

Forest Biotechnology and its Responsible Use

A publication by the Institute of Forest Biotechnology

Dear Colleague,

This whitepaper discusses the basic concepts of forest biotechnology, how biotech trees are managed, and how the IFB is creating a set of stewardship principles for responsible use of these technologies. We hope that you find this paper informative and provocative. Feel free to print this PDF for your personal use.

We have also hyperlinked many of the terms and concepts in an HTML version of this document available at our Responsible Use website: responsibleuse.org/biotechtrees.html This site is the main portal for the Responsible Use: Forest Biotechnology Principles initiative. There we make work products and draft versions of the principles and practices available to stakeholders and biotech tree users.

Biotech trees hold the promise of enhancing our environment and providing sustainable resources for society if used responsibly. The IFB is dedicated to discovering the social and environmental effects of using these technologies through science, dialogue, and stewardship.

We would like to thank our Forest Biotechnology Partners and our Initiative Sponsors for providing the technical and financial resources to make this work possible. Together, we are the most comprehensive information source on forest biotechnology – anywhere.

Thank you for your interest in protecting the future of forestry. Please contact us if you have any questions about forest biotechnology in general, or if you would like to participate in the Responsible Use initiative.

Thank you,



Adam Costanza
President - Institute of Forest Biotechnology

Institute of Forest Biotechnology's website: www.forestbiotech.org
PDF Location: www.responsibleuse.org/resources/biotechtrees.pdf

Forest Biotechnology and its Responsible Use

Adam Costanza¹ and Susan McCord¹

Summary

Biotechnology is being used as a tool to grow trees with special characteristics. When used responsibly, society and the environment can benefit from advanced tree breeding technologies. The next few years will be a time of rapid expansion for biotech trees throughout the world in an attempt to meet global demand for forest products and to protect future forests from invasive pests and climate change. The world will benefit from a mechanism to determine which uses of this technology can bring benefit. The Institute of Forest Biotechnology (IFB) along with a broad set of stakeholders from around the world, is developing principles for the responsible use of biotech trees. Through a highly transparent and open process the benefits of these trees can be enhanced while risks are minimized.

Forest Biotechnology

“The term biotechnology² came into common usage in the 1980s, and its several definitions continue to change. Broadly defined, it is anything that combines biology and technology. Biotechnology has become more controversial as the level of the technology has increased.” An excerpt from “Genetically Modified Forests from Stone Age to Modern Biotechnology” (Burdon et. al. 2006). This book is the most comprehensive review of forest biotechnology to date. Within the context of forest biotechnology we can refer to “modern” biotechnology as that which postdates the discovery of the structure of deoxyribonucleic acid, or DNA. Modern biotechnology is centered on the analysis and manipulation of DNA and the insertion of DNA fragments into organisms. Biotechnology has advanced to where we can research biological systems at the DNA level, and even sequence entire genomes. This feat was accomplished through years of research in plant and agricultural life sciences. While we can sequence a human’s genome today, it is not as simple for some trees. For example, a representative conifer (pine tree) genome is many times larger than a human’s (Keim, 2008); the Loblolly pine’s genome is seven times larger. Such a feat has yet to be accomplished in whole, but the Pine Genome initiative is working towards this goal to improve future biofuel production from pine trees, improve forest health, and gain insight into plant evolution (Pine Genome Initiative, 2008).

As we consider the spectrum of techniques that can be considered forest biotechnologies, it is useful to split out two general groups: breeding technologies, and genetic engineering technologies.

Breeding Technologies

Breeding technologies are described in this section to differentiate them from the scope of the Responsible Use: Forest Biotechnology Principles³ that will be discussed in more detail later in this paper. The technologies are ordered from least to most advanced in terms of their reliance on advanced techniques for

¹ Institute of Forest Biotechnology. <http://www.forestbiotech.org>

² “Biotechnology: Any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use.” (Convention on Biological Diversity, 1995)

³ Responsible Use: Forest Biotechnology Principles is an initiative of the Institute of Forest Biotechnology to create principles for the stewardship of biotech trees. Currently in process as of printing, the principles are being developed through a multi-stakeholder, transparent process. More information is available at <http://www.responsibleuse.org>

success. Be aware that one or more of these breeding technologies are used to produce genetically engineered⁴ trees.

Conventional Breeding

Purposeful breeding of trees involves producing hybrids, progeny of parents from different genetic populations, to produce a desired phenotype. An example of this would be a cross between a tree that has exceptional growth and one that shows resistance to a fungus that attacks that particular species. This is an imprecise method of producing a tree with a specific characteristic because there is no control over additional genetic material being incorporated along with the desired phenotype.

Asexual Propagation

Also referred to as clonal or vegetative propagation, is in contrast to sexual reproduction that requires fertilization via pollen. Sexual reproduction is how most plants reproduce. Asexual propagation produces genetically identical trees and does occur naturally by some tree species. For example, breaking off a branch of a willow tree and sticking it in the ground will produce roots from the branch. Over time a new willow that is genetically identical to the original tree will grow. Foresters have used this technology to their advantage as a breeding tool for centuries. Propagating a tree by grafting or with rooted cuttings allows the production of individuals that are genetically identical to the original and are therefore members of a clonal family. Tissue culture has become the preferred method of clonal production for some species of plants including several species of forest trees. This technology is also useful for moving clones across quarantine barriers since the cultures are free of insects and diseases and can easily be grown into mature plants.

Organogenesis

A type of asexual propagation that literally means ‘organ genesis’. It is accomplished by growing a mass of cells in tissue culture that have the ability to produce shoots and grow into full trees.

Somatic Embryogenesis

Cells in a tree other than the pollen and egg cells are called somatic cells. This technology-intensive technique is used to rapidly proliferate plant tissue via asexual propagation that mimics steps of the normal embryo development process. Single cells in tissue cultures from shoots, buds, roots, or leaves are induced to form complete embryos that can form individuals identical to the original plant where the cells were taken. Large numbers of a given clone can be produced in a short time with this technology.

Genetic Engineering Technologies

Genetic engineering is an advanced science in which DNA sequences encoding for very specific and desired traits are introduced into the plant genome. We must be precise in our language and terms because as discussed above, forest biotechnology includes a wide range of technologies that are used to improve trees.

Certain types of forest biotechnology require the most immediate attention for principles to guide their responsible use. Clonal propagation of trees is not necessarily the result of biotechnology. Some types of trees in the forest, such as willows, can asexually propagate through shoots or branches without any human intervention. Conventional breeding techniques that include various crossing and selection methods can produce trees that can be asexually propagated. Both breeding and asexual propagation have been used for over 3,000 years and are generally regarded as familiar and safe. Society should focus its efforts on developing principles for the truly advanced forest biotechnologies rather than on trees that were originally developed through conventional breeding techniques.

⁴ “Genetically Engineered and Genetic Engineering: The use of recombinant DNA and asexual gene transfer methods to alter the structure or expression of specific genes and traits.” (Food and Agriculture Organization of the United Nations, 2004)

The Institute of Forest Biotechnology defines 'biotech trees' as: "Any tree that is a product of targeted genetic engineering, and the progeny of these types of trees propagated through sexual or asexual methods." Given this definition, biotech trees encompass a spectrum of advanced technologies that introduce genes into trees via genetic engineering. A generic term commonly used for transferred genes is transgenes⁵. The following are technologies that can produce a biotech tree.

Altered native gene function

This technique does not insert a gene, so it would not technically be considered transgenic⁶. Instead, a regulatory section of DNA, often called a promoter, is inserted into the gene of interest. This regulatory section can cause an increase or decrease (upregulation or downregulation) of the expression of native genes. By altering how a gene is expressed, scientists can adjust phenotypic aspects of the tree. This technique can be used to increase the growth of trees, control flowering, and modify wood composition. Often these types of trees mimic those already in natural tree populations.

Insertion of one or more novel genes from plants that could naturally cross

These transgenes could be found in the normal gene pool for the tree in which they are inserted. Since the genes are from trees that could naturally interbreed, conventional breeding techniques may achieve the same results if enough time and effort were expended. Because of the long generation times of trees it may take decades for a conventional breeding program to produce the same results as a genetic engineering approach. This technique can be used to produce trees that have desirable attributes from other trees. For example, transferring the genes that confer resistance to the Chestnut blight from the Chinese chestnut and inserting them into an American chestnut would use this technique.

Insertion of one or more novel genes from plants that could not naturally cross

These transgenes would not typically be found in the normal gene pool for the tree in which they are inserted. The genes inserted are from other plant or tree species to produce novel trees that would not normally occur through natural selection on a human timescale. However, since the genes do come from the same kingdom it is within the realm of possibilities that given enough time, those genes could naturally become part of the tree's genome. This technique is being used to produce trees that are resistant to disease, drought, pesticides, and cold temperatures.

Insertion of one or more novel genes from non-plants

These transgenes would not typically be found in the normal gene pool for that tree and come from organisms in a different kingdom. This application produces novel trees that would not normally occur through natural selection because the genes come from organisms other than plants. Trees engineered to absorb pollutants from the environment rely on these types of genes.

Transgenes providing new industrial applications

These introduced genes can use any type of transgenes mentioned above, but the end result is a tree that has a novel use or application. Usually the resulting tree is used as a vector to produce material for industrial applications and would not naturally occur. For example, it may be possible to engineer a tree to produce pharmaceuticals, unique biofuels, or chemical feedstock intermediaries. This technology is on the very cutting edge of forest biotechnology today.

⁵ "Transgenes: a gene or gene construct that has been transferred into an organism such as a plant, using genetic engineering techniques, including transformation techniques, i.e. the process of inserting transgenes into the genetic material (DNA) of an organism." (Convention on Biological Diversity, 2006)

⁶ Regulating a native gene in this manner still requires that DNA is inserted and therefore it can be regulated as a 'transgenic technology' even though it is not an actual gene being inserted. For example, in the United States, promoter insertions would be regulated as transgenic.

Not Genetic Engineering - Mutagenesis

Mutagenesis⁷ is discussed here only to clarify why it is not considered a targeted genetic engineering technology. Some new varieties of trees, such as new fruit tree varieties, have been generated from the selection of natural or induced mutations that can alter color, smoothness, shape, and seed characteristics. Mutated branches can be asexually propagated to preserve and maintain the new characteristic resulting from the mutation. Although these trees do contain genes that are modified, the process of non-targeted human induced mutation are not considered genetic engineering here and do not fall within the IFB's definition of a biotech tree in part because many plant mutations are deleterious to the plant and only a few are able to become desirable new varieties. This is mainly because mutagenesis has multiple large impacts on the plant genome that cause a pleiotrophic, or chain reaction of effects in the genetic structure of the tree, that are usually both positive and negative. Wide ranging and random effects on the genetic structure of any organism are rarely beneficial to its survival. Today this technology is unlikely to be used in place of genetic engineering in trees where generation times severely restrict looking for a needle (the phenotype you want) in the haystack (all the cell lines you would have to generate and test). In short, mutagenesis is not a form of targeted genetic engineering. It is a random approach that alters a suite of genes in unknown ways.

While it is impossible to rank-order every possible benefit and risk associated with a technology, we can reasonably expect society to make a distinction for trees that differ most from their native relatives based on the assumption that unfamiliar traits may pose more risk to humans or the environment. It will be society's concerns which will set the boundaries in the commercialization and stewardship of biotech trees.

In many ways, the source of society's concern involves speed. It has been argued, and will continue to be in some circles, that what humans are doing with genetic engineering is a faster version of the natural processes occurring all the time. Nothing is static. Species evolve over time. The 'natural' state of the earth's ecosystem is dynamic and always changing. For example, human beings are generally thankful for the mutations that have made us distinct from our ancestors. Together mutations and natural selection have created the myriad species on earth today, including the vast variety of trees in our forests. What we are able to do with biotechnology is twofold. We are able to speed up natural evolutionary processes that we can reasonably expect would happen over many millennia. An example of 'accelerated evolution' could be creating a tree that is resistant to a particular virus. We are also able to extend the abilities of trees in ways that we can reasonably expect would never happen naturally. An example of 'novel evolution' could be creating a tree that produces pharmaceutical products. Many of our drugs today are derived from tree products, such as tamoxifen (Geffen et. al. 2001), a drug originating from trees and used to fight breast cancer. In the future there may be trees that are engineered to produce products that are not naturally tree-based.

Biotech trees will change future forests. There are a number of ways that society can address the appropriate use of this technology: through laws and regulations, certification programs, and industrial pledges. Since society places a high value on the earth's forests and the ecosystem services they provide, we believe that social interests and the ecological need for science-based stewardship warrants more comprehensive options to address the use of forest biotechnology, and provide assurance that biotech trees can be used responsibly. To fill this gap in performance the Institute of Forest Biotechnology has launched an initiative that will create a set of principles for stewardship of these trees. This initiative focuses only on biotech trees; those depicted by the orange colors in the chart below. In very broad terms, increasing technical advances in biotechnology can potentially lead to greater deviations from native phenotypes. In other words, the more gene function is modified in a particular tree, the more likely that tree will have different characteristics from its native relatives. As the figure below shows, there is a higher *potential* to produce trees with characteristics that are different or altered from native phenotypes as we increase the amount of technology we apply.

⁷ Human induced mutagenesis changes a genetic structure through the use of mutagens such as ultraviolet light, radiation, or chemicals. It is fair to say that inducing mutations, whether novel or not, rapidly alters the genetic composition of an organism. However, this is not biotechnology that uses living systems to produce the mutated plant, and it is not genetic engineering that uses targeted DNA sequences encoding for very specific and desired traits.

However, more technology does not necessarily mean more genes are being modified. Many of the advances in biotechnology are to make gene modification more precise and thereby limit the extent of potential risks. This is an important distinction because a common belief is that applying more biotechnology equates to more significant changes in an organism's DNA. In reality, genetic engineering makes much more precise changes at the DNA level than traditional breeding. Even a considerable amount of genetic engineering would pale in comparison to the large DNA alterations that traditional breeding makes. It is the specific, targeted, and unique changes through biotechnology that make phenotype changes possible that differ from native ones. The graphic below is showing the *potential* changes from native phenotypes when more biotechnology is applied.

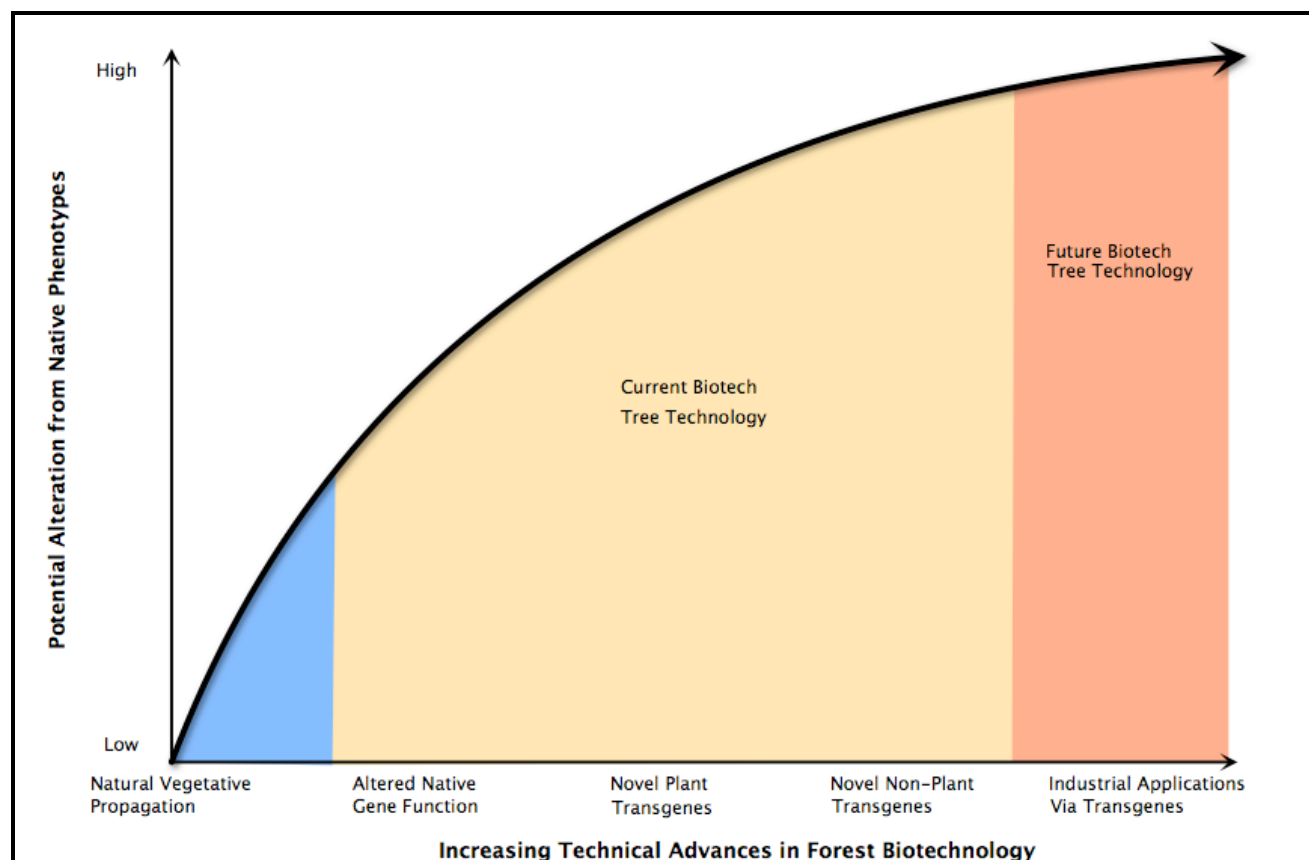


Figure 1

As we will discuss, the Responsible Use initiative will develop a set of principles that people can use to guide stewardship of biotech trees. There are various types of control imparted on biotech trees by regulatory systems around the world that are described generally in the next section. Rather than duplicate these systems, the Responsible Use initiative will create a high level of stewardship that is performance based.

How biotech trees are controlled

There are four main levels of containment for biotech trees to consider. Though there are varying types of release control throughout the world, we can think about the relative control of biotech trees. Control requirements typically start in the lab under highly controlled environments like greenhouses and then continue to outdoor test plots with a high level of oversight. Finally, some biotech trees are released to the open environment without the requirement for any control. The reason these four distinct levels exist is based

on both the need to study the phenotypic aspects of growing trees, and the potential for biotech trees to interact with the natural environment. Each level has its own unique aspects that are managed in different ways.

Level 1 – Confined to the lab or greenhouse

By confining early results of genetically engineered trees to highly controlled environments, there is almost zero chance that any genetic introgression⁸ will occur with trees in the natural environment. This level of control allows scientists to conduct research towards improving and understanding the biology of trees without the risk of affecting living systems outside of the lab or greenhouse. The downside is that labs are much smaller than outdoor plots so space often limits how many trees can be tested, or how long they can be allowed to grow since most trees will grow many meters high.

Level 2 – Field trials with oversight

The outside environment is highly dynamic and can never be perfectly replicated in the lab. For this reason many biotech trees are moved into fields where they are exposed to natural conditions. The spatial and temporal distribution of biotech trees is tightly controlled in field tests in the United States, although other countries may require different levels of specific oversight. This level of control allows researchers to grow more trees, usually to an older age, in real-world conditions to test the performance of the trees and the efficacy of the inserted DNA sequences. In most cases this level requires that each biotech tree planted in the field be managed and tracked according to a specific plan established by the regulating authorities.

Level 3 – Released for planting with monitoring requirements

While there are a number of specific details based on the regulatory system and the biotech tree itself, this level of control is less restrictive on the spatial and temporal range of the tree. It is possible that a regulatory agency could allow release on the condition that certain aspects of trees and plantings are monitored for potential environmental risks.

Level 4- Released for planting without monitoring requirements

At this level, a biotech tree is treated no differently than any other planted tree, and there is no requirement for monitoring or regulatory oversight⁹. To date, there are only two biotech trees at this level in the world today: virus resistant papaya (United States) (Zakour, 1998), and insect tolerant poplar (China). Another tree, the plum pox virus resistant plum (United States) is awaiting approval from the U.S. Environmental Protection Agency for release at this level at the time of printing (Scorza, 2009).

There are orders of magnitude in the number of trees at each level. With thousands of highly confined biotech tree specimens and several hundred field tests around the world there are still only two biotech trees that do not require regulatory oversight and can be planted like any other tree. This relatively small number reflects in part the stringency by which biotech trees are tested and move through some regulatory approval processes. However, some of the most powerful forces slowing biotech tree progression between levels of control are high overall costs to develop and test biotech trees, and public perceptions of biotech trees.

Status of biotech trees in 2009

As of the date of this publication, there were two species of biotech trees in the environment that are either deregulated or not regulated, meaning that there is no governing body looking specifically at these trees and how they interact with the environment and society. Information regarding the number, type, and governing body of non-regulated biotech trees is available at the IFB's website.¹⁰

⁸ Genetic introgression: The infiltration of the genes of one species into the gene pool of another.

⁹ U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) has the authority to repeal an unregulated status on any plant if it subsequently becomes detrimental to society.

¹⁰ Updated list of biotech trees is available at <http://www.forestbiotech.org/biotechtrees.php>

Deregulated - Papaya, U.S. 1997. The three U.S. agencies that have regulatory oversight (U.S. Environmental Protection Agency, U.S. Food and Drug Administration, U.S. Department of Agriculture's Animal and Plant Health Inspection Service) gave the papaya a non-regulated status for use in Hawaii to combat a virus. This made the tree available to any farmer interested in planting it. Because papaya is a food crop it had to be reviewed by plant, environmental, and food related agencies: U.S. Department of Agriculture's Animal Plant Health Inspection Service, The Environmental Protection Agency, and the Food and Drug Administration respectively.

Not regulated - Poplar, China 2002. China commercially released 1.4 million genetically modified Poplar (*Populus*) trees in an area of 300 – 500 hectares (Food and Agriculture Organization of the United Nations, 2004). As opposed to the Papaya, which is considered a food crop, this event marked the first biotech forest tree ever released into the environment. These trees were predominately modified with the Bt gene that produces a protein toxic to insect pests. This gene is produced by a bacterium in the soil called *Bacillus thuringensis* and is used in a number of biotech crops including corn, cotton, and soybeans. Today there are spurious reports that these trees are now readily available to tree farmers to plant for various purposes.

Pending deregulation - Plum, U.S. 2009. In 2007 The U.S. Department of Agriculture deregulated the C5 "HoneySweet" Plum tree engineered to be resistant to the plum pox virus (Animal and Plant Health Inspection Service, 2007). Like the Papaya, this tree is also a food crop and was subject to similar requirements. As of printing, this tree is awaiting approval from the U.S. Environmental Protection Agency.

Of these tree species the million plus Poplars released in China is the most interesting test case because these forest trees can cross with native relatives. This can change the genetic make-up of the natural forests; for better or worse, or there may be no significant change at all. There is of course no going back – modified genes will be in future forests. This fact has raised the question of whether society should put principles in place for users of biotech trees to follow.

Risks and benefits of using biotech trees

Biotechnology is a powerful tool. Humans have had the ability to change living organisms for thousands of years and have had to reckon with consequences ever since they began breeding and translocating plants. Forest biotechnologies that modify genetic operations are no exception.

However, unlike the implementation of some technologies that mankind has embraced with disregard for social and environmental implications, such as the introduction of the automobile, many experts believe that the use of biotech trees can take a radically different course. To date, biotech tree work has focused on either environmental or economic benefits. This fact is in large part because of the technical difficulties that have to be overcome to genetically modify trees. The difficulties make it very costly and time consuming to make even minor adjustments in trees. The major institutions around the world doing this work are thoughtful in their approaches with many checks and balances along their research chain that ensure resulting biotech trees are useful to society. In the end there has to be a significant ecological, social, or economic return, or the research is discontinued for more relevant work. The rigor of this process does not eliminate all risks or unintended consequences associated with biotech trees, but it has created broad categories of risks and benefits that are generally accepted among forest biotechnologists as important to consider during the research and development stage.

Potential benefits of using biotech trees

The following are some beneficial uses for biotech trees identified by the Forest Biotechnology Partnership¹¹.

Enhance bio-based products

Trees can be engineered to adjust the characteristics of its wood to suit specific needs. The global demand for biofuels has put an unprecedented amount of resources into developing trees that can readily be converted into liquid fuels. For example, adjusting the ratio of lignin and cellulose can create a cellulose feedstock that is significantly easier to convert into a liquid fuel (United States Department of Agriculture, 2007). Whether it is ethanol, butanol, synthetic gasoline, or even biodiesel, the interest in advanced forest fuels will forever change how society considers purpose-grown trees. However, it is not just the race to produce cellulosic biofuels that is putting biotech trees on the fast track to commercial production. Conventional forest products can benefit from biotechnology as well. Developing trees that grow faster, denser, and straighter is desirable to lumber companies. Making more cellulose and less lignin means more pulp and paper can be produced from a single tree. The list of commercial benefits from biotech trees is long and must include the ancillary benefits of providing renewable products that society uses.

Combat invasive threats

Engineering trees so they are more resilient to changing climates and are better able to defend against foreign pests is critical to keep our forests healthy. Earth's climate is changing at the same time invasive pests are able to travel from one side of the earth to the other in less than 24 hours in cargo holds. Forests evolved over millennia of relatively stable climates and large spatial separations. Demanding that native trees combat the onslaughts of threats they encounter today without human intervention will result in significant tree deaths and ecosystem change around the globe. This is already being seen in British Columbia, Canada. The mountain pine bark beetle there is estimated to claim 80 per cent of the mature Lodgepole pine by 2013 (Natural Resources Canada Program Description, 2007).

Maximize forest productivity

Growing more material on less land more quickly has potential benefits to the forest products industry, the new liquid biofuels industry, and as a method to sequester carbon more quickly. A significant amount of research has gone into biotech trees that make more fiber on less land. These trees have the potential to reduce demand on native forests and make it easier to use trees as a fast rotation crop in intensely managed tree plantations (ArborGen Bioenergy Factsheet, 2008). Dense wood crops may also play an important role in international incentive-based programs, such as the United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (UN-REDD). UN-REDD is designed to avoid deforestation, slow forest degradation, and reduce the economic incentives that promote illegal logging (UN-REDD Framework Document, 2008).

Replenish indigenous people's forest resources

In many lower income communities in South America, Africa, and Asia, the forests that indigenous people have historically relied on are decimated. The reasons are multifaceted but the fact remains that people are struggling, forests are disappearing, and these two situations reinforce one another through complex negative feedbacks. The solution is not as easy as producing biotech trees to reclaim degraded land, but advanced societies interested in improving these situations should not overlook the power of forest biotechnology when novel solutions are needed.

¹¹ The Forest Biotechnology Partnership is made of expert individuals and organizations working with the Institute of Forest Biotechnology to promote science, dialogue, and stewardship in the field of forest biotechnology. More information is available at: <http://partners.forestbiotech.org>

Potential risks of using biotech trees

A recent symposium of international experts highlighted the following areas of risk that should be addressed when biotech trees are used in the open environment (Institute of Forest Biotechnology, 2008). Summaries of the symposium findings are given below¹².

Gene flow and introgression

Gene flow refers to the introduction of a transgene into a native population of the same tree species. Before gene flow can occur there must be seed or pollen dispersal, establishment of the propagule, and survival of the plant to sexual maturity. In some situations gene flow is the desired outcome of releasing biotech trees into the environment. Forest health projects to protect threatened trees species from invasive threats plan on gene flow from genetically modified trees to native ones and thereby confer resistance to the native population. In some instances gene flow will have to be managed appropriately if the intent is to protect native forests from genetically modified tree genes. Introgression is the infiltration of a transgene from one species into the gene pool of another. This can occur through repeated backcrossing of a hybrid with one of its parents. This situation has similar ramifications to gene flow, but it adds a confounding factor of moving a transgene from one species to another.

Exceptional fitness

While one of the main goals is to produce trees that are better able to thrive in the environment, there are concerns that these more biologically fit trees may outcompete native species. This characteristic is commonly referred to as weediness. If a biotech tree is exceptionally fit when compared to its native relatives, there is a chance that it will be so successful in the forest that it keeps other trees from growing as they naturally would. Again, there are instances when exceptional fitness is the desired outcome as well as situations where it can cause ecological problems.

Effects on non-target species

Possible effects to non-target species might include harm to beneficial soil organisms, insects, birds, or other plants. For example the Bt gene that is one of the more common genetic modifications in plants produces a protein toxic to some insect pests. Using the Bt Poplars planted in China as an example, we can envision a situation where the Bt gene might inadvertently harm a non-target species of insect. This specific situation is extremely unlikely in appropriately constructed and well-managed trees because of the rigorous research that has gone into the Bt gene, but it is nonetheless a concern. Situations where thorough research on the expressed gene has not been completed could potentially harm organisms that interact with the biotech tree.

Biodiversity effects

These concerns are broader and involve interrelations among forest species that affect whole ecosystems. One such concern focuses on the idea that stands of sterile GE trees would not support a diverse population of species in the larger forest ecosystem. Another concern is that the target function of the biotech tree will have unintended ecosystem consequences. A situation could be envisioned where a biotech tree is exceptionally fit, contains a transgene that inadvertently affects non-target species, and there is gene flow to native trees. This situation could have negative biodiversity effects for the native forest.

These concerns highlight scientific questions that need to be addressed through ecological research. In addition, there are social concerns that are valid even if all of the scientific concerns are addressed. The proliferation of sustainable forestry certification schemes shows that the public places a high value on responsible management of natural resources and the well being of forest ecosystems. By recognizing the ecosystem-changing potential that irresponsible biotech tree use can cause, we are in the enviable position today of being able to construct and implement safeguards *before* biotech trees reach the market en masse.

¹² A PDF of the book, "Genetically Engineered Forest Trees: Identifying Priorities for Ecological Risk Assessment" is available free at the IFB's website: http://www.forestbiotech.org/pdf/GE_Trees_Ecorisk_online_v1.pdf

Currently, there is no set of practices that can ensure the long-term stewardship of biotech trees. That is why the IFB has created the Responsible Use: Forest Biotechnology Principles, an initiative to develop these critical practices in a highly transparent and multistakeholder driven process.

Responsible Use: Forest Biotechnology Principles

The Responsible Use initiative will help protect the future of our forests. This initiative is grounded in basic truths about forests and biotechnology:

- Forests are important to people
- Biotechnology is a powerful tool
- Biotech trees have the potential for unique and diverse applications
- Biotech trees are being planted around the world
- Oversight of biotech trees is different around the world

The framework of the Responsible Use initiative builds on these real-world realities with principles that provide a guiding sense of the requirements and obligations of using biotech trees responsibly. These principles are in recognition that responsibly used biotech trees have the potential to benefit society, the environment, economies, and cultures in ways that other trees cannot. Having a process that is transparent and inclusive of a wide range of perspectives is critical to determine what is ‘responsible’ and based on science. We also need practices that are not so prescriptive that a practitioner wanting to be a responsible user of forest biotechnology cannot afford to put these principles into action.

The IFB is managing this initiative by working with Sponsors, Forest Biotechnology Partners, experts from around the world, and any interested stakeholders. Draft reports, meeting documents, and all other non-proprietary material relating to this initiative is available online at responsibleuse.org. There is also an online form where anyone interested in participating in the development of these principles can comment. These comments are available to the public for review; more importantly, they will be used by the Implementation Committee when developing the principles.

Society Demands Sustainability

We need sustainably managed trees for communication, packaging, housing, food, and renewable energy. Currently the world does not have enough sustainably managed forests to fill all these needs. Instead we have illegal logging, land being converted from forests to sprawling housing developments, and an onslaught of invasive threats damaging the health of our forests. Forest biotechnology can be a powerful tool against these threats. While the debate of whether or not the use of biotech trees is sustainable carries on, the trees are being planted and used. As a non-profit organization based on science, dialogue, and stewardship, the IFB is committed to advancing the discussion of biotech trees and sustainability while at the same time developing a living set of principles that address the majority of current social concerns and scientific uncertainties. The future of our forests cannot be protected through inaction.

Scope of Responsible Use

In addition to developing a practical set of practices and principles for using biotech trees that can be applied in any circumstance and in any country, this initiative is designed to:

- Establish practices that can be used to complement certification schemes or regulatory programs
- Create teaching material to educate young students – society’s future forest stewards
- Evolve with the science of biotechnology, societal demands on trees, and sustainable resource management techniques

It is critical to keep Responsible Use practical and inexpensive to implement so it can be used extensively throughout the world. Because of this strict requirement, Responsible Use is not a certification mechanism. Nor is it designed to supersede any country's regulatory mechanism. Instead, it is designed to complement current stewardship and regulatory practices through principles that provide high-level guidance and practices, are actionable by any biotech tree user, and verifiable by other parties.

Taken together, the principles and practices encompass the entire biotech tree value chain: from idea conception to disposal of products. Through numerous discussions with stakeholders we have delineated 10 discrete steps of the value chain. Each of these steps will include one or more verifiable practice to help guide biotech tree use, as described below.

1. Product Conception: the initial research and development of a biotech tree.
2. Lab Research: testing ideas in a highly controlled indoor environment that includes work in the lab, at bench-scale, and in greenhouses up to the point of planting a tree outside.
3. Evaluation Research: testing trees outside of a confined lab with control.
4. Approval to Sell: the point when biotech tree developers have authority to sell trees to be grown in the environment.
5. Biotech Tree Purchase: beginning with the transfer of living biotech trees from the producer to the user.
6. Growth, Use, and Transfer: includes planting, growing, using, and transferring biotech trees in the environment.
7. Harvest, End of Life: The last step in the growth and use stage of a biotech tree's life determined by tree stem harvest or otherwise ceasing life processes in the tree.
8. Sale or Purchase of Products: beginning with the transfer of non-living products derived from a biotech tree.
9. Product Use: includes the processing or use of biotech tree products.
10. Product Disposal or By-product Resale: includes disposal of biotech trees or their products and the resale of by-products made from biotech trees.

The practices will be concise while still providing the structure needed to implement each one effectively and to verify it has been followed. Since the principles and elements are meant to evolve as forest biotechnology does the number and scope may change over time. It is best to refer to the most recent Responsible Use: Forest Biotechnology Principles document online at responsibleuse.org.

Developing the Principles & Practices

The IFB will manage development of the principles so they are flexible and do not restrict innovation, yet are straightforward for easy implementation. The most current information will always be available at www.responsibleuse.org, but as of printing, these are the draft set of Principles:

- Biotech trees will benefit people, the environment, or both.
- The risks and benefits of a biotech tree will be assessed before it is used in the environment.
- Transparency is important – stakeholders will be engaged.
- Social equity and indigenous rights are important and will be respected.

The Implementation Committee of this initiative is in the process of developing the Practices. The Committee includes experts in academia, tree growers and users, public interest professionals, environmental scientists, and government representatives. An ideal committee will have representation in each of these categories from every continent. Input from stakeholders will be addressed by the Implementation Committee and the IFB in a strong bottom-up process. The objective of the committee is to produce a global set of verifiable, performance-based practices.

Since the Practices are what practitioners will follow for each part of the value chain in which they are involved, there is much more instruction, discussion, and tools to make it a streamlined and effective process. Each step in the value chain has drafts of these elements to date. However, one Practice has been unanimously decided upon.

Responsible Use Practice Zero: Responsible Use Principles must follow all applicable laws and national and institutional guidelines pertaining to biotech trees.

This practice is important for two reasons. First, it makes it clear that following current laws and institutional guidelines is a foundational requirement to every practice that follows it. Second, it underscores the point that these principles and practices are meant to supplement regulations and not to supersede them.

Implementing the Principles

If we believe that society and the environment will benefit by having thoughtful experts create Responsible Use principles before any biotech trees are released into the natural environment, then we are already too late. As previously discussed, over a million Bt Populus have already been released into the environment in China, and as of printing, just one fruit bearing trees in the U.S. However, we still have the opportunity to significantly help to protect the future of forestry. There will be another wave of biotech trees in the next few years that will apply for commercial release (control level four)

Our goal is to have an initial set of Responsible Use: Forest Biotechnology Principles that practitioners can use to guide stewardship of biotech trees before they arrive on the market en masse: most likely in 2010 or 2011 at the latest. Involving a broad set of stakeholders from around the world, and testing the practices in real, on-the-ground situations is critical to developing a solid, broadly accepted, and highly streamlined set of practices. When they are available, practitioners will have a concise set of tools that have worksheets and guidance associated with each practice. There will also be a place to discuss with other practitioners in an open online forum at responsibleuse.org.

This initiative is designed to continue gathering input to refine the practices and add or remove them as necessary to keep abreast with forest biotechnology. Furthermore, the Responsible Use initiative strives to create a globally applicable set of principles. To do this we will coordinate with additional organizations and experts throughout the world.

The Institute of Forest Biotechnology

The Institute of Forest Biotechnology (IFB) is uniquely able to achieve the goals of this initiative. It is the only non-profit organization in the world to address the sustainability of forest biotechnology on a global scale. The IFB has the largest network of experts in this field. With the help of our Partners and Sponsors we bring diverse stakeholders together to address the societal, environmental, and economic aspects of forest biotechnology.

The IFB currently has five Initiatives. Some of these have dedicated websites for ease of use and enhanced transparency:

- Responsible Use™: Forest Biotechnology Principles – responsibleuse.org
- Forest Fuels™: Unlocking the potential of fuels made from trees – forestfuels.org
- Pine Genome Initiative (PGI™): Decoding pines for vital forests – pinegenomeinitiative.org
- Heritage Trees®: Species Protection through biotechnology heritagetrees.org
- Addressing Forest Biotechnology Concerns: Dialogue on ecological and social issues

Together we can improve future forests through science, dialogue, and stewardship. Please visit our website, forestbiotech.org, to learn more about protecting the future of forestry.

References

The Animal and Plant Health Inspection Service (APHIS), “Approval of USDA-ARS Request (04-264-01P) Seeking a Determination of Non-regulated Status for C5 Plum Resistant to Plum Pox Virus” United States Department of Agriculture (USDA). June 27, 2007.
www.aphis.usda.gov/brs/aphisdocs2/04_26401p_com.pdf

ArborGen Bioenergy Factsheet. “A New Vision in Alternatives”, 2008.
<http://arborgen.com/cms/upload/ArborGen%20Bioenergy%20Fact%20Sheet%204.07.pdf>

Burdon, Rowland D., William Libby and Robert Kellison. “Genetically Modified Forests from Stone Age to Modern Biotechnology” Forest History Society Issues Series, Durham NC, 2006.

Convention on Biological Diversity. June 1995. Online: <http://www.cbd.int/convention/convention.shtml>

Food and Agriculture Organization of the United Nations. Preliminary review of biotechnology in forestry, December 2004. Summary available online at: <http://www.fao.org/docrep/008/ae574e/AE574E03.htm>

Forest Genetic Resources Working Paper. “Preliminary review of biotechnology in forestry, including genetic modification.” Food and Agriculture Organization of the United Nations – Forestry Department. 2004.
<ftp://ftp.fao.org/docrep/fao/008/ae574e/ae574e00.pdf>

Geffen, David B. MD and Sophia Man MD. “New Drugs for the Treatment of Cancer, 1990-2001”, Department of Oncology, Soroka University Medical Center and Faculty of Health Sciences, Ben-Gurion University of the Negev, Beer Sheva, Israel.

“Genetically Engineered Forest Trees: Identifying Priorities for Ecological Risk Assessment” The Institute of Forest Biotechnology, September, 2008. http://forestbiotech.org/pdf/GE_Trees_Ecorisk_online_v1.pdf

Institute of Forest Biotechnology. www.forestbiotech.org

Keim, Brandon. “The Cheapest Genome Sequence Ever: For Real?” Wired Science Online. October 6, 2008.
<http://blog.wired.com/wiredscience/2008/10/the-cheapest-ge.html>

Natural Resources Canada. “Forest. Forward. Moving Beyond the Pine Beetle” Program Description.
http://mpb.cfs.nrcan.gc.ca/index_e.html

Pine Genome Initiative, 2007. <http://www.pinegenomeinitiative.org>

Scorza, Ralph. Personal communication regarding the regulatory status of the Honeysweet Plum tree March 6, 2009. Information available online: “Honeysweet Plum Trees: A Transgenic Answer to the Plum Pox Problem”,
<http://www.ars.usda.gov/is/br/plumpox/>

Submission to the Convention on Biological Diversity on Advice of the Report of the Ad Hoc Technical Expert Group on Genetic use Restriction Technologies. Convention on Biological Diversity, 2006.
<http://www.cbd.int/doc/meetings/tk/wg8j-04/information/wg8j-04-inf-17-en.pdf>

United States Department of Agriculture. “Trees, A Poplar Source for Biofuels”, Cooperative State Research, Education, and Extension Service. October, 2007. <http://www.csrees.usda.gov/newsroom/research/2007/poplars.html>

UN-REDD Framework Document. "UN Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries", Environmental Defense Fund, 2008.
http://www.edf.org/documents/7975_REDDandCarbonMarketAnalysisReport_EDF_0508.pdf

Zakour, John and Linda McCandless. “First Genetically Engineered Papaya Released to Growers in Hawaii” April 18, 1998. Available online at: <http://www.nysaes.cornell.edu/pubs/press/1998/papayarelease.html>