Ecological and Social Impacts of Fast Growing Timber Plantations and Genetically Engineered Trees

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Abstract: Plantations, as distinct from forests, are uniform agroecosystems that substitute for natural ecosystems and their biodiversity. As such, plantations are frequently associated with negative environmental and social impacts: decrease in water availability, modifications in the structure and composition of soils, depletion of biological diversity, encroachment on indigenous peoples' communities, agricultural lands and forests, and eviction of peasants and indigenous peoples from their lands with loss of livelihoods.

Introducing genetically engineered trees into monoculture plantations will exacerbate these negative impacts. In addition, the traits for which trees are being engineered—reduced lignin, faster growth, insect resistance and sterility—will have other serious and irreversible consequences for the world's native forests and forest dwelling peoples. The UN Convention on Biological Diversity's March 2006 statement on genetically engineered trees urges careful examination of potential environmental and socio-economic impacts, including long-term and transboundary impacts, and an overall precautionary approach toward the issue of genetically modified trees.

Around the world people are rising up in opposition to the spread of industrial monoculture tree plantations. In the Southern US, millions of acres of natural forests and wetlands have been converted to industrial tree plantations igniting concern among rural families, hunters, scientists, conservation groups, and even large businesses. In Brazil, plantations are called "green deserts," because they destroy biological diversity. In South Africa they are known as "green cancer," because of the tendency of the non-native eucalyptus trees to escape the plantations, spread wildly into other areas and wreak ecological havoc, and in Chile plantations are "green soldiers," because they stand in straight lines and are steadily and destructively advancing.

The establishment of industrial tree plantations has devastated the environment and local communities around the world. Problems associated with industrial tree plantations extend well beyond loss of biodiversity to include socio-economic issues related to flooding, spraying of toxic chemical fertilizers and herbicides in communities, poverty, land ownership and human rights. Not only have industrial tree plantations replaced some of the world's most diverse forests, they have also been the source of social and economic stress in human communities ranging from indigenous cultures in developing countries to rural families living in the developed world.

The spread of plantations has been driven by large producers of paper and wood products. Industrial tree plantations are managed intensively with chemical herbicides and fertilizers to accelerate growth rates for maximum production efficiency. To further this process, research and development of genetically engineered (GE) trees is underway and despite uncertainties regarding the impacts, industry appears to be gearing up for the widespread, industrial scale development of GE tree plantations. While these practices may perhaps increase profits for wood and paper products firms, the high economic, ecological and social costs associated with industrial tree plantations are paid by those living in and around large-scale plantations and by society at large. Despite industry claims to the contrary, the current industrial model of plantation forestry is neither economically, socially nor ecologically sustainable. Practices such as the continued conversion of natural forests to plantations, the routine use of toxic chemicals and the introduction of GE trees must be stopped in favor of forestry practices that sustain important ecological functions and local communities. Forestry can and should be practiced responsibly.

The Southern U.S.

Indisputably the most diverse forests in North America, the temperate forests of the Southern US are recognized by biologists worldwide for their biological richness. Beyond biological diversity, forests in the region help sequester carbon and therefore play a vital role in mitigating global warming. (Songhen and Brown) Besides helping to moderate the Earth's climate, Southern forests help protect drinking water in the most populated region of the US. (US Census Data) Despite their obvious ecological importance, less than 2% of the forests in the South are characterized as strictly or moderately protected. (Conservation Biology Institute)

The Southern US is currently the largest wood producing region in the world. (USFS, SFRA 2002) The large-scale production paper and wood products has led to the extensive conversion of natural forests to plantations that are dependent on the routine use of chemical fertilizers and herbicides. Forest trends in the Southern US contradict industry claims that plantations relieve pressure on natural forests and positively influence the economic well-being of rural communites.

In the 1980s and 1990s, nine million acres of the region's natural forests were converted to industrial tree plantations. (USFS, SFRA 2002); According to the US Fish & Wildlife Service the conversion of wetlands to plantations is the leading cause of fresh water forested wetlands loss in the region (USF&WS 2000) and has caused increased flooding in major watersheds such as the Waccamaw River watershed in North and South Carolina (Riggs et.al 2000); Despite 32 million acres of industrial plantations, in 1999 logging in plantations only accounted for approximately 22% of the total acres logged. (USFS, SFRA 2002); According to the US Forest Service "Pine plantations generally provide poor wildlife habitat." (USFS, SFRA 2002); From 1989 to 1999 chemical spraying of fertilizers in pine plantations increased by 800% (USFS, SFRA 2002) causing health concerns among families living near pine plantations.

The conversion of natural forests to plantations has not only degraded the region's rich biological heritage but also the socioeconomic well-being of rural communities. In fact, rural communities with high concentrations of plantations and chemical spraying exhibit low levels of education and high levels of poverty and unemployment among other indicators of poor socio-economic status when compared to other rural communities. (USFS, SFRA 2002)

Indigenous Communities Unite Against Plantations

In developing countries, companies are implementing strategies that enable them to expand plantations without purchasing land. In Ecuador foreign corporations are convincing indigenous and rural communities to sign over their rights to their traditional lands so the companies can expand plantations into high altitude ecosystems previously inaccessible. This practice also allows them to abandon the land after it is no longer productive. Some communities in Ecuador have signed 25-99 year contracts with companies, agreeing to tend the plantations in return for compensation. However, the paltry sum they receive is inadequate for the labor required. As a result, some communities in these mountainous regions have begun to rebel, breaking the contracts and burning the plantations. (Bravo, E. 2006)

Non-native tree plantations are also taking over agricultural land. In the Lumaco district of Chile, plantations are taking over farmland in the traditional territory of the Mapuche indigenous people. Since 1988, plantations in Lumaco increased from 14% of the land to over 52% in 2002. As a result, Mapuche communities are being forced off their lands, or are completely surrounded by plantations. In this region where water has traditionally been plentiful year-round, water-intensive plantations have dried up water supplies leaving farming communities dependent on water trucks. The contamination of ground and surface water from toxic chemicals used on the plantations, along with the high pollen levels blowing from pines are leading to rising rates of sickness. (Seguel, A. 2005) Escalating poverty in Mapuche communities is also associated with the expansion of plantations. Lumaco is one of the poorest regions of Chile, with 60% living under the poverty level including 33% in extreme poverty. (Cuenca, L. 2005)

Mapuche biologist Lorena Ojeda describes the changes: "The first plantations of *Pinus Radiata* were established in Chile in 1920. [Since then,]…the forward march of this single-crop cultivation has gone unhindered and in recent decades, the result has been environmental change and degradation…[such as]: environmental homogeneity …; biodiversity reduction…; increasing vulnerability from pest invasions and the indiscriminate application of pesticides to control them; and the use of prime agricultural land for cultivating tree plantations, resulting in the underutilization of this important natural resource." (Ojeda D., L. 2004)

Nearby in Brazil's state of Espirito Santo, indigenous Tupinikim and Guarani peoples have begun the process of reclaiming their traditional lands taken by Aracruz Cellulose for eucalyptus plantations. Brazil's landless workers, the Movimento dos Trabalhadores Rurais Sem Terra is taking over *Eucalyptus* plantations for their encampments using Articles 184 and 186 of the Brazilian constitution allowing for large estates to be expropriated and the land redistributed for agrarian reform. (Barros, M. 2003) But at the same time in Brazil, Aracruz Cellulose, Suzano, International Paper and Arborgen are involved in research into GE trees. Arborgen, a research venture between Rubicon (New Zealand), MeadWestvaco (US) and International Paper (US), is focusing much of its attention on *Eucalyptus* in Brazil. According to Rubicon CEO Luke Moriarity, Brazil is ArborGen's "most important geography." Arborgen is working on "improved pulping" (i.e. low-lignin) *Eucalyptus* in Brazil they believe will be highly profitable since they are cheaper to turn into paper. (Moriarty, L. 2005)

In a declaration on plantations to the UN Forum on Forests, the Latin American Network Against Tree Monocultures writes: "Accumulated experience on large-scale tree monocultures clearly shows their social, environmental and economic impacts: Deforestation … in nearly all the countries of the region where large scale monoculture tree plantations have been installed. It is… irresponsible to continue insisting on the falsehood that plantations…help to lessen pressure on forests, when the real situation shows the contrary; Destruction of equally valuable ecosystems, such as grasslands. The cases of Uruguay, Argentina and the south of Brazil are paradigmatic in this respect and the substitution of grasslands by monocultures of eucalyptus and pine trees is seriously affecting the biodiversity of these ecosystems; Impact on water resources [including] the drying up of watercourses, wetlands and wells on which the local populations depend; The social impact. Large-scale plantations [occupy] areas once occupied by local populations -- indigenous peoples, Afro-American communities and peasants. This has meant the loss of all or of a major part of the resources that they had had at their disposal, forcing them to migrate or thrusting them towards poverty." (Latin America Network Against Tree Monocultures 2003)

Sarah Tyack (Friends of the Earth) adds, "The idea that intensively-managed plantations take pressure off natural forests is a myth. What is happening is that natural forest is being cleared to make way for intensive plantations. GM trees will accelerate that process." (Tickell, O. 1999)

Genetically Engineered Trees: Ecological Impacts

Our fundamental knowledge of tree biology, ecology, and data gathered from GE agricultural crops suggests a wide array of environmental and human health problems that could result from large-scale plantings of GE trees. Experts from around the world agree that the commercial release of GE trees into the environment will contaminate native forest ecosystems with widespread impacts, both predictable and unpredictable. A small sampling of these potential impacts include disruption of pollinator and other insect populations in native forests with associated impacts on songbirds and other insectivorous wildlife; forest trees with high susceptibility to insects, disease, fungus or environmental stresses like wind, cold or drought; genetically engineered trees out-competing native trees and plants for light, water and nutrients.

China is so far the only country with developed plantations of GE forest trees—*Populus nigra* engineered to produce the bacterial toxin *Bacillus thuringiensis* (Bt). GE poplar plantations have been so widely planted throughout ten provinces that, according to Dr. Huoron Wang of the Chinese Academy of Sciences , "it is almost impossible to reduce the risk of gene flow from GM trees to non-GM trees… poplar trees are so widely planted in northern China that pollen and seed dispersal cannot be prevented." (UNFAO) His predictions have come true. The Nanjing Institute of Environmental Science has reported that contamination of native poplars with the Bt gene is already occurring. (Pearce, F. 2004)

Following is a summary of the main GE tree traits under development and associated impacts.

Herbicide Resistance

Researchers promoting herbicide resistance in trees make the counter-intuitive claim that engineering trees to resist inundation by broad spectrum herbicides like glyphosate-based RoundUp will reduce the quantity of herbicides applied to tree plantations.6 But in a recent study by agricultural researcher Dr. Charles Benbrook found that growers of RoundUp resistant soy *increased* their overall pesticide use by 11% with some growers using over 300-600% *more* chemicals than those growing conventional soy. (Benbrook, C. 2001)

The potential for huge increases in the quantity of glyphosate sprayed onto forests is of great concern since glyphosate is water soluble and has been linked to health problems in humans and fish due to water contamination.(Martinez, T.T. et. al. 1990) Glyphosate also binds to soil in the same manner as inorganic phosphates and may take years to break down. Damaging effects on beneficial soil fungi and bacteria have been recorded. Glyphosate also affects beneficial insects such as lacewings and ladybugs, not to mention birds and other animals that rely on a diversity of plant life to sustain their food and shelter needs.(Santillo, D. et. al. 1989) Overall, little is known about the long-term environmental impacts of glyphosate and similar broad-spectrum herbicides.

Concerns even exist over use of the glyphosate resistance gene itself. In soybeans, the herbicide resistance trait led to a 20% increase in the lignin content, causing the soybeans to become brittle and susceptible to fungal infection. This led to a 5% yield decrease compared to non-GE soy. Such unintended side effects in trees could be ecologically disastrous. (Elmore, R.W. et. al)

Insect Resistance

As with herbicide resistance, industry claims engineering trees to produce Bt toxin will eliminate applications of toxic chemicals on tree plantations. There is no evidence this is true. In agriculture, use of the Bt trait results in use of new, more toxic chemicals, as the development of Bt crops ultimately leads to Bt-resistant super-insects. (Gould, F. 1996) World Wildlife Fund reports "Bt crops will augment the selection pressure placed on target pests and that this will inevitably lead to an increased frequency of Bt resistance genes within the insects' gene pool."

According to the journal *Nature*, Bt was found by researchers to exude from plant roots, bind to soil, and remain in an "active, lethal state" for more than seven months mainly due to the high concentrations. (Owusu, R.A. 1999) The implications of these findings could be enormous. It is not known how genetically engineered Bt-toxins affect organisms present in the soil or the soil community as a whole, or how other soil bacteria pick up the Bt trait and transfer it throughout the soil community. Bt could impact nutrient cycling and uptake, soil microbes and pathogens and other little-understood soil processes. It is also unknown how Bt-toxin production will alter the rotting process of dead Bt trees. (Saxena, et.al. 1999) Bt toxin also impacts wildlife and non-target insects including beneficial insects that feed on the Bt target insects. (Hilbeck et. al. 1998)

Salt, Cold, Wet & Drought Tolerance

The mechanisms and complex gene interactions of stress tolerance are poorly understood as it involves multiple genes. Geneticist Dr. Ricarda Steinbrecher (Federation of German Scientists) describes potential complications of gene stacking: the insertion of multiple genes necessary to engineer growing condition tolerances such as those desired by industry. Dr. Steinbrecher: "While 'simple' traits such as herbicide-resistance or insecticide production already interfere with the plant's own internal biochemical pathways and gene regulation, creating unpredictable side effects, this is likely to be exacerbated for complex traits." (Steinbrecher, R. 2001)

In 2004, Dr. Steinbrecher co-authored the technical report "Genome Scrambling: Myth or reality? Transformation-Induced Mutations in Transgenic Crop Plants" that documented significant increases in genetic instability, higher mutation rates, and other disturbing effects at the site of artificial gene insertion. (Wilson, A. et.al. 2004)

One example of the difficulty in predicting responses to genetic manipulation, particularly in trees is the case of GE aspens engineered for increased growth rates. The GE aspens were genetically manipulated to respond differently to day length, and grow in daylight as short as six hours. However, the trees lost their ability to cope with cold temperatures. (Olsen, J.E. et. al.) Other concerns related to salt, cold, wet and drought tolerance include the use of foreign or exotic species that could become invasive, as well as the overtaking of formerly inhospitable landscapes by species existing nearby, thus displacing native species.

Trees have evolved over millennia to play a complex role in their ecosystems. The manipulation of trees to enable them to grow into the winter, or to exist on desert sands, is to drastically alter the entire ecology of that area, in ways that can be neither predicted nor reversed.

Disease Resistance

Concerns about the use of disease resistant traits have also been identified. Trees genetically modified for resistance to disease are likely to cause fresh epidemics. Just as engineering Bt into trees will lead to Bt-resistant insects, engineering trees to be resistant to disease will likely lead to diseases more potent than the original.

Dr. Steinbrecher elaborates on the potential for engineered viruses to recombine with others to create new, more deadly viruses: "The potential of such newly recombined viruses to overcome the defenses of related wild plants, or even be able to infect new host plants, is a serious concern. In laboratory experiments infecting viruses have also swapped their protein coat for that of another virus that had been engineered into a plant...the new coat enabled a virus to travel between plants, carried by aphids." (Steinbrecher, R. 2001)

Fungicide production engineered into GE trees may dangerously alter soil ecology, decay processes and the ability for the trees to efficiently take up nutrients… As with the pesticide Bt, fungicides engineered into trees are likely to be exuded by the roots into the soil, killing beneficial soil fungi and damaging soil ecology. (Sampson, V. et.al. 2000)

Lignin Reduction

One of the most prominent modifications to tree structure is repression of lignin biosynthesis. Lignin, which plays a vital role in the tree's natural defense system due its phenolic chemistry, comprises about one third of the dry weight of wood. Researchers at Oregon State University have cited numerous side-effects of suppressing lignin production, including decreased seed survival, increased animal browsing, changes in feeding patterns of defoliating insects, and alterations in soil fertility from changes in wood decomposition rates. (James, R.R. 1998)

Other industry researchers have confirmed that, due to shared biochemical pathways, suppression of lignin biosynthesis could weaken trees' defenses against pathogens and suppress the development of the trees' reproductive organs. Additional side effects of reduced lignin include stunted growth and collapsed vessels, leaf abnormalities and an increase in vulnerability to viral infection. (Séguin, A. et. al. 1998) The weakening of a tree's natural defenses is likely to encourage increased pesticide use. An additional fear is the high probability that, low-lignin trees will also rot more readily – affecting soil structure, fertilizer use, and forest ecology – and will release carbon dioxide more quickly into the atmosphere—contributing to global warming.

Industry argues reduced lignin trees will mean a cleaner, more efficient paper-making technology. (Sedjo, R. 1999) However, substantially cleaner, safer, and more efficient methods of lignin extraction already exist, such as closed-loop delignification. Better sources of low lignin fiber can be obtained from agricultural by-products from wheat, rice, barley, corn and other food crops, as well as low-lignin sources like kenaf and hemp, to satisfy all of the world's paper needs.

The Threat of GE Tree Contamination

The UN Food and Agriculture Organization surveyed GE tree researchers for their opinions about the economic, health and environmental benefits and risks of GM trees. More than half reported "the environmental threat of escape of GM pollen or plants into native ecosystems and forests and their impacts on non-target species" as their top concern. (UNFAO 2005)

Dr. David Suzuki, a Canadian geneticist and author, agrees. “We have no control over the movement of insects, birds and mammals, wind and rain that carry pollen and seeds. Genetically engineered trees, with the potential to transfer pollen for hundreds of miles carrying genes for traits including insect resistance, herbicide resistance, sterility and reduced lignin, thus have the potential to wreak ecological havoc throughout the world's native forests. GE trees could also impact wildlife as well as rural and indigenous communities that depend on intact forests for their food, shelter, water, livelihood and cultural practices.” (Suzuki, D. 2004)

Long-Distance Dispersal of Pollen

In 1993 the *New Physiologist* published a report entitled, “Pollen-Rain from Vegetation of Northwest India,” that found pine pollen in Northern India more than 600km from the nearest pine trees. (Singh et al.) Pollen transport models used by Duke scientists demonstrated the potential for long-distance dispersal of forest pollen from native forests in South Carolina. (Goris, K. et al. 2004) While most of the pollen remained near the forest source even after its ejection into the atmosphere, the model predicted that pollen can be transported in strong, windy air currents all the way into eastern Canada. (Goris, K. et al. 2004)

Another research team at Duke studied long-distance dispersal of transgenic conifer pollen using a mechanistic dispersal model and reported limited maximum pollen dispersal of 6m to 800m. (Katul, G. et al. 2004) This group’s modeling found that conifer pollen long-distance dispersal “can readily exceed 8km in less than 1 hour without escaping the atmospheric boundary layer (ABL),” which was thought to be critical for pollen dispersal. (Katul, G. et al. 2004) They used a conservative terminal velocity (Vt) value of 0.07m/s. Other conifer pollen modeling simulations indicated the dispersal increasing by a factor of 3, from 8.62km to 21km for trees in their reproductive onset and from 13.5km out to 33.5km when the conifers reached harvesting age. (Katul , G. et al. 2004) Since the conifer pollen was traveling for many kilometers below the ABL avoiding exposure to cold temperatures and excess UV-B radiation, while achieving long-distance dispersal, it demonstrates greater sustained pollen viability than previously thought and has important implications for ecological risk assessment. (Katul, G. et al. 2004)

Dr. Jim Clark points out that pollen dispersal is the most efficient mechanism for gene flow in most conifer species, especially in pines with high rates of pollen production and pollen grains easily blown long distances by wind currents; it would be no different in fertile transgenic conifers. (Clark, J. 2004) The potential for widespread transboundary contamination by GE tree plantations is high, requiring that GE tree release be prevented at the international level.

Long-Distance Dispersal (LDD) of Seed

Transgenic forest-tree seed dispersal plays a vital role in predicting gene flow from genetically engineered trees into wild relatives. Seed dispersal modeling simulations were performed for *Pinus taeda*, the native loblolly species since it’s the primary plantation timber tree in the Southeast U.S. (Williams et al.) The seed transport model found that only a small percentage of loblolly seeds were transported by long-distance dispersal pathways at distances from 11.9 - 33.7 km, indicative of the sheer difficulties in establishing containment. (Williams et al.) They concluded “the probability of LDD occurrence of transgenic conifer seeds at distances exceeding 1 km approached 100%.” (Williams et al.)

According to investigations by Dr. Ran Nathan, long distance dispersal of plants is widespread and known to occur from rare events, including extreme climatic events, which are driven by complex and highly stochastic processes. (Nathan, R. 2006) As frequently as once every ten years, seed dispersal from plants can trigger transport of seeds far beyond normal. (Nathan, R. 2006) Nathan notes evidence from two key sources: 1) ecological studies of small-scale dispersal and 2) biogeographical studies of intercontinental disjunctions of remote islands. (Nathan, R. 2006) Colonization of initially barren oceanic islands formed by volcanic activities and other remote habitats provides classical evidence of long distance seed dispersal. (Nathan, R. 2006)

Terminator Trees

Due to the universally accepted problems of cross contamination with wild species, industry insists genetically engineered trees will be sterile. However, trees are one of the most complex organisms the biotechnology industry has yet taken on. With complex interactions among different genes to express various traits, and with genes activating and deactivating throughout a tree's life, the prospect of scientists manufacturing a permanently sterile tree is practically nil.

Dr. Martha Crouch argues that any unreliability in sterility technology could potentially lead to the cross-contamination of sterile traits to native trees with appalling consequences for human and wildlife communities that rely on fruit, seeds, nuts, nectar or pollen. (Crouch, M. 2001) Other studies found that the sterility technology itself causes serious unintended side effects such as mutations and genome scrambling that are impossible to predict. Dr. Steinbrecher states, "Trees are not an annual crop, but live hundreds of years, exposed to many stresses such as frost, fire, drought, storm and insect attacks. No risk assessment can predict the interference that genetic engineering will have on the stress response and aging of trees." (Steinbrecher, R. 2001)

Finally, sterile trees growing significantly faster than trees devoting their energy to reproduction could lead to rapid loss of soil nutrients and ground water. (Sampson, V. 2000) As a result, soils could become rapidly barren, requiring the clearing of new land for new plantations.

Contamination Threat to Land Owners and Public Lands

GE contamination in annual farm crops has occurred rapidly, and contamination from GE trees is expected to occur even faster. A Union of Concerned Scientists study concluded that seeds of non-GE varieties of corn, soybeans, and canola are pervasively contaminated by GE varieties. GE contamination was detected in 50% of the corn and soybeans, and 83% of the canola varieties tested. These crops have only been in production since 1996. (Mellon et al., 2004)

Patents on GE plants give biotechnology corporations exclusive ownership rights to *any plants* that contain the DNA they engineered. This means if native trees on private or public lands are pollinated by GE trees, or if GE tree seeds drift onto these lands, the offspring (seeds, plants, and crops) that result may be the legal property of the patent holder. Landowners may violate the law by saving seeds or using natural regeneration to produce timber. Biotechnology corporations have successfully sued landowners whose land was contaminated by GE plants by no fault of their own. In addition, landowners also face losses in productivity and markets. GE plants are designed for specific uses, and if these uses are not compatible with a landowner's land management goals, then contamination results in negative economic impacts. For instance, contamination from low-lignin GE trees will result in trees unsuitable for saw timber.

Genetically Engineered Trees and Human Health

The potential impact of GE trees on human health is virtually unstudied. It is possible to have an idea only by looking at studies of agricultural crops altered for similar traits. Such studies indicate risks include exposure to toxic chemicals applied to plantations of transgenic trees and harmful effects of inhaling pollen from trees that produce Bt toxin. (Bernstein et al., 1999)

Numerous studies highlight the potential health impacts of exposure to Bt toxin. Studies involving US farm workers exposed to Bt sprays found 2 of 123 had antibodies to toxin proteins. (Bernstein et al., 1999) A series of studies by scientists from Cuba and Mexico found that Bt toxin Cry1Ac is a potent systemic immunogen, binds to gut cells and Can cause changes in the permeability of the gut. (Vasquez-Padron et al., 1999a, 1999b, 2000) They concluded, "We think that previous to commercialization of food elaborated with self-insecticide transgenic plants it is necessary to perform toxicological tests to demonstrate the safety of Cry1A proteins for the mucosal tissue and for the immunological system of animals." (Vazquez-Padron et al., 2000)

Finally, the risk of immune response from Bt via inhalation is greater than the response from ingestion as inhaled substances are not exposed to gut digestive enzymes and go directly into the circulatory system. In addition, some of the inhaled proteins can make it to the digestive system via the connection between the nasal passage and the esophagus. (Bernstein et al., 1999) Establishment of plantations of pines that produce Bt pollen could lead to widespread sickness, as pines are known for heavy pollination, spreading pollen for hundreds of kilometers.

Trees engineered to resist glyphosate-based herbicides (e.g. Roundup) also pose a threat, due to the potential for increased use of these toxic herbicides. Studies in Oregon found that glyphosate exposure significantly increased the risk of late term spontaneous abortions and De Roos and other authors found an association between glyphosate use and the cancers non-Hodgkins lymphoma and multiple myeloma. (De Roos et al. 2003, 2005) Additional studies have found that inhaling Roundup is much more dangerous than ingesting it orally. Roundup is commonly sprayed from the air where it can drift into nearby communities. (Savitz, D.A. 2000)

Lack of US Federal Regulatory Oversight

Author Jeffrey Smith concludes, "Americans … usually assume that the FDA has tested [genetically engineered food] and proven it safe. Not true. Documents made public from a lawsuit [May 1998] revealed that FDA scientists had repeatedly warned their superiors that GM foods might create unpredictable, hard-to-detect allergies, toxins, new diseases and nutritional problems. They had urged the political appointees to require long-term safety studies. But the person in charge of FDA policy was the former attorney (and later vice president) of biotech giant Monsanto… The policy that was adopted in 1992 and still stands is that no safety tests whatsoever are required by the FDA. Thus, varieties that had never been rigorously safety tested with animals, and probably never even fed to humans, were approved for sale." (Smith, J. 2006)

A basic concern with the lack of USDA oversight is that many GE tree field trials are not monitored by regulators to determine compliance. Dr. Doug Gurian-Sherman elaborates on the inadequate US regulatory oversight: "As of 2000, confinement requirements in individual tree field trials prohibited flowering, and USDA reportedly did not allow flowering of any genetically engineered trees. However, the author is aware of no current policies that prohibit flowering of forest tree field trials. If unpublished, internal, policy prohibitions against flowering exist, they can be easily revoked unlike regulations or statutes." (Gurian-Sherman, 2006)

Too many unknowns

The release of GE trees in large plantations worldwide raises too many unanswered questions. We simply do not know the long-term implications of planting GE trees, because the research has not been conducted and may require several decades. The rush to plant GE trees is a dangerous step that needs to be halted. Tree ecology researchers including Dr. Thomas Whitham have investigated the complexities of forest ecosystems and noted that transgenic variants of dominant pine species have extended phenotypes and that a community genetics perspective was needed to comprehensively assess their impacts. (Whitham 2003; Whitham et al. 2003) Dr. Steven Strauss concurred in his "State of the Science" presentation with Dr. Whitham and proposed that "large-scale, long-term studies" are needed, due to the potential for transgenic trees as dominant and keystone species having "unintended consequences." (Strauss, S. 2003).

Just a few of the parameters that must be addressed in an independent risk assessment of GE trees prior to release into the environment were proposed at a conference on transgenic forest and fruit trees including: stress adaptations – biotic and abiotic factors; hardiness; symbionts – effects on mycorrhizae, microbials, others; life span; growth habit and morphology; vegetative vigor – weediness; number of years to maturity (flowering) – invasiveness; disease and insect resistance and susceptibility; pollen parameters – production, viability, stickiness, size, etc.; impact on pollinators or associated species; seed dispersal factors – weediness potential; seed parameters – production, dormancy, emergence, viability; outcrossing – gene flow through hybridization; self compatibility – measure of potential for invasiveness; fruit maturity and ripening; fruit yield; fruit quality; and wood quality/chemistry – lignin, pulp quality. (USDA). Additional research is needed on the social, cultural, economic and health impacts on indigenous and rural populations.

Conclusion

The complex interactions of trees, understory plants, insects, animals, fungi, bacteria and soil micro-organisms is poorly understood. At best we have an outline of the principles of interaction, but by no means do we have a complete picture. This, combined with the inherent uncertainty of genetic engineering means that large-scale use of genetic engineering is dangerous. Threats posed by genetically engineered trees are simply too great to allow them to be released into the environment, much less to allow them to be mass cultivated in huge plantations.

At their Eighth Conference of the Parties in Curitiba, Brazil in March 2006, the UN Convention on Biological Diversity emphasized the potential dangers of GE trees. At this meeting, delegates from ten countries called for a global moratorium on GE trees. Others called for a global risk assessment. The resulting CBD declaration states, in part: "The Conference of the Parties, *Recognising* the uncertainties related to the potential environmental and socio-economic impacts, including long-term and trans-boundary impacts, of genetically modified trees on global forest biological diversity, as well as on the livelihoods of indigenous and local communities, and given the absence of reliable data and of capacity in some countries to undertake risk assessments and to evaluate those potential impacts, *recommends* parties to take a precautionary approach when addressing the issue of genetically modified trees." This is a direct reference to the Precautionary

Principle, enshrined in the CBD. The Precautionary Principle demands proof of a need for GE trees and their safety before they are released. Today, there is neither.

"New biotechnologies, in particular genetic modification, raise concerns. Admittedly, many questions remain unanswered for both agricultural crops and trees, and in particular those related to the impact of genetically engineered crops on the environment. Given that genetic modification in trees is already entering the commercial phase with genetically engineered *Populus* in China, it is very important that environmental risk assessment studies are conducted with protocols and methodologies agreed upon at a national and international level. It is also important that the results of such studies are made widely available." (UNFAO, 2005)

That the global timber industry is running out of forests to plunder is clear. However, there are alternatives to opening the Pandora's Box of GE trees. Consumption reduction, alternative fibers, better and greater recycling of paper all are very basic steps which can be taken to significantly reduce the amount of forest being plundered to drive the wheels of our society. That the very industry that has wiped out native forests worldwide should now claim to offer the salvation to those forests in the form of GE trees demonstrates their unscrupulous and cynical opportunism.

References

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Bravo, Elizabeth, from a presentation at a side event of the Eighth Conference of the Parties of the United Nations Convention on Biological Diversity, Curitiba, Brazil, March, 2006.

Cuena, Lucio, from a presentation at a strategy meeting on GE trees and plantations, Vitoria, Brazil, November, 2005.

Seguel, Alfredo, "Modelo forestal chileno y Pueblo Mapuche: Las posiciones irreconciliables de un conflicto territorial" 12/13/05

Ojeda D., Lorena, "Genetically Modified Trees in Chile: A New Forest Conflict," mapuche@mapuexpress.net

Barros, Miguel, "Los Sin Tierra: Por Los Caminos de America" DVD, 2003

Moriarty, Luke, address to shareholders, www.rubicon-nz.com, July, 2005.

Declaration by the Latin American Network against Tree Monocultures, United Nations Forum on Forests, Geneva, May 2003

World Wildlife Fund, Terrestrial Ecosystems of North America

Songhen, Brent, Ohio State University and Brown, Sandra, Winrock International *The Influence of Conversion of Forest Types on Carbon Sequestration and Other Ecosystem Services in the South Central United States,* December 15th 2004.

U.S. Census Data: http://www.census.gov/population/www/projections

Analysis of State Natural Heritage and NatureServe data by Conservation Biology Institute

Tickell, O. and Clover, C, "Trees That Never Flower Herald a Silent Spring," *The Daily Telegraph* (London) July 17.

Pearce, Fred, "Altered trees hide out with the local poplars," *New Scientist*, September 18, 2004

Benbrook, C.M. "Troubled Times Amid Commercial Success For Roundup Ready Soybeans: Glyphosate Efficacy is Slipping and Unstable Transgene Expression Erodes Plant Defenses and Yields," Northwest Science and Environmental Policy Center, May 3, 2001, p.10.

Martinez, T.T. and K. Brown, "Oral and Pulmonary Toxicology of the surfactant used in ROUNDUP Herbicide," Proceedings of the E\Western Pharmacology Society vol. 34, pp. 43-46, 1991; Martinez, T.T., et. al., "Comparison of the Toxicology of the Herbicide ROUNDUP by Oral and Pulmonary Routes of Exposure," Proceedings of the Western Pharmacology Society, Vol. 33, pp. 193-197, 1990.

Santillo, D. et. al, "Response of Small Mammals and Habitat to Glyphosate Application on Clearcuts," *Journal of Wildlife Management*, Vol. 53, (1), pp. 164-172, 1989; Freedman, B., "Controversy Over the Use of Herbicides in Forestry, with Particular Reference to Glyphosate Usage," *Journal of Environmental Science and Health*, Vol. 8 part C, pp. 277-286, 1990-91.

Elmore, R.W. et. al., "Glyphosate Resistant Soybean Cultivar Yields Compared with Sister Lines," *Agronomy Journal* 93, pp. 408-412.

Sedjo, D. op. cit., 1, p. 20

Owusu, R.A., "GM Technology in the Forestry Sector, A Scoping Study for WWF," November, 1999

D. Saxena, S. Flores and G. Stotsky, "Insecticidal toxin in root exudates from Bt corn," *Nature* 402, 1999 p. 480

Hilbeck, A. et. al., "Effects of transgenic Bacillus thuringiensis corn-fed prey on mortality and development time of immature Chrysoperla carnea (Neuroptera: Chrysopidae)," *Environmental Entomology* vol. 27, no. 2, 1998, pp. 480-87; Hilbeck, A. et al., "Toxicity of Bacillus Thuringiensis Cry1Ab toxin to the predator Chrysoperla carnea (Neuroptera: Chrysopidae)," *Environmental Entomology* vol. 27, no. 5, 1998, pp. 1255-63; Hilbeck, A. et al., "Prey-mediated effects of Cry1Ab toxin and protoxin and Cry2A protoxin on the predator Chrysoperla carnea," *Entomologia Experimentalis Et Applicata* Vol. 91, no. 2, 1999, pp. 305-16.

Steinbrecher, Dr. Ricarda, "The Ecological Consequences of Genetic Engineering," in Brian Tokar, ed.., *Redesigning Life? The Worldwide Challenge to Genetic Engineering*, London: Zed Books, 2001, p. 89-90.

Olsen, J.E. et. al., "Ectopic Expression of Oat Phytochrome A in Hybrid Aspen Changes Critical Daylength for Growth and Prevents Cold Acclimatization," *Plant Journal*, vol. 12 no. 6, 1997, pp. 1339-50

Sampson, Viola and Lohmann, Larry, *Corner House Briefing 21: Genetically Modified Trees*, December, 2000, p. 8

"Sequestered Carbon Dioxide," *Green Energies Newsletter*, August 9, 1998 at www.nrglink.com/archives/nrgs898.html, p. 93

Séguin, A. et. al., "Transgenic Trees," in Bruce and Palfreyman, eds., *Forest Products Biotechnology*, Bristol, PA.: Taylor and Francis, 1998 p. 291.

Wilson A., Latham J., Steinbrecher R. "Genome Scrambling - Myth or Reality? Transformation-induced mutations in transgenic crop plants." Technical report, EcoNexus 2004, www.econexus.info

Savitz, D.A., Arbuckle, Kaczor D., Curtis, K.M., "Male Pesticide Exposure and Pregnancy Outcome," *Am. J. Epidemiol.*, 2000, 146

Williams,C.G, LaDeau,S.L., Oren,R., and Katul,G.G., "Modeling Seed Dispersal Distances: Implications For Transgenic Pinus Taeda," *Ecological Applications*: Vol. 16, No. 1, pp. 117-124.

Nathan,R., "Long-Distance Dispersal of Plants," 11 August 2006, *Science* 313: 786-788.

Goris,K. and Avissar,R., "Dispersal of Pollen in Southeastern US," Genomics and Transgenic Conifer Forests: A Nicholas Environmental Leadership Forum, Duke U., November 17-19, 2004.

Katul,G., Williams,C.G., Siqueria, M., Poggi,D., Porporato,A. and Oren,R., "Spatial Modeling of Transgenic Conifer Pollen," Genomics and Transgenic Conifer Forests: A Nicholas Environmental Leadership Forum, Duke University, November 17-19, 2004.

Clark,J. "Potential for Spread of Transgenic Conifers through Pollen and Seed Dispersal," Genomics & Transgenic Conifer Forests: Nicholas Environmental Leadership Forum, Duke U., November 17-19, 2004.

G. Singh et al., "Pollen-rain from vegetation of North-west India." *New Physiologist* 72, 1993, pp. 191-206.

Sedjo, R., Biotechnology and Planted Forests: Assessment of Potential and Possibilities, Resources for the future discussion paper 00-06, Washington, 1999, p. 8, 20, 22

Bradshaw,H.D., Jr. and Strauss,S.H. 2001. Breeding strategies for the 21st century: Domestication of poplar. In Poplar Culture in North America. Edited by D.I.Dickmann, J.G.Isebrands, J.E.Eckenwalder, and J.Richardson. NRC Research Press, Ottawa pp. 383-394.

Hamrick,J.L., Godt,M.J.W., and Sherman-Broyles,S.L. 1992. Factors influencing levels of genetic diversity in woody plant species. *New Forests* 6: 95-124.

Slavov,G.T., DiFazio,S.P., and Strauss,S.H. 2002. Gene flow in forest trees: From empirical estimates to transgenic risk assessment. In Ecological and Agronomic Consequences of Gene Flow from Transgenic Crops to Wild Relatives. Ohio State University, Columbus, pp. 106-119. http://www.biosci.ohio-state.edu/lspencer/Proceedings.pdf.

Wells,M.J., Poynton,R.J., Balsinhas,A.A., Musil,K.J., Joffe,H., Van Hoepen,E., and Abbott,S.K. 1986. The history of introduction of invasive alien plants to southern Africa. In The ecology and management of biological invasions in southern Africa: proceedings of the National Synthesis Symposium on the Ecology of Biological Invasions. Edited by I.A.W.Macdonald, F.J.Kruger, and A.A.Ferrar. Oxford University Press, Cape Town, S.A. pp. 21-35.

Martha L. Crouch, "From Golden Rice to Terminator Technology: Agricultural Biotechnology Will Not Feed the World or Save the Environment," in Brian Tokar, ed., *Redesigning Life? The Worldwide Challenge to Genetic Engineering* (London: Zed Books 2001).

Mellon,M. and Rissler,J. "Gone To Seed: Transgenic Contaminants in the Traditional Seed Supply," Union of Concerned Scientists, UCS Publications, Cambridge, MA, 2004.

Bernstein et al., 1999.

Gendel,S., 1998b: 60.

Vasquez- Padron et al., 1999a, 1999b, 2000; Vazquez-Padron et al., 2000b: 58.

Smith, J.M., Institute for Responsible Technology, www.responsibletechnology.org; "Rice Industry: Keep Genetically Engineered Varieties in the Lab", October 2006.

Gurian-Sherman, Dr. Doug, "Contaminating the Wild? Gene Flow from Experimental Field Trials of Genetically Engineered Crops to Related Wild Plants," Center for Food Safety, 2006, Washington, D.C. Website: http:://www.centerforfoodsafety.org

Whitham,T.G., "Community and Ecosystem Consequences of Transgenics: The Importance of Quantifying the Extended Phenotype," USDA/ APHIS Conference: Genetically Engineered Forest and Fruit Trees: Public Meeting, July 8-9, 2003, Riverdale, Maryland; Whitham,T.G., Young, W.P., Martinsen,G.D., Gehring,C.A., Schweitzer,J.A., Shuster,S.M., Wimp,G.M., Fischer,D.G., Bailey,J.K., Lindroth,R.L., Woolbright,S. and Kuske,C.R., "Community and Ecosystem Genetics: A Consequence of the Extended Phenotype," *Ecology*: Vol. 84, No. 3, 2003.

Strauss,S.H., "Genetic engineering of forest trees: Goals, benefits and safety," USDA/APHIS: Genetically Engineered Forest and Fruit Trees: Public Meeting, Riverdale, MD, July 8-9, 2003.

Deleted: ¶

USDA/APHIS document "Background information on possible data required for environmental assessments of transgenic trees and other woody plants," presented at USDA/APHIS: Genetically Engineered Forest and Fruit Trees: Public Meeting, July 8-9, 2003, Riverdale, MD.

Deleted: ¶

Tickel, O. et. al., "Trees That Never Flower Herald a Silent Spring," *The Daily Telegraph*, July, 1999.

UN Food and Agriculture Organization, "A Preliminary Review of Biotechnology in Forestry including Genetic Modification," July, 2005.

Sampson, V. and Lohmann, L., *Corner House Briefing 21, Genetically Modified Trees,* Dec. 2000.

James, Rosalind R., et.al., "Environmental Effects of Genetically Engineered Woody Biomass Crops," *Biomass and Bioenergy*, Vol. 14, No. 4, 1998.

Suzuki, Dr. David, from a letter to Global Justice Ecology Project, March, 2005.

De Roos, AJ et al. Integrative assessment of multiple pesticides as risk factors for non-Hodgkin's lymphoma among men. Occup Environ Med 2003, 60, E11; De Roos, AJ, et al. Cancer incidence among glyphosate-exposed pesticide applicators in the agricultural health study. *Environ Health Perspect* 2005, 113, 49-54.

Bernstein, et al. 1999. Immune responses in farm workers after exposure to *Bacillus thuringiensis* pesticides. *Environmental Health Perspectives*, 107(7): 575-582

Vazquez-Padron, RI, et.al. 1999a. Intragastric and intraperitoneal administration of Cry1Ac 1999a. Intragastric and intraperitoneal administration of Cry1Ac protoxin from *Bacillus thuringiensis* induces systemic and mucosal antibody responses in mice. *Life Sciences*, 64(21): 1897-1912.; Vazquez-Padron RI, et.al. 1999b. *Bacillus thuringiensis* Cry1Ac protoxin is a potent systemic and mucosal adjuvant. *Scandinavian J Immunology* 49: 578-584; Vazque-Padron, R.I., et al. 2000. Cry1Ac protoxin from *Bacillus thuringiensis* sp. kurstaki HD73 binds to surface proteins in the mouse small intestine. *Biochemical and Biophysical Research Communications* 271, pp. 54-58

Savitz, D.A., Arbuckle, Kaczor D., Curtis, K.M., "Male Pesticide Exposure and Pregnancy Outcome," Am. J. Epidemiol., 2000, 146, pp. 1025-36.