality, rather than genes conferring herbicide or pesticide resistance.
- Transgenic conifers bring a special set of challenges which has no parallel among transgenic food crops.
- No regulatory agency is prepared to cope with the oversight of a transgenic organism which can disperse its pollen and seeds on a scale of kilometers for ten or more years prior to harvest.
- Transgenic mitigation methods—including reproductive sterility for conifers—are not available at this time.
- Benefits of improved wood quality from transgenic conifer forests, if any, will accrue to corporate shareholders but ecological risks, if any, will be shared by all citizens.
- Studying ecological risks of transgenic conifers has received no priority within federal government granting agencies. To accomplish this, cross-agency cooperation among USDA-Forest Service, National Science Foundation, USDA’s Biotechnology Risk Assessment Program and other federal agencies should be sought.
- Several of our non-governmental organization (NGO) panelists are actively seeking a permanent moratorium on planting any transgenic forest trees.
On November 17-19, 2004, the Nicholas School of the Environment and Earth Sciences at Duke University hosted a special forum entitled "Landscapes, Genomics and Transgenic Conifer Forests" to deliberate the pros and cons of transgenic conifers. This is a timely topic because commercialization of transgenic forest trees is imminent as evidenced by transgenic field trials here in the southeastern US. On hand were venture capitalists, biotechnology firms, timber corporations, state and federal government officials, academicians and environmental groups.

Forum speakers first explored high through-put genomics and new gene discovery. For conifers, this centers on genes influencing wood quality, rather than genes conferring herbicide or pesticide resistance. New methods for DNA insertion will be coming from molecular nanotechnology. Community ecology and evolution of early seed plants provided good examples of alternative genomics applications.

Gene flow concerns were the common ground during the forum. Transgenic conifers bring a special set of challenges which do not parallel transgenic food crops. Windborne conifer pollen and seed disperse on a scale of kilometers and reproductive sterility systems for conifers have not yet received serious study. Attendees discussed potential gene flow from future transgenic forests to surrounding landscapes. This is an emerging issue because landowners, public and private, adopt technology innovations at different rates or even eschew innovation altogether. At the last, a panel of non-governmental organization representatives emphasized ecological risks of transgenic forests, reminding the audience that scientific advance is not the only dimension to the complex question of whether or not to commercialize transgenic forest trees.

Public deliberation is so needed. To further this, my colleagues and I are completing a book entitled "Landscapes, Genomics and Transgenic Conifer Forests" to provide a foundation for emerging policy issues. The book, written for a broad scientific audience, is planned for release later this year. In the meantime, this report consists of my own synthesis and identification of salient emerging issues followed by forum speaker abstracts. Please feel free to share these proceedings with colleagues or request additional copies.

Sincerely,

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Chair & Organizer
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CLAIRED W I L L I A M S
Department of Biology, Duke University
Chair and Organizer
2004 Forum: "Landscapes, Genomics and Transgenic Forests"

Dr. Williams is Research Professor at the Department of Biology at Duke University, formerly Visiting Professor in the Nicholas School of the Environment and Earth Sciences in 2004. Her research focus has been at the interface of natural resources management and genomics tools, an emerging research area, best defined as landscape genomics. Her research ranges from the genetic mechanisms behind the conifer mating system, DNA analysis of presettlement forests to gene flow dynamics of genetically modified forest. She has worked with the North Carolina Biotechnology Center on forest biotechnology problems analysis, ultimately serving on the advisory committee founding the Institute of Forest Biotechnology. Over the past 20 years, Dr. Williams’ research achievements have won recognition as a Guggenheim Fellow, a senior Fulbright Scholar to Canada, a Dr. Lee Senior Fellow at Oxford University and a Bullard Fellow at Harvard University. Prior to coming to Duke University, Dr. Williams was a full professor in the Faculty of Genetics and in Forestry at Texas A&M University. She has over 100 publications, of which more than half are peer-reviewed journals, books and book chapters. Her book, Genetics of Conifer Reproduction, is forthcoming with Cambridge University Press.
How has this happened? Creating novel transgenic phenotypes for forest trees, fueled by private sector investment, is moving faster than public deliberation—or policy—can accommodate. Existing US forest policy tends to be an extension of agricultural policy. Yet few public policy decision makers are clear how much ecological risks of transgenic conifers differ from those associated with transgenic food crops.

We have two choices: 1) halt commercialization of transgenic conifers altogether or 2) delay commercialization while shifting research priority to quantifying ecological risks and developing effective transgenic mitigation. Effective regulatory statutes rely on these sources of new knowledge to protect the vast indigenous pine forests in the southern US but there are no data for either risk or benefits associated with transgenic conifers. Continuing to ignore the complexity and scale of transgenic gene flow from working forests into surrounding indigenous forests is contrary to good stewardship. And it is too simplistic to view transgenic conifers as just another transgenic food crop.

Emerging issues for transgenic Pinus taeda
Transgenic conifers are distinctive from transgenic food crops in a number of important ways, including 1) an unprecedented scale of pollen and seed movement, 2) recurrent and abundant seed and pollen production recurring each plant which starts years before its harvest and 3) technology-intensive forests as a minority ownership, surrounded by neighboring public and private forest landowners with less technology-intensive management practices. The importance of these attributes can be best seen when subjected to scrutiny on a case-by-case evaluation. As an example, the case study of Pinus taeda is discussed in the next four sections.

LEXICON

CHROMOSOME: A chromosome consists of a long, continuous strand of DNA and associated proteins. It resides within the nucleus of a cell. Each parent contributes a set of chromosomes to each offspring, so an individual receives half of its chromosomes from its mother and half from its father.

DNA CONSTRUCT: An artificially constructed segment of nucleic acid injected into resident DNA of the host organism's tissues. Transgenic constructs are novel combinations of genes.

GENES: A gene is a region on DNA on a chromosome which codes for biological information. A gene refers to a functional unit composed of coding DNA sequences, non-coding introns and its regulatory DNA sequences. A gene corresponds to a sequence used in the production of a specific protein or another nucleic acid, RNA.

GENE FLOW: Exchange of genes between species, usually taking place by reproduction, such as cross-pollination, or directly through horizontal gene transfer.

GENE POOLS: Refers to genetic information segregating within a species. The genetic information is coded by genes which reside on chromosomes. Variants of genes, defined as alleles, range from common to rare in frequency.

GENETIC MODIFICATION OR GENETIC ENGINEERING: Eliminating or adding copies of specific genes often from the same organisms or other organisms through using genetic transformation and other molecular biology techniques. Refers to a series of techniques used to transfer the genes from one organism to another or to alter the expression of an organism's genes. For example, a genetic modified plant may produce a new protein or be prevented from producing its own proteins. Also known as gene splicing or recombinant DNA (or rDNA) technology.

HETEROZYGOSITY: The state of having two different alleles at a single gene locus residing on a chromosome.

HORIZONTAL TRANSFER: Transfer of genes between organisms without benefits of reproduction. Horizontal or lateral transfer of genes has occurred over millions of years without benefit of sexual reproduction or genetic engineering techniques.

MOLECULAR DOMESTICATION: A domesticated plant, strictly defined, is one whose reproductive success depends on human intervention.

SOMATIC EMBRYOGENESIS: Clonal propagation of a single individual or genotype by culturing undifferentiated cells from immature embryos.

TRANSGENE: A foreign gene(s) or DNA construct transferred into another organism using genetic modification methods.
1. Movement towards Molecular Domestication

Biotechnology firms such as Arborgen and CellFor are offering clonal *Pinus taeda* forests to timber companies. Given success of clonal propagation by somatic embryogenesis, molecular domestication of *Pinus taeda* plantations is technically feasible. The numbers of transgenic field trials for this species in the southeastern US are mounting annually although no commercial transgenic plantations exist yet.

Understanding the commercial appeal of this indigenous US species begins with the prevalence of private land ownership. The Southern Resource Assessment from the USDA-Forest Service shows over 89% of the timberlands in the southeastern US are privately held.

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204 MILLION HECTARES OF US TIMBERLAND

Among private landowners, combined holdings of forest products companies and institutional investors amount to roughly 22%. Of these, few timber companies cultivate technology-intensive plantations. Harvest age for *Pinus taeda* ranges from 25 to 35 years so standing timber may be bought and sold several times prior to its harvest.

Unlike agricultural crops, these plants can thrive without human intervention if their seeds or pollen escape into less managed ecosystems. Selective breeding programs for *Pinus taeda* have no parallel to breeding agricultural crops. Breeding programs, started in mid-20th century, place priority on conserving genetic diversity. As a result, genetically improved *Pinus taeda* is not truly domesticated but rather highly heterozygous, lacking inbred lines or breed structure. Costs have been borne by timber companies and a few state agencies for five decades. Genetic composition of our forests is poised to change with movement towards molecular domestication. Federally funded gene conservation program or public germplasm repositories do not exist for *Pinus taeda*.

2. Transgenic Pollen and Seed Move Long Distances

Transgenic conifers are outcrossing and wind-pollinated, producing an abundance of unwanted pollen and seeds. Gene flow is complex when compared to any agricultural crop. As a tree gets taller, seed and pollen escape travel farther, and as a tree gets older, it produces more seeds and pollen.

Transgenic seeds and pollen move by way of two separate processes. The first process is local neighborhood dispersal (LND) which accounts for 99% of the seeds and pollen falling near source. The second process, long-distance dispersal (LDD), accounts for a tiny fraction (1%) of escaped seeds or pollen yet poses the greatest ecological concern. LDD seeds and pollen are vertically uplifted above the forest canopy by air currents then move on the order of kilometers from source.

“Genetically engineered trees — Who controls the technology? Who owns the risk?”

KATHY JO WETTER, ETC GROUP

“Genetically engineered forests pose greater risk than GE crops. Gene flow from conifer plantations may reduce diversity in our native forests and national forests.”

NEIL CARMAN, SIERRA CLUB
Unlike agriculture, forest ownership in the United States is divided among various private and public sectors. Within the Pinus taeda range, small woodlot owners are the dominant stakeholders. Many of these owners are more technology risk-averse than corporate forest landowners. Their willingness to take risks is tempered by the smaller size of their timber holdings. A few small woodlot owners seek more investment risk because they view transgenic plants as favorable, whether food crops or conifers.

Decisions to adopt or forego molecular domestication technology by this large group of forest landowners will shape genetic composition of the southern US forested landscape. Eschewing technology adoption for one’s own family forest is a deliberate decision, weighed by investment objectives or personal philosophy, rather than wealth or technology access. This peculiar aspect of forestry was described by Aldo Leopold in his book, A Sand County Almanac. Some forest landowners see forestry as akin to food production or agronomy (Group A) while others view forestry as fundamentally different from agronomy because forest trees are largely undomesticated and forests are managed in a natural or less managed ecosystem (Group B).

If small forest landowners, as a group, decide against adopting use of clonally propagated transgenic conifers, then rates of biotechnology adoption or so-called technology portfolios are likely to diverge rapidly between corporate forest landowners and their neighbors, whether private woodlots or public lands. Why? Technology-intensive portfolios on private corporate timberlands are needed for meeting rising timber demand. By contrast, private woodlots and public forests in the US tend to be managed far less intensively. With a biotechnology divide in place among different forest landowner classes, then seed or pollen flow from technology-intensive plantations is vast enough that unwanted contamination of wild gene pools is likely to occur in public forests and neighboring woodlots. Ecological consequences of investment decisions on private lands across the broader landscape deserve closer study.

Risk analysis is similarly incomplete. Mathematical models suggest movement of escaped transgenic seed and pollen on the scale of kilometers from source is a certainty. Gene flow is a problem only if there is potential harm. Potential harm, like benefit, cannot be tested hence we currently have a regulatory “Catch-22.” To be harmful, the transgenic trees must exhibit enhanced invasiveness properties compared to its wild-type. Increased invasiveness becomes harmful if it translates into displacement of local endemic species or results in long-term forest maladaptation. No one knows whether transgenic forests are beneficial, benign or harmful at this early stage of technology development. But it is clear that the staggering expense of regulatory oversight alone may drive the political outcome in the absence of appropriate benefit-risk analyses.

“We need government regulation but also need to recognize that all transgenes do not bear equal risk.”
- ROBERT KELLISON INSTITUTE OF FOREST BIOTECHNOLOGY
Emerging Issues to Consider Prior to Commercial Use of Transgenic *Pinus taeda*:

- Widespread use of clonal forests with or without transgenes is ushering in molecular domestication of the forest on private forest lands yet no formal, federally funded conservation programs exist for *Pinus taeda* at this time.
- Reproductive sterility research for conifers offers no solution at this time thus warrants serious consideration as a national research priority in competitive grants program.
- Gene flow from transgenic *Pinus taeda* to neighboring pine forests can be predicted using computer simulated meteorological models on localized and landscape scales.
- Determining if pine pollen remain viable when traveling great distances deserves research priority. What is the probability that viable pollen will land in an area populated by conspecific plants with receptive female strobili?
- Experimental results for benefits or risk analyses associated with transgenic *Pinus taeda* are not available for any class of transgenes.
- To obtain suitable data for sound benefits-risk analysis will require US regulatory reform.

Evaluating Regulatory Reform for All Transgenic Conifers

Regulation of transgenic organisms has matured since inception of a tripartite government regulatory entity among three agencies: USDA, EPA and FDA. Today, primary responsibility resides with USDA-APHIS’s Biotechnology Regulatory Services, an agency which recognizes that one set of regulations no longer fits all transgenic plants. Regulatory reform is pending for transgenic forest trees.

During the forum, I asked several focus groups representative of the audience at large to evaluate four hypothetical regulatory options. Their thoughtful deliberations are collectively summarized here (Table 1, following page). It should be noted individuals within each focus group rarely reached consensus on the best regulatory options but each person’s contribution, pro or con, moved dialogue forward. Continued regulatory oversight was the point of agreement for all groups (Table 1, following page). One individual proposed a fourth option, a singular need for a permanent moratorium for transgenic forest trees.

“Are GE trees needed or simply wanted? We are not consumers. We are owners and taxpayers. Public participation is a process of deliberation and necessary to the acceptance of this technology. Public awareness is low but without openness, hard to swallow.”

ALYX PERRY
WILDLAW/SOUTHERN FORESTS NETWORK
### TABLE 1

**PROS AND CONS OF FOUR HYPOTHETICAL OPTIONS FOR REGULATING GENETICALLY MODIFIED FOREST TREES**

<table>
<thead>
<tr>
<th>OPTION</th>
<th>MORATORIUM</th>
<th>RESEARCH AGENDA</th>
<th>RELAXED REGULATIONS</th>
<th>FREE MARKET</th>
</tr>
</thead>
<tbody>
<tr>
<td>DESCRIPTION</td>
<td>Halt outdoor planting of transgenic or genetically modified (GM) conifers for ten years on public and private lands. Permit laboratory and greenhouse research.</td>
<td>Continue to test GM conifers with domesticated wood quality transgenes in field tests under current APHIS regulations. Shift priority for competitive funding to exploratory research on other genomic applications suited to a wider range of silvicultural applications.</td>
<td>Allow certain GM field trials to reach timber harvest age in order to assess full benefits. These selected trials will test trees with DNA constructs only from functional genes discovered in conifers.</td>
<td>Remove government regulation. GM seedlings can be sold for-profit to any customer who wants to buy them.</td>
</tr>
<tr>
<td>PROS</td>
<td>No risk of seed or pollen escape</td>
<td>Stimulates new funding for forest tree genomics</td>
<td>Benefits from current investment in R&amp;D pipeline realized</td>
<td>Benefits from current investment in R&amp;D pipeline realized</td>
</tr>
<tr>
<td></td>
<td>Technology develops during moratorium. For example, we can test for unintended effects</td>
<td>Allows time to shift investment into new areas without losing materials in current pipeline</td>
<td>Timber and seedling industry can stay competitive in global markets</td>
<td>Timber and seedling industry stay competitive in global markets</td>
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<tr>
<td></td>
<td>Provide time for public input</td>
<td>Acquire real data for benefits analysis</td>
<td>Acquire better data on gene flow data from GM trees for a full rotation</td>
<td>Industry forced to self-regulate</td>
</tr>
<tr>
<td></td>
<td>Potential harm suspended</td>
<td>Increased funding for marker-assisted breeding and for functional genomics</td>
<td>Test methods for reproductive sterility</td>
<td>Reduced cost of final product, decrease time to market</td>
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<tr>
<td></td>
<td>More time to identify societal benefits</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td>Basic research focus will be deepened with less pressure on immediate application</td>
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<tr>
<td></td>
<td>Consider release and field testing in Southern Hemisphere where there are no indigenous pine forests</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CONS</td>
<td>All transgenes do not have the same adverse (or beneficial) effects</td>
<td>Stifles GM research</td>
<td>Potential benefits suspended yet potential harms not avoided</td>
<td>Early adopters could face unforeseen problems without data collection, tracking or regulatory oversight</td>
</tr>
<tr>
<td></td>
<td>Cost borne by private sector</td>
<td>Current regulations are inadequate for preventing escape of GM pollen and seeds</td>
<td>Increased gene flow from GM conifers</td>
<td>Effect on indigenous forests question-able due to high rate of transgenic escapes from commercial plantations</td>
</tr>
<tr>
<td></td>
<td>Current investment in R&amp;D pipeline wasted</td>
<td>Current regulations would have to be changed to allow reproduction</td>
<td>International embargo against GM timber from US</td>
<td>GM timber might meet with embargo on world market</td>
</tr>
<tr>
<td></td>
<td>No field data would be available at the end of the moratorium for calibrating regulations</td>
<td>Too little competitive funding even at this time so not likely to have enough to research or develop genomics alternatives</td>
<td></td>
<td>Sets negative precedent for any other technology or methods for producing novel organisms</td>
</tr>
<tr>
<td></td>
<td>Potential benefits suspended</td>
<td>No emphasis on forest genomics funding as is. Research funding mostly occurs in the for-profit sector.</td>
<td></td>
<td>Buyer obligations and liability are unclear so harm will not borne by those who benefit financially</td>
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<tr>
<td></td>
<td>Subversion of investor commitment</td>
<td>Decreased private investment</td>
<td>Untested risks from gene flow</td>
<td></td>
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<tr>
<td></td>
<td>Other countries have less regulatory restriction and will capture market</td>
<td>Dilutes benefits from forest biotechnology by starting other avenues of inquiry</td>
<td>Increase in legal action and litigation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Decreased funding for research</td>
<td></td>
<td></td>
<td>Patchwork of local and state regulations would restrict GM trees and this is the wrong scale for biotechnology governance</td>
</tr>
<tr>
<td></td>
<td>Create backlog in R&amp;D pipeline which would release an huge amount of regulatory works after moratorium is over</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>A SUGGESTED OPTION</td>
<td>Permanent ban is needed for GM forest trees because they exceed our limits of biotechnology governance; no regulatory oversight would be a cost savings</td>
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</tbody>
</table>
Shifting Research Priorities—
Or is it too late?
Biosafety and ecological risks associated with transgenic forests must receive serious consideration separately from agricultural crops. In the US, we must act now to either 1) halt commercialization of transgenic conifers in the US or 2) delay commercialization and shift research priority in national competitive funding programs towards gauging ecological risks and seeking effective transgene mitigation methods. There is no scientific justification for dismissing or downplaying the scale of potential gene flow from transgenic conifer plantations to neighboring pine forests.

Commercial use of transgenic forests is technically feasible but stymied by concerns about gene flow. Despite 20 years of genetic transformation research on conifers, no experimental data are available for transgenic gene flow. This means gaining social license for commercial use of this technology at this late date is fraught with obstacles.

First and foremost, we must consider the possibility that public deliberation may be starting too late to identify alternatives to commercial use of transgenic conifers or even to come to any consensus. Another consideration is that public participants, stakeholders and landowners alike, may require more specialized knowledge to make sound decisions about genetic composition of our future forests. This means informing small forest landowners through fair and balanced continuing education. The counter-argument is that the issue of genetic pollution in forests is inconsequential, dwarfed by health care or food supply concerns. My view is that genetic composition of our nation’s indigenous forests deserves attention now and that this means better educational opportunities for landowners. Let public and private sectors work together towards obtaining the right experimental data and the right predictive models to move towards sound benefit-risk analysis. In any event, commercialization of transgenic Pinus taeda needs to be put on hold.

ABSTRACTS

JEFFREY BOORE
DOE Joint Genome Institute
“Will your Favorite Genome be Sequenced?”

We are entering the Age of Genomics. Soon, young biologists will wonder how research was done before the availability of large amounts of DNA sequence, as some do now when reflecting on the days before computers or DNA cloning. Large scale genome sequencing efforts are complete, underway, or planned for dozens of eukaryotes and hundreds of prokaryotes. Yet, much of the scientific community is unaware of the processes used for selecting genomes to target and the important considerations that must be addressed for a successful genome sequencing project. The DOE Joint Genome Institute (JGI) is one of the leading centers for producing and analyzing DNA sequence. (JGI’s current capacity tops 55,000 nucleotides per minute, 24 hours per day, 7 days per week). I will discuss our processes for producing high depth draft sequences, our research programs underway, our newly established programs for greater interaction with the scientific community, and our processes for selecting genome targets.

JESSE H. AUSUBEL
Program for the Human Environment, Rockefeller University
“Precision Forestry”

From Neolithic times up to our new millenium technical advances have been exploited for intensification, to increase the specific productivity of land. Yields per hectare measure the productivity of land and the efficiency of land use. Low yields squander land, and high yields spare land. Agriculture essentially reduces the amount of land needed to support a person. Without machines but using a thousand bioinformatic tricks, by 1900 Chinese farmers reduced the amount of land to support a person to 100 square meters compared to a few square kilometers for a hunter-gatherer, a factor of 10,000 times in intensification. The ecological systems farmers create bear no resemblance to any natural ecosystem, if only because of great structural simplification. Equilibrium and resilience tend to be lost, and the system becomes unstable and difficult to manage. The wits and toil of almost half the Chinese population are still employed to keep their farms going. To match the Chinese wits and toil, machines and chemicals have hugely increased farm yields throughout the world, stabilizing land used for agriculture since about 1950 even as population and income soared. In recent decades under the rubric of precision agriculture information has substituted for energy in lifting farm yields as inputs such as nitrogen fertilizer have flattened. The essence of the strategy for foresters to achieve a

STEWARDSHIP FOR GENETICALLY ENGINEERED CONIFER FORESTS

- Analysis of risk and benefits for domestication transgenes
- Better regulations for testing GE conifers
- Conservation program for indigenous conifers
- Deliberate GE Forests in public forums
- Ecological research priority given to GE forests before allowing commercialization

“GE trees—it is not all about science. It is about social and environmental impacts too.”

ANN PETERMANN
GLOBAL JUSTICE ECOLGY PROJECT
ABSTRACTS

Great Restoration of woods is the same as that for farmers: more bits and fewer kilowatts. Call it precision forestry. Working precisely, we can spare farmland and spread forests. Precise bits of information called DNA are finally the forester’s inevitable and most powerful tool.

MAUD HINCHEE
Arboregen LLC, Summerville, SC, USA
“The Application of Biotechnology for Forestry”

Over the next 50 years, human demand will put extreme pressure on our natural forests unless wood harvests can be shifted towards highly productive forest plantations. Biotechnology will be an important tool in the technology toolbox for sustaining the world’s forests. Improved genetics, provided through clonal forestry and biotechnology, together with improved silviculture and plantation management practices, will be required to meet the wood demands of the future. Genomic research is expanding the forestry industry’s capabilities to identify and utilize molecular techniques toward tree improvement. ArborGen, a forest biotechnology company dedicated to improving the sustainable productivity of plantation forests, is developing plantation forestry species with improved wood properties, growth and stress tolerance. Transgenic tree product development requires multiple competencies, and ArborGen has invested several years towards developing the following platforms: 1) elite genotypes as a genetic base for transgenic products, 2) elite clone transformation capabilities, 3) gene licensing or discovery for introduction of valuable traits, 4) tree performance assessment in the greenhouse and the field, 5) quality assurance and regulatory safety, 6) commercial level scale up of transgenic tree products, and 7) marketing and public acceptance. ArborGen has made significant progress and effort in all of these key areas, with an expectation that we will develop improved plantation forestry trees that can benefit the forest industry but also positively impact on the environment and the world’s natural forests.

THOMAS URBAN
CellFor, Inc., Vancouver, B.C, Canada
“The Role of Somatic Embryogenesis in Clonal Forestry”

As progress is made in the genetic transformation of conifers it becomes increasingly important to understand the propagation system by which those genetic improvements will eventually reach the market. The critical characteristic of a successful system will be the ability of that system to deliver cost effective, genetically uniform seedlings to the market without giving up on any of the traditional criteria of yield, disease resistance and other traits that forest owners have come to expect.

There are a number of delivery systems in development today using varying combinations of organogenesis, somatic embryogenesis and rooted cuttings. This presentation will explain the important criteria for a successful delivery system and give a more detailed look at the system CellFor is using to deliver over 2 million varietal seedlings in 2004.

TIM MCKNIGHT
Oak Ridge National Lab, Oak Ridge, TN, USA
“Nanoscale Architectures for Gene Delivery: A Platform for Control of Gene Fate?”

by TE McKnight, AV Melechko, GD Griffin, J Cairney, ML Simpson

Monitoring and manipulating biological processes within the single cell can be facilitated by emerging toolsets that interface to living cells at the subcellular, and ultimately molecular-, scale. For example, advances in the synthesis and assembly of nanostructured materials are beginning to provide practical, functional architectures that close the dimensional gap between the macroscale, physical world of the researcher and the molecular scale processes within live cells. We will present one such architecture, where arrays of vertically aligned carbon nanofibers and nanofiber-derived structures can be used to both monitor and manipulate events within and around individual cells. As electrochemically-active elements, nanofiber arrays with individually-addressable electrode elements may be used as a platform for parallel informational exchange with cell matrices, including generation and monitoring of electrochemically-active species. Even more exciting however is that the penetration and nuclear residence of DNA-modified nanofibers can provide a unique new approach to inserting new genetic information. Genetic material tethered to the penetrant nanofiber scaffold remains transcriptionally active within the interfaced cell. This tethered-gene strategy provides new opportunities for transcription. We will describe our approaches at fabricating and implementing these devices for cellular studies.

JOHN CAIRNEY
Georgia Institute of Technology, Atlanta, GA, USA
“Gene Containment Strategies for Trees”

As transfer of specific, modified genes (‘transgenes’) was shown to be successful in altering specific characteristics in recipient plants, so concern grew that these same enhanced characteristics might be transferred in the field by cross-pollination to non-target plants, possibly even to different plant species. Where the newly acquired trait was resistance to a herbicide or pathogen, the specters of ‘superweeds’ and fractured food chains were quick to emerge, along with predictions of ecological disaster.

Concern over the potential environmental impact of transgene escape led to the development of gene-containment strategies. These approaches have focused, mainly, on preventing flower formation or pollen or seed production. The techniques employed generally seek to block these developmental paths by directing synthesis of a destructive protein to the cells or tissues involved in the genesis of the pertinent structures. Thus in addition to the trait of interest, the ‘transgenic plant’ must carry genes for a ‘cell ablation system’ which, by virtue of the strict specificity of its control mechanism, is active only in the tissue of choice.

Gene containment systems have been developed for annual or biennial angiosperm plants. The programs of gene activity throughout the
life cycle of perennial angiosperm trees, whose growth is punctuated by periods of winter dormancy, and the manner in which their reproductive cycle is regulated, is poorly understood at the molecular level. Further, the distinctive and often unique aspects of gymnosperm biology may render current gene containment strategies ineffective or inappropriate and necessitate new, species-specific approaches.

I will review the methods employed to prevent gene dispersal by transgenic plants, their strengths and limitations, and discuss features of tree reproductive biology which must figure in the management of gene flow in transgenic trees.

HELY HÄGGMAN
University of Oulu, Finland
"Metabolic Profiling and Genetically Modified Trees"
by Hely Häggman and Riitta Julkunen-Tiitto

Genetically modified trees have been produced since late 1980s and this has been possible due to previous challenges to create new combinations of genetic material from DNA molecules of different origin. Since the early days genetic modifications have been done either to create new combinations or to regulate endogenous gene function to study transgene expression, regulation or to consider more holistic gene expression in genetically modified plants. The possible complexity of changes in metabolism followed by introduction of transgene (or change in a single enzyme) has, however, in most of the cases not been studied or considered. The studies on plant metabolism are essential because metabolism is not co-linear with DNA sequence. Specific feature of plant metabolism and metabolites is their fluidity i.e. the metabolites can be converted to other molecules. Plant kingdom is rich of metabolites, over 100 000 have been identified today. Metabolic profiling means monitoring and quantification of metabolites representing selective classes of the biochemical pathways in specific tissues. By profiling it is possible to differentiate genotypes, to identify loci involved in metabolic composition etc. in the metabolic-engineering projects, it is possible to reveal pleiotropic effects of transgenes and transgene function in the performance of complex organism and to achieve deeper understanding of plant metabolic networks. Technically this can be done by mass-spectroscopy and separation techniques but the technically challenging part today is to expand the technology to high-resolution, high-throughput analysis covering diverse chemical compounds and the pathways in different tissues of plants. This far, studies on metabolic profiling have been applied to some specific transgenic plant species (potato, tomato, Arabidopsis etc.) and these reports have mainly been addressed on primary metabolism such as sucrose-starch transitions in potato tubers. In genetically modified trees most of the work done has been focused lignin biosynthesis pathway. Metabolic profiling of genetically modified trees is still at its very infancy but there is certainly a need for a more comprehensive research and technology outcome also at metabolome level.

GARY PETER
School of Forest Resources and Conservation, University of Florida, Gainesville, FL, USA
"Structure, Function and Adaptation of the Woody Stem in Forest Trees"

The evolution of the woody stem of forest tree species is of large ecological significance. This significance is evident by large areas where forest trees dominate the landscape and by forest tree’s role in global carbon cycling, storage, and watershed quality. The woody stem provides a critical competitive adaptive advantage for trees ability to compete for sunlight. However, woody stems must transport water and nutrients over large distances and must survive seasonal changes in temperature, water and nutrient availability. In gymnosperm trees, woody stems are composed of bark, phloem, cambial and secondary xylem, and it is the lignified tracheids that function in both mechanical support and water transport. Angiosperm stems contain more specialized secondary phloem and secondary xylem cell types: the lignified vessel elements, which conduct water, and the lignified fiber cells, which provide mechanical support. Both angiosperm and gymnosperm trees have at least four distinct types of wood heartwood, earlywood, latewood and reaction wood. Patterns of wood cell adaptation correlate with natural species range and climate. In each of these wood types, the tracheid wall composition, structure and functions are different and each provide important selective advantages under conditions of high and low soil moisture, mechanical bending or freezing temperatures. Understanding the importance of wood cell adaptation in relation to different growth environments, its regulation and the molecular basis for secondary growth and wood cell adaptation remains an important challenge for tree biologists.

Recent results from ecophysiological, genetic and genomic analyses investigating the mechanisms by which wood cells adapt will be discussed from ecological and evolutionary perspectives. For example, recently a very important practical goal was achieved by genetic engineering aspen trees to contain mostly syringyl lignin in their wood cells (Li et al., 2003:100:4939-44). These trees are novel from an evolutionary perspective because syringyl lignin now accumulates in both the fiber cells and the water transporting vessel elements and, whereas angiosperm and gymnosperm trees naturally only have guaiacyl lignin in the water transporting cells. Characterization of the hydraulic conductance of these trees will test whether S lignin can replace the highly conserved G-lignin in water transport cells. We have recently identified loblolly pine genotypes which make greater proportions of latewood. These genotypes also show more discrimi nation against 13C, for the first time correlating stomatal regulation and latewood formation. In collaboration with R. Sederoff’s lab we have used expressed sequence tags (ESTs) and microarrays to identify large number of genes that have significantly different mRNA levels in earlywood and latewood. Most of the lignin biosynthetic genes are more abundant in latewood. We have also compared gene expression profiles of normal vertical wood with compression wood. Again large numbers of genes show differential regulation in vertical vs. compression wood. Comparisons of genes expressed different wood types in both gymnosperms and angiosperm species is well underway.
ABSTRACTS

DAVID RICHARDSON
University of Stellenbosch, South Africa
"Conifers as Invasive Aliens—Emerging Concepts"

Organisms are being moved around the world intentionally or by accident through human activity at ever increasing rates. Alien (or exotic) species are now indispensable for human well-being in most parts of the world, and new uses are emerging for an increasing number of species. Most alien species are welcome or benign residents, but a small sample of introduced species proliferate, spread from sites of introduction, and cause a wide range of problems in their new ranges. Biological invasions are one of the primary threats to biodiversity worldwide and its importance is increasing rapidly.

Substantial advances have been made in the field of invasion ecology in the past few decades. We now have a slightly better idea of why some species become invasive, what makes ecosystems susceptible to invasion, and the many ways that invasive species impact the structure and functioning of ecosystems. The ability to predict the outcome of an introduction, however, remains a largely illusive goal of invasion ecology.

In plant invasion ecology, most work has been done on herbaceous plants—species that most people would call "weeds." In many parts of the world, however, alien trees are among the most damaging of invasive alien plants. Considerable research has been undertaken on alien tree invasions recently, especially in the southern hemisphere. This paper provides a brief review of some approaches and findings, and some ideas on the challenges for the future, with special emphasis on conifers, and pines in particular.

A general review is given of naturalization and invasion in conifers worldwide—which taxa are doing what and where? Insights from the global transplant experiment have been very useful for developing a preliminary predictive framework. Besides a marked taxonomic bias in favour of some groups of conifers, invasiveness in conifers is associated with a syndrome of life-history traits associated with reproduction and dispersal. Predictions derived for pines seem to work well for other conifers, and also for angiosperm trees. The opportunities for, and limitations of, drawing conclusions from this type of natural experiment are discussed. The objective separation of invasive and non-invasion species through such natural experiments has made it possible to test whether invasiveness is associated with specific traits. Results of this work suggest a casual network of traits associated with invasiveness.

A short overview is given of some of the detailed studies of pine invasion dynamics in South Africa—this work shows the importance of different life-history traits, interactions between these and environmental factors, modeling studies, the role of long-distance dispersal, etc. Reference is made to the history of invasion, and the evolution of management interventions in this region.

Finally, some conclusions are drawn how studies of conifer invasions have shed new light on aspects of invasion ecology, and what further studies are needed to improve our ability to manage alien conifers in the future.

JAMES CLARK
Nicholas School of the Environment and Earth Sciences and Department of Biology, Duke University
"Potential for Spread of Transgenic Conifers through Pollen and Seed Dispersal"

Genes are redistributed across landscapes from one generation to the next in a two-part process of pollen dispersal followed by seed dispersal. For continued spread, dispersal must be followed by successful establishment, leading to reproduction. Predicting the potential spread of transgenic conifer genes across landscapes that already support large resident populations requires understanding of not only dispersal, but also the factors that control growth, survival, and reproduction by offspring. The novel challenge of anticipating spread potential must be met with insights derived from experimental, observational, and paleo-evidence of past invasions, reproductive potential, and landscape effects on establishment and growth. In this talk, I summarize the evidence that may help us to anticipate spread potential of conifer transgenics.

Pollen dispersal will provide the most effective means of gene dispersal for most conifers. For pines, pollen production is especially high, and pollen grains are transported long distances by wind. (Other conifers, such as spruce and fir produce less pollen, and it is not so widely dispersed) By contrast, seed production is much lower than pollen production, and seed dispersal is much less efficient than pollen dispersal. Rapid spread of populations is possible if sufficient seeds are dispersed long distances and if it arrives at sites where new populations can establish and, eventually, reproduce. In principle, such spread is possible for some conifer species, but the large number of unmeasurable means that useful predictions are not yet possible. For example, the record of past tree migrations suggests that rapid spread (100 m yr⁻¹) has sometimes occurred, but it may have been the exception, depending on presence of dispersal vectors that are not commonly available. The fecundity of trees varies widely among species and years, providing the large seed crops that can support rapid spread only sporadically. Experimental evidence suggests that tree fecundity may increase with future increases in atmospheric CO₂, but we do not yet know for which species and by how much. For species like loblolly pine, moderate fecundity levels, coupled with the capacity to exploit disturbed landscapes, will facilitate spread. Weighed against these factors that facilitate spread will be competition not only from resident pines, which will supply substantially more seed to nearby sites, but also from woody and non-woody competitors for the same sites.

Taken together, the data suggest that, unless gene transfer through pollen dispersal is effectively stopped or offspring are effectively sterile, spread of new genes through landscapes having resident populations will be far more effective through pollen than through seed dispersal. Nonetheless, if large stands containing transgenics are established, and offspring are viable, we can expect seed establishment to occur outside the resident stands.
Long-distance dispersal (LDD) of pollen in conifers presents a risk for transgenic escape into unmanaged forests. Here, we report simulations of transgenic pollen dispersal and LDD from genetically modified forests using a mechanistic dispersal model. The dispersal model is based on coupled Eulerian-Lagrangian closure (CELC) principles that explicitly compute the turbulent transport mechanics, including updrafts and downdrafts, within the canopy. Contrary to recent studies and measurements from annual crop canopies, which reported maximum pollen dispersal distances ranging from 6 m to 800 m, conifer pollen LDD can readily exceed 8 km in less than 1 hour without escaping the atmospheric boundary layer (ABL). These LDD estimates were conducted using a conservative terminal velocity (Vt) estimate of 0.07 m/s. When using a Vt of 0.03 m/s (+/-0.02 m/s), which is characteristic of jack pine and black spruce pollen, LDD increased by a factor of 3, from 8.62 km to 21.0 km for a stand at its reproductive onset and from 13.5 km to 33.5 km for a stand at near-harvesting age. The fact that pollen can travel such distances without being exposed to excess UV-B radiation and cold temperatures above the ABL has significant implications for sustained pollen viability and ecological risk assessment.

**RONI AVISSAR**

Department of Civil and Environmental Engineering, Duke University

*Dispersal of Pollen in Southeastern US*

by Kristen Goris and Roni Avissar

We use the Regional Atmospheric Modeling System (RAMS) in conjunction with a Lagrangian Particle Dispersal Model (LPDM) to study the dispersal of pollen emitted from forests in South Carolina during the first two weeks of April. RAMS simulates the evolution of atmospheric conditions (i.e. 3D wind, temperature, humidity, pressure) based on fundamental conservation principles (mass, motion, energy). The LPDM uses the 3D winds simulated by RAMS to calculate how particles are advected and diffused from a source point. Preliminary results indicate that most of the pollen ejected into the atmosphere remains near its source. However, under strong wind, it can be transported very far away from its source.

**ERIC BRENNER**

New York Botanical Garden, New York, NY, USA

*Comparative Genomics among the Basal Gymnosperms*

by Eric D. Brenner, Dennis Stevenson, de le Torre, Eduardo, Manpreet Katari, Stephen Rudd, Suzan Runko, Rob Martienssen, Richard McCombie, Richard W. Twigg, Phillip N. Benfey and Gloria Coruzzi

Despite the critical role that cycads and Ginkgo play as “living fossils” of early seed plants, little work has been done to understand their molecular developmental profile. This is partly because these species are difficult to work with on the genetic level. To correct this deficiency, we have undertaken a genomics approach to isolate, discover and study genes involved in cycad and Ginkgo evolution and development. In this endeavor, we have created an EST database made from developing leaves and ovules. To date, we have sequenced nearly 11,000 genes from cycads and Ginkgo. By taking a comparative-genomics approach, we have determined that a number of genes appear to be unique to gymnosperms and lower plants but are not found in angiosperms. Such “gymnosperm-specific” genes may have been lost or dramatically changed in the evolutionary advance towards higher plants. Conversely, in this comparison we have found other genes in cycads and Ginkgo with high similarity to genes in angiosperms. In angiosperms these genes regulate key developmental processes in the production of the flower. The study of these genes in the formation of reproductive and vegetative structures will help understand the evolution of such important characters as the seed (ovule) in early spermatophytes.

**STEPHEN DIFAZIO**

Oak Ridge National Lab, Oak Ridge, TN, USA

*From Ecosystem Genomics to Genome Ecology: Opportunities at the Interface of Complex Systems*

by Stephen P. DiFazio, Anthony W. King, and Gerald A. Tuskan

Ecosystem genomics has vast potential for enhancing understanding of ecosystem functioning as genomic information, methods, and analysis tools continue to develop. However, at present these tools are in an early stage of development, and much exploratory and proof-of-principle work is needed to develop and validate approaches for extending genomic information to ecosystem scales. Poplar (*Populus* spp.) provides an excellent point of departure for ecosystem genomic research. A large number of molecular tools exist, including a whole genome sequence and efficient transformation protocols. In addition, the poplar genus consists of 29 species distributed throughout the northern hemisphere across a wide range of ecological amplitude, and poplars often play a keystone role in riparian ecosystems, where they are pioneers on newly formed sediments, and may be the dominant tree species on the landscape. Individual poplar populations harbor a tremendous amount of genetic diversity in adaptive traits due to an outcrossing breeding system and extensive potential for gene flow among populations. Also, closely-related, sympatric poplar species form natural hybrid zones, further increasing the range of genetic variation in wild populations and creating excellent opportunities for studying the genetic mechanisms controlling species distributions. Therefore, poplar offers an immediate opportunity for tractable studies of the molecular bases of adaptation with ecosystem-scale implications.
ABSTRACTS

ANN BARTUSKA
USDA-Forest Service, Washington, D.C., USA
“Forest Service Research and Development in the Age of Genomics”

Genetics research is an important component of several of the research emphasis areas for Forest Service Research & Development. The age of genomics provides powerful new tools with which to address many areas of research and development. These include molecular phylogenetics, which aids our understanding of evolution, paleobotany and paleoecology, and helps predict how populations may react to climate change, an improved ability to detect, monitor and ameliorate the impact of invasive species, and to more efficiently develop strategies to conserve or restore threatened and endangered species. Genetics research also provides us with more fundamental knowledge about the genomes of commodity tree species that supports the commercialization of novel genetic constructs. The potential for the application of molecular genetics in support of traditional tree breeding programs and to produce genetically engineered trees creates the need for new research in traditional areas of FSR&D. If genetically engineered trees are to be deployed then we should understand the ecological implications, the risks and benefits from such deployment, and sociological studies to address the ethical, legal, and sociological issues.

ALVIN YANCHUK
British Columbia Ministry of Forests, Victoria, B.C., Canada
“Genetically Modified Trees and Crown Forests in Canada: ‘trees with novel traits’ and their use in semi-natural plantations”

Forests in Canada are largely under the stewardship and management of the provincial and territorial governments (the ‘Crown’), and therefore must meet many regional forest land and range objectives. Wood production is certainly an important component of most forest management goals in Canada, as it contributes substantially to the gross national product of the country. However, the public expects wood production not to come at the expense of many other values; such sensitivities exist that the Government of Canada does not even report to the Food and Agriculture Organization of the UN (in the State of the World’s Forests Report) that Canada has forest tree plantations. As such, plantation forestry in Canada is usually viewed as ‘semi-natural.’ Moreover, even though several commercially important species in Canada reproduce naturally by vegetative means (i.e., natural ‘clonal forestry’), there are substantial concerns about industrial monocultures, even without the use of the term ‘clonal forestry.’ While some provinces have policy and standards around minimum levels of genetic diversity that are required in reforestation seedlots, large questions still remain about the economics and need for clonal forestry in relation to most Crown forest management objectives.

To fully capture the technical advantages that genetically modified (GM) trees may offer foresters in Canada, various forms of ‘clonal forestry’ will have to be accepted. The specific genetic manipulations will also have to add significant ecological or economic advantages for the public, governments and industry, in that order, before we may be able to consider such large shifts to forest gene resource management policy. It is also noteworthy, that Canada has chosen to regulate products of biotechnology not from the process aspects, but from the products aspects. Therefore, it is the novelty of the change to the plant or tree that must be regulated, considered, and monitored (i.e., Trees with Novel Traits). A GM tree, e.g., with a Bt resistance gene, and a new exotic species, will largely be considered of equivalent risk. This presents an additional challenge with respect to developing forest gene resource management policy.

Currently, no GM trees are expected to be put into ‘ecological testing’ situations, in order to pass to the next level of unconfined release into the Canadian forest landscape. Even if future conditions change that can reverse public and government opinion, it is doubtful, except perhaps in some very special cases of exotic disease or pest introductions, that such GM trees would ever gather such support in Canada. Ironically, it is the developed countries like Canada and the US that are developing this technology, yet they are also the least likely countries to allow its use, particularly on government owned forest land. While the developed countries can currently afford such ‘choices,’ developing countries are considering using GM technology. This is occurring in China and may actually be the new arena where the rest of the world watches and determines how risky this technology may be for their own publicly owned forests.

DAVID WEAR
USDA-Forest Service, Research Triangle Park, NC, USA
“Economic Prospects and Policy Framework of Biotechnology in the Southern USA and Latin America”

The economic framework for analysis of impacts of forest biotechnology is presented, based on the theory and applications of evaluating impacts of technical change and economic welfare analyses of increased timber supply. Examples of potential impacts of forest biotechnology are presented in this context, including southern timber supply, potential impacts of eliminating fusiform rust in the US South, and prospects for increased timber investment returns from plantations in the Americas. Policy issues related to biotechnology applications in forestry are summarized, and prospective regulatory responses examined with a case study in Uruguay. Based on this review, implications for forest biotechnology are discussed.

MARK MEGALOS
North Carolina Division of Forest Resources, Raleigh, NC, USA
“GM Trees and the Private Land Owner”

Genetically modified trees have the potential to save family forests, open new markets, sequester carbon, sustain native forests, and restore polluted ecosystems and blighted species. Successfully deploying these technologies in the US will, by necessity, require the involvement of private forest owners. Private ownership accounts for 390 million acres of US forestlands with a large share in the productive Southern region. Forest landowner motivations are reviewed for insights about likelihood of innovation adoption.
Cultivating private forest landowner support for GM trees can yield crucial public investment in research, technology transfer, extension, market development and promotion. Successful promotion of GM tree benefits to a landowner audience must focus on problems relevant to their needs, while also persuasive enough to emotionally disarm environmental opposition.

LEE HANDLEY
USDA-APHIS Biotechnology Regulatory Service, Riverdale, MD, USA
“Changing Biotechnology Regulations—Impact on Forestry”

APHIS regulates genetically engineered organisms under authority granted by the Plant Protection Act 2000 and coordinates the regulation of field testing of genetically engineered plants with EPA and FDA under the Coordinated Framework for Regulation of Biotechnology 1986. The first regulated field test occurred in 1987 and after the first six years of evaluating permits, experience demonstrated that criteria and performance standards could be defined for certain field test that do not present novel plant pest risks. This gave rise to the notification option that became effective in 1993. The notification option originally covered six major crops and was modified in 1997 to cover nearly all plants. The notification option represents a simpler, streamlined application and review process for importation, interstate movement and field testing but meets the same safety standards as field trial under permit. Transgenic plants which raise certain safety issues, for example pharmaceutical-producing plants, engineered microorganisms, and engineered insects are not eligible for this option. As technology changes and as new applications in biotechnology emerge, regulations must also change and adapt. APHIS recently announced a plan to do a programmatic Environmental Impact Statement in anticipation of changes in the regulations for field testing and deregulation of transgenic plants. An overview of the current regulatory process along with potential changes will be given, with a discussion of the opportunity for the forestry community to have input into the new regulations.

ANNE-CHRISTINE BONFILS
Canadian Forest Service, Ottawa, ONT, Canada
“Canada’s Regulatory Approach: Trees with Novel Traits”

While genetically engineered trees may offer considerable benefits, they also raise a number of important questions regarding safety and genetic diversity. In 1993, Canada’s federal government has put in place a science-based regulatory framework to ensure that the products of biotechnology meet standards for human health and environmental safety. This framework is based on the development of regulations under existing legislation and using the Canadian Environmental Protection Act as a ‘safety net’ for products that would not be appropriately covered under other Acts. The Seeds Act provides authority to the Canadian Food Inspection Agency for the regulation of seeds (i.e. propagation material), including tree seeds. Regulations under the Seeds Act were amended in early 1997 to clarify the information requirements for environmental safety of plants with novel traits, including trees, prior to release. Regulatory oversight is triggered by the novelty of the plant material rather than the specific means by which it was produced. The Plant Protection Act covers the importation of seed. In Canada, provincial governments own 71% of the forest, federal and territorial governments own 23%, and only 6% of forest land in Canada is privately owned. Provincial and territorial governments have legal authority to manage Crown land use: they set the rules for forest management and ultimately decide what materials can be planted. Sound regulations require policy developments that integrate the various national and international levels. The Canadian Forest Service is the largest Canadian forest science policy organization. It plays a facilitation role for federal, provincial, international and ad hoc expert committee discussions on the issue. Canadian regulatory principles and challenges will be described: terms and conditions for confined research field trials; evaluation criteria; regulatory harmonization; international involvement with the OECD and under the Cartagena Protocol on biosafety; and environmental safety research in support of regulations.

ROBERT B. JACKSON
Nicholas School of the Environment and Earth Sciences and Department of Biology, Duke University
“Genetically Modified Trees and Carbon Sequestration”

The use of genetically modified tree species offers great promise for industrial forestry and as a potential mechanism of carbon sequestration. In this presentation I will examine that promise, focusing on plantations as a tool for storing carbon and the role that genetic modifications will likely play as climate changes in the coming century. I will also discuss some of the uncertainties and caveats that such strategies bring. These include potential gene flow from transgenic conifer pollen, possible changes in water use and streamflow, and the safeguards that are needed for fire, storms, and other disturbances that will impact sequestration rates.
SPEAKERS

JESSE H. AUSUBEL
Program for the Human Environment, Rockefeller University
Jesse H. Ausubel directs the Program for the Human Environment at The Rockefeller University in New York. Since 1994, Mr. Ausubel has served concurrently as a program director for the Alfred P. Sloan Foundation. Increasingly interested in biodiversity, in 2000 Mr. Ausubel helped bring into existence a major international program to assess and explain the diversity, distribution, and abundance of life in the oceans, the Census of Marine Life. He has also played a leading role in development of DNA barcoding for species identification and the formation of the Consortium for the Barcode of Life in 2004, which is creating a reference library of short DNA sequences for animals and plants which will eventually be accessible via a handheld device for DNA-based field identification of specimens. As a member of the Council on Foreign Relations (CFR), Mr. Ausubel has led activities on energy and on forests.

ANN BARTUSKA
USDA-Forest Service
Dr. Bartuska is Deputy Chief for Research and Development, USDA Forest Service. An ecosystem ecologist, she came to that position in January 2004 from The Nature Conservancy, where she was Executive Director of the Invasive Species Initiative from 2001–2003. She is active in the Ecological Society of America, serving as Vice-President for Public Affairs from 1996–1999 and President in 2003. She also is a member of the Society of American Foresters.

PHILIP BENFEY
Department of Biology, Duke University
Dr. Benfey is the Paul Kramer Professor and Chair of the Department of Biology at Duke University. His research interests include plant developmental genetics and genomics. Currently he is investigating how Arabidopsis thaliana develops an entire root system from a single cell.

ANNE-CHRISTINE BONFILS
Canadian Forest Service
Dr. Bonfils is Science Advisor for the Biotechnology Research Program for the Canadian Forest Service (CFS), Natural Resources Canada. She chairs the CFS Biotechnology Management Committee, which has a mandate to advise on strategic orientations and budget allocations for research.

JEFFREY BOORE
DOE Joint Genome Institute
Dr. Boore heads the Evolutionary Genomics group at the Joint Genome Institute (JGI). His research interests include comparative genomics, molecular evolution, systematics, organelle genomics, and high-throughput DNA sequencing.

ERIC BRENNER
New York University and New York Botanical Garden
Dr. Brenner is Assistant Research Professor with joint appointments at the New York University and in the New York Botanical Garden. He is also a project leader in the genomics research lab at the New York Botanical Garden studying the evolutionary origin of seeds.

JOHN CAIRNEY
Georgia Institute of Technology
Dr. Cairney is Associate Professor in the School of Biology at Georgia Tech in Atlanta, GA. Since 1994, his workplace has been the Institute of Paper Science and Technology on the Georgia Tech campus.

NEIL CARMAN
Sierra Club
Dr. Carman serves on the Sierra Club’s genetic engineering committee working on national policy issues concerning genetically engineered organisms.

JAMES CLARK
Duke University
Dr. Clark is H. L. Blomquist Professor of Biology in the Nicholas School of the Environment and Earth Sciences. At Duke University, Dr. Clark teaches Community Ecology and Ecological Models & Data.

STEPHEN DIFAZIO
Oak Ridge National Lab
Dr. DiFazio is a Research Scientist at the Environmental Sciences Division at Oak Ridge National Lab and Adjunct Professor of Plant Sciences Department and Genome Sciences and Technology Program at the University of Tennessee. He has been instrumental in completing the sequencing of the entire poplar genome in 2004, the first forest tree genome to be completely sequenced.
DAVID ELLIS
USDA-ARS National Center for Genetic Resources Preservation
Dr. Ellis is Director at the USDA-ARS National Center for Genetic Resources Preservation in Fort Collins, Colorado. He was one of the first research pioneers to successfully genetically engineer conifers and establish the first field tests. His group currently works on the cryopreservation of mint, strawberry, grapes, pears, apples, sweet potato, currants and garlic.

HELY HÄGGMAN
University of Oulu
Dr. Hely Häggmann is Professor of Plant Physiology at the University of Oulu, Finland. Her research interests range from molecular biology, biotechnology and ecological effects of transgenic forest trees.

LEE HANDLEY
USDA-APHIS Biotechnology Regulatory Service
Dr. Handley represents the USDA’s Animal and Plant Health Inspection Service in the Risk Assessment Branch within Biotechnology Regulatory Services in Washington, DC. His focus is risk assessment for pharmaceutical crops and perennial species.

MAUD HINCHEE
ArborGen, LLC
Dr. Hinchee is Chief Technology Officer at ArborGen, a timber biotechnology company focused its current research on four main themes: improved forest productivity, better paper manufacturing processing, improved wood quality and restoring threatened tree species.

ROBERT B. JACKSON
Duke University
Dr. Jackson is Professor in Biology and at the Nicholas School of the Environment and Earth Sciences as well as Director of the Center for Global Change, University Program in Ecology and the new Stable Isotope Mass Spectrometry Laboratory. He teaches and studies ecosystem functioning and feedbacks between global change and the biosphere.

HONORABLE JOSEPH JEN
U.S. Department of Agriculture
Dr. Jen is the Undersecretary for research, education, and economics. He oversees four agencies of the U.S. Department of Agriculture: the Agricultural Research Service, the Cooperative State Research, Education, and Extension Service, the Economic Research Service, and the National Agricultural Statistics Service. Dr. Jen is a widely recognized agricultural scientist and educator, with experience in both the public and private sectors.

GABRIEL KATUL
Duke University
Dr. Katul is Professor of Hydrology and Environmental Fluid Mechanics at the Nicholas School of the Environment and Earth Sciences and in the Pratt School of Engineering.

ROBERT KELLISON
Institute of Forest Biotechnology
Dr. Kellison chairs the Institute of Forest Biotechnology in Research Triangle Park, North Carolina. Past employers have included International Paper, Champion International Corp., and North Carolina State University.

LYNN MAGUIRE
Duke University
Dr. Maguire is Associate Professor of the Practice of Environmental Management and Director of Professional Studies in the Nicholas School of the Environment and Earth Sciences at Duke University. Dr. Maguire’s current research focuses on integrating public values with environmental decision making.

TIM MCKNIGHT
Oak Ridge National Laboratory
Mr. McKnight is a research scientist at the Oak Ridge National Laboratory since 1989, developing and studying nanoscale devices for subcellular measurement and manipulation.

MARK MEGALOS
North Carolina Division of Forest Resources
Dr. Megalos is Forest Legacy Coordinator for the state of North Carolina. Dr. Megalos initiated the Forest Legacy program, securing over $8.5 million for the purchase of development rights on forested properties since 1999.

William Schlesinger, as Dean of the Nicholas School of the Environment and Earth Sciences, is launching Duke University’s new Nicholas Institute for Environmental Policy Solutions. The Institute is designed to meet the nation’s need for the best science, delivered without bias, aimed at the development of effective environmental policy. The changing genetic composition of our forests is a prime example of where the Institute can inform the policy process. How can we best use growing genomics wealth to ensure healthy forest ecosystems and long-term sustainable productivity? As they tackle these issues, policy makers need the best science that academia can supply and the answers to the questions behind transgenic forests are no exception.
SPEAKERS

RAM OREN
Duke University
Dr. Oren is Professor in the Nicholas School at Duke University. Together with colleagues, Dr. Oren studies the coupled water-carbon cycles and their transfers and transformation primarily in forested ecosystems.

ALYX PERRY
WildLaw/Southern Forests Network

GARY PETER
University of Florida
Dr. Peter is Associate Professor in the School of Forest Resources and Conservation and in the Plant Molecular and Cellular Biology Graduate Program at the University of Florida.

ANNE PETERMANN
Global Justice Ecology Project

JANE PREYER
Environmental Defense
Ms. Preyer has been the Director of the Environmental Defense North Carolina office since 1993. She manages environmental policy and political strategy, coordinates the collaborations with external organizations and key constituents, and works as a policy analyst on air and water quality issues.

DAVID RICHARDSON
University of Stellenbosch
Dr. Richardson is Professor at the University of Stellenbosch, South Africa. Dr Richardson edited the book *Ecology and Biogeography of Pinus* (Cambridge University Press, 1998). In 2004, Dr Richardson was appointed Deputy Director of the South African Department of Science and Technology’s Centre of Excellence for Invasion Biology.

WILLIAM H. SCHLESINGER
Duke University
Dr. Schlesinger is James B. Duke Professor of Biogeochemistry and Dean of the Nicholas School of the Environment and Earth Sciences. His research focus is on the global biogeochemical cycles of the chemical elements, especially on the role of soils in the global carbon cycle. He was elected to the National Academy of Sciences in 2003.

JAMES SIEDOW
Duke University
Dr. Siedow is the Vice Provost for Research at Duke University. Dr. Siedow’s own research is focuses on the study of oxidative processes in higher plants with an emphasis on those related to plant respiration.

THOMAS URBAN
CellFor, Inc.
Mr. Urban is President and CEO of CellFor, Inc. in Vancouver, British Columbia. He began his professional career with Goldman, Sachs & Co. in 1988 in the Mergers and Acquisition group in New York and Los Angeles. In 2004, he joined the early-stage forest genetics company, CellFor, Inc.

DAVID WEAR
Southern Research Station, USDA Forest Service
Dr. Wear is a project leader with the research branch of the US Forest Service, located in Research Triangle Park, North Carolina. Since 1995 he has managed a research program in the economics of natural resource use, valuation, and management and conducts research in the areas of forest management, land use changes, and forest policy.

KATHY JO WETTER
ETC Group
Dr. Wetter works as a researcher for the Ottawa-based Action Group on Erosion, Technology and Concentration (ETC Group), a civil society organization dedicated to the conservation and sustainable advancement of cultural and ecological diversity and human rights. To this end, ETC group supports socially responsible developments of technologies useful to the poor and marginalized, and addresses international governance issues and corporate power.

ALVIN YANCHUK
British Columbia Ministry of Forests
Dr. Yanchuk is Senior Scientist and Forest Genetics Program Manager at the Ministry of British Columbia in Victoria, B.C., Canada and Adjunct Professor at the University of British Columbia, Vancouver. Dr. Yanchuk is a member of the Forest Genetics Council of British Columbia and Chairman of the Forest Genetics sub-committee for the Science Council of B.C.

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AGENDA
FROM NOVEMBER 17–19, 2004
All sessions were held at the Washington Duke Inn, Durham, North Carolina

Wednesday, November 17
3:00 – 5:00 p.m.
Field trip to Duke Experimental Forest
Rob Jackson, Forum Welcome
Love Auditorium, Levine Science Research Center, Duke University
Philip Benfey, Professor and Chair of the Department of Biology, Duke University
William Schlesinger, James B. Duke Professor of Biogeochemistry and Dean of the Nicholas School of the Environment and Earth Sciences, Duke University
University Speaker: Jeffrey Boore
Evolutionary Genomics Department Head, DOE Joint Genome Institute
“Will your Favorite Genome be Sequenced?”
8:30 – 9:30 p.m.
Welcome Reception
Hall of Science, Levine Science Research Center, Duke University

Thursday, November 18
8:00 – 8:30 a.m.
Forum Registration
8:30 – 9:20 a.m.
Welcome: James Siedow
Vice Provost for Research, Duke University
Keynote Speaker: Jesse H. Ausubel
Director, Program for the Human Environment, Rockefeller University
“Precision Forestry”
9:20 a.m. – 12:05 p.m.
SESSION 1A: Genomics is Driving Gene Discovery & Transgenics
Discussion Leader: Claire Williams, Duke University
Evolutionary Genomics
Dennis Stevenson and Eric Brenner, New York Botanical Garden
“Comparative Genomics among the Basal Gymnosperms”
Ecological Genomics
Stephen Diffazio, Environmental Sciences Division, Oak Ridge National Lab
“From Ecosystem Genomics to Genome Ecology: Opportunities at the Interface of Complex Systems”
Reception followed by dinner
Washington Duke Inn

Friday, November 19
SESSION 2: Ecosystem Interface with Biototechnology Products
Discussion Leader: Ram Oren, Duke University
Plenary: David Richardson, Professor, University of Stellenbosch, South Africa
“Conifers as Invasive Aliens—Emerging Concepts”
Jim Clark, Duke University
“Potential for Spread of Transgenic Conifers through Pollen and Seed Dispersal”
Gabriel Katul, Duke University
“Spatial Modeling of Transgenic Conifer Pollen”
Roni Avissar, Duke University
“Dispersal of Pollen in Southeastern US”
SESSION 1B: Future Direction of Genomics
Discussion Leader: Claire Williams, Duke University
Evolutionary Genomics
Dennis Stevenson and Eric Brenner, New York Botanical Garden
“Comparative Genomics among the Basal Gymnosperms”
Ecological Genomics
Stephen Diffazio, Environmental Sciences Division, Oak Ridge National Lab
“From Ecosystem Genomics to Genome Ecology: Opportunities at the Interface of Complex Systems”
Reception followed by dinner
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SESSION 3: Landscape Perspective
Discussion Leader: Lynn Maguire, Duke University
Plenary: Ann Bartuska, Deputy Chief, Research, USDA-Forest Service
“Forest Service Research and Development in the Age of Genomics”
Alvin Yanchuk, British Columbia Ministry of Forests
“Genetically Modified Trees and Crown Forests in Canada: ‘trees with novel traits’ and their use in semi-natural plantations”
Dave Wear, USDA-Forest Service
“Economic Prospects and Policy Framework of Biotechnology in the Southern USA and Latin America”
Mark Megalos, NC Division of Forest Resources
“GM Trees and the Private Land Owner”
SESSION 4: Regulatory Oversight of Genetically Modified Forests
Discussion Leader: David Ellis, USDA
Lee Handley, USDA-APHIS Biotechnology Regulatory Service
“Changing Biotechnology Regulations—Impact on Forestry”
Anne-Christine Bonfils, Canadian Forest Service, Natural Resources Canada
“Canada’s Regulatory Approach: Trees with Novel Traits”
Rob Jackson, Duke University
“Genetically Modified Trees and Carbon Sequestration”
SESSION 5: Panel on Community Perspective
Neil Carman, Sierra Club
Alyx Perry, WildLaw/Southern Forests Network
Robert Keilison, Institute of Forest Biotechnology
Kathy Jo Wetter, ETC Group
Jane Preyer, Environmental Defense
Anne Peterman, Global Justice Ecology Project
University Speaker: Honorable Joseph Jen
U.S. Undersecretary of Agriculture, U.S. Department of Agriculture
“Genomics Research and its Potential Impacts on Science and Society”
Forum Wrap-up and Adjournment: Claire Williams, Duke University
FORUM SPONSORS

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National Science Foundation Plant Genome Program
and Ecosystem Sciences Program

USDA-Forest Service
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