GE Trees, Cellulosic Biofuels & Destruction of Forest Biological Diversity

With concerns mounting about the competition between food and fuel due to crop-based agrofuels, industry is heavily promoting fuel produced from woody sources such as trees as the solution to this conflict.

This is not a solution, but will have dangerous impacts on biological diversity as well as indigenous and rural communities. It will further exacerbate the global food shortage and contribute to the climate crisis. In particular, the proposal to manufacture trees genetically engineered with traits that will enhance their usefulness as a feedstock for cellulosic biofuels will have serious ramifications for forest biological diversity and forest dependent communities.

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There is a rising emphasis on use of cellulosic feedstocks to produce agrofuels, in order to eliminate food-fuel competition. Cellulose-based agrofuels, however, will not address this problem. In many countries of the world, industrial timber plantations already compete with agricultural land. The growing incentive to develop tree plantations to feed the rising global demand for timber caused by producing agrofuels from trees will only exacerbate this competition for land between timber plantations and agriculture. In addition, the massive new demand for wood generated by production of agrofuels from cellulose will accelerate deforestation and illegal logging in forests all over the world, with serious consequences for forest biological diversity, forest-dependent communities and the climate.

In the Lumaco District of Chile, for example, the expansion of pine and eucalyptus plantations is taking over agricultural land used by indigenous Mapuche communities. Since 1988, plantations in this region increased from 14% of the land to over 52% in 2002. This farmland conversion is forcing people off their land and leading to escalating rates of poverty. In the Lumaco District 60% of the people live in poverty, with one-third in extreme poverty. The government of Chile provides financial incentives to encourage people to stop growing food and grow trees instead. Lucio Cuenca B., the National Coordinator for the Observatorio Latinamericano de Conflictos Ambientales in Santiago, Chile explains,

> "*The response by the State has been to provide favorable legal and social conditions to enable the forestry companies to fulfill their production goals and continue their expansion. One the one hand, repression and criminalization [of Mapuche opposition], on the other … rerouting subsidies formerly aimed at the large forestry companies towards the small farmers and indigenous land owners [that] oblige them to convert to forestry activities. Thus the strategy for expansion becomes more complex, operating through political and economic blackmail that leaves no alternatives.*"[1]

The rising economic incentive to grow trees resulting from the enormous increase in demand for wood generated by use of trees for cellulosic agrofuels will only worsen the conflicts between communities who need land for food, and companies who want the land to grow trees.

Another consequence of the rising emphasis on cellulosic agrofuels as the next generation of biofuels technology is the accelerated promotion of fast-growing, easily digested genetically engineered (also called genetically modified) trees. Genetically engineered (GE) trees have been widely promoted as a future feedstock for cellulose-based agrofuels. Additional genetic research is targeting oil palm and jatropha for greater and higher quality oil production for biodiesel.

In the US, GE low-lignin poplar plantations for agrofuel production are being proposed for 'unused' agricultural land. A statement by Purdue University in the US touts the possibilities: *"Researchers believe that using the hybrid poplar in its present form could produce about … 700 gallons of ethanol [per acre annually]. Changing the lignin composition could increase the annual yield to 1,000 gallons of ethanol per acre, according to experts. Planted on 110 million acres of unused farm land, this could replace 80 percent of the transportation fossil fuel consumed in the United States each year."*[2] Besides greatly exaggerating the potential benefits of low-lignin trees, this statement encourages us to accept the widely peddled myth that any "unused" farmland is better suited to fueling motor vehicles in the US than to feeding people or providing habitat for wildlife. It also ignores the tremendous quantities of water consumed by the manufacture of cellulosic agrofuels, and the impact this will have on communities and ecosytems. For every gallon of ethanol produced, about 4 gallons of water are used in the refinery process.[3] A refinery

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[1] Lucio Cuenca, Observatorio Latinoamericano de Conflictos Ambientales, presentation at the Vitoria Meeting Against Monoculture Timber Plantations, November 2005, Vitoria, Brazil.

[2] *"GM Tree Could be Used for Cellulosic Ethanol, Fast-Growing Trees Could Take Root as Future Energy Source",* Purdue University Release, August 24, 2006
http://www.purdue.edu/UNS/html4ever/2006/060823.Chapple.poplar.html

[3] Pate, R., M. Hightower, C. Cameron, and W. Einfeld. 2007. Overview of Energy-Water Interdependencies and the Emerging Energy Demands on Water Resources. Report SAND 2007-1349C. Los Alamos, NM: Sandia National Laboratories.

producing 100 million gallons of ethanol per year therefore requires about 400 million gallons of water. Cellulosic ethanol, if it becomes feasible, will likely place even greater demands on water.

GE Trees & Contamination of Wild Forests

Beyond the threats to food are the threats to forests. Richard Meilan, a faculty member at Purdue University points out that *"The genus Populus includes about 30 species that grow across a wide climatic range from the subtropics in Florida to subalpine areas in Alaska, northern Canada and Europe."*[4] While he makes this point to demonstrate the flexibility of the poplar as an energy crop, he also raises a serious red flag concerning the potential genetic contamination that could be caused by the commercial release of a GE tree that has such a large and widespread population of wild relatives. According to *The Economist*, countries like Sweden are also considering use of GE poplars for cellulosic agrofuels.[5] Even the use of non-native tree species, such as GE eucalyptus in the southern US, raises serious concerns about the impacts that the escape of genetic material from GE trees could have on native forests.

Our understanding of the contamination potential from future plantings of GE trees is largely based on known contamination incidents from GE food crops and experimental plantings of engineered grasses.[6] While there has not yet been a fully comprehensive study of crop contamination from GE varieties, several well-documented incidents have alerted the world to the seriousness of this problem.

Two incidents of transgenic contamination of wild relatives have been studied in some detail - the transmission of an herbicide-tolerance gene from oilseed rape (canola) to weedy wild turnip hybrids in Canada; and the detection of herbicide-tolerant grasses up to 21 kilometers from a test site in the US state of Oregon.

There have also been two attempts to systematically address the contamination potential of GE crops. Since 2005, Greenpeace, in collaboration with GeneWatch in the UK, has maintained an online database of GMO contamination incidents, known as the GM Contamination Register.[7] Their 2006 report lists 142 publicly documented incidents, in 43 countries, since the introduction of commercial GE crops in 1996. These include instances of contamination of food, seed, animal feeds and wild relatives of crops, as well as illegal releases of unapproved GE varieties and documented negative agricultural side effects.[8] Also in 2006, the US-based Center for Food Safety released a report on the contamination potential from field trials of new, experimental GE crop varieties, reviewing the prevalence of field trials of GMOs with known wild relatives across the US.[9]

The incidents of contamination listed in the side box show that gene escape and GE contamination cannot be prevented once GE crops are released. This in turn suggests that the widespread planting of GE trees would over time lead to a persistent contamination of the world's native forests, with disruptive ecological consequences.

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[4] ibid.

[5] Derek Bacon, *"Woodstock Revisited"*, *The Economist*, 8 March 2007.

[6] While 'contamination' is the preferred terminology for this phenomenon in most non-technical literature, advocates of genetic engineering have sought to replace it with the less familiar and more ambiguous term 'adventitious presence'. The research literature is mainly concerned with the 'introgression' of novel traits, *ie* the successful and inheritable incorporation of transgenic DNA into the genome of a population of native organisms or non-modified crops.

[7] http://www.gmcontaminationregister.org/

[8] Greenpeace International, *GM Contamination Register Report: Annual review of cases of contamination, illegal planting and negative side effects of genetically modified organisms*, February 2007, at http://www.genewatch.org/uploads/f03c6d66a9b354535738483c1c3d49e4/gm_contamination_report_2006.pdf

[9] Doug Gurian-Sherman, *Contaminating the Wild? Gene Flow from Experimental Field Trials of Genetically Engineered Crops to Related Wild Plants*, Washington, D.C.: Center for Food Safety, 2006.

An additional problem with GE trees grown for agrofuels extraction is that (unlike most crops) they are likely to be grown in the vicinity of genetically similar native and uncultivated tree populations. In these instances, well-documented cases of GE contamination of wild relatives are of particular relevance.

In one example, herbicide tolerance genes from GE oilseed rape were found in a weedy wild turnip hybrid species in Canada, as well as in a sample of charlock, a weedy related plant in the UK.[10] Charlock is considered to be a significant weed of oilseed rape, and was previously believed to be incapable of spontaneous hybridization with domesticated rape varieties.

Further complicating the situation, several common weedy plants in agricultural regions of the US have evolved resistance to glyphosate as a result of continued exposure to elevated levels of this herbicide by growers of Monsanto's 'Roundup Ready' GE crop varieties.[11] These include important weed species such as horseweed (marestail or *Conyza canadensis*), common ragweed (*Ambrosia artemisiifolia*) and rigid ryegrass (*Lolium rigidum*).[12]

Also highly relevant to our understanding of the potential threat from GE trees is a carefully studied instance of native grass contamination in the US state of Oregon, from a test plot of creeping bentgrass genetically engineered for glyphosate resistance. In 2004, researchers from the US Environmental Protection Agency found numerous grasses within 2 km of the experimental plot—as well as two samples 14 and 21 km away—that were tolerant to glyphosate. Upon genetic analysis, they were found to contain one of the major components of the inserted DNA that imparts this trait.[13] In a follow-up study two years later, researchers determined that the transgene had established itself in resident grass populations, as well as in a non-GE bentgrass that had been planted nearby to facilitate monitoring of potential gene flow.[14]

With their investigation limited to publicly accessible areas within 310 km^2 of the test plot, the researchers found nine established transgenic plants downwind, *"spread over an appreciable distance beyond the border of the control area"*.[15] Through further DNA analysis, they determined that the contamination had been caused by a combination of pollen and GE seed dispersal. This is a highly significant result, given the fact that glyphosate tolerance would not be particularly advantageous for plants outside the test zone. As tree pollens can potentially travel two orders of magnitude farther than grass pollen, these experiments suggest that effective containment of contamination from GE trees would be highly improbable. This study is also relevant to non-native GE tree species in biofuel plantations, since contamination was not only by pollen, but by seed as well.

What these studies reveal is the virtual impossibility of preventing contamination of native forests with pollen from native tree species that have been genetically engineered. The impacts of this contamination, however, would depend to a large extent on the traits involved. Nevertheless, irrespective of the specific traits, the genetic manipulation itself gives rise to risks. Several researchers have reviewed the ecologically disruptive character of genetic modifications, in terms of gene expression, ecological fitness and the production of potentially dangerous new metabolites. In one brief review, Allison Snow of Ohio State University writes:

> *"Although crops and weeds have exchanged genes for centuries, genetic engineering raises additional concerns because it not only enables introduction into ecosystems of genes that confer novel fitness-related traits, but also allows novel genes to be introduced into many*

[10] http://www.gmcontaminationregister.org/index.php?content=re_detail&gw_id=35, and references therein.
[11] Andrew Pollack, *"Widely Used Crop Herbicide Is Losing Weed Resistance"*, *New York Times*, January 14, 2003.
[12] These specific examples are from the Monsanto-originated site at http://www.weedresistancemanagement.com.
[13] Lidia S. Watrud, *et al.*, *"Evidence for landscape-level, pollen-mediated gene flow from genetically modified creeping bentgrass with CP4 EPSPS as a marker"*, *Proceedings of the National Academy of Sciences, USA*, Vol. 101, No. 40, pp. 14533-14538, October 5, 2004.
[14] Jay R. Reichman, *et al.*, *"Establishment of transgenic herbicide-resistant creeping bentgrass (Agrostis stolonifera L.) in nonagronomic habitats"*, *Molecular Ecology* Vol. 15, pp. 4243–4255, 2006.
[15] *ibid.* p. 4252.

diverse types of crops, each with its own specific potential to outcross."[16]

David Schubert of the Salk Institute also writes that:

> *"unintended consequences arising from the random and extensive mutagenesis caused by GE techniques opens far wider possibilities of producing novel, toxic or mutagenic compounds in all sorts of crops."*[17]

In a detailed analysis of over 200 published studies, researchers at EcoNexus in the UK documented significant increases in genetic instability, higher mutation rates, large-scale deletions and translocations of DNA, and other disturbing effects at the site of artificial gene insertion.[18] These disruptions in gene expression are also likely to impact on native species that become contaminated via cross-pollination with GE varieties.

Low-Lignin Trees

These studies underscore the serious likelihood of contamination of native forests from plantings of GE trees, and the resulting consequences for the earth's living ecosystems. This is especially serious in the case of trees genetically manipulated for decreased lignin production, to facilitate the production of agrofuels from tree feedstocks. Lignin is an important structural polymer that is also significantly responsible for the high levels of insect and disease resistance in trees. The very fact that it is difficult to break down lignin has been shown to be essential to the resiliency of native tree species in the wild. Thus the consequences of a reduced lignin trait spreading from agrofuel plantations to native forests could be severe and irreversible.

Fast growing, reduced lignin GE trees, growing undetected in a native forest setting as the result of gene escape, could die off at an early age due to their inability to cope with environmental stresses. Their reduced lignin would cause them to decompose rapidly, damaging soil structure and emitting carbon. Their faster growth at the seedling and sapling stage, however, could give them an evolutionary advantage over their non-modified cousins, resulting in a domination of GE low-lignin seedlings and saplings in the forest. How this will affect the forest ecosystem as it evolves is impossible to predict. Low lignin trees also have implications for the climate, according to the UK-based Institute for Science in Society:

> "*Aspen (*Populus tremuloides*) modified for reduced stem lignin had normal cellulose content accompanied by reduced lignin content. The transgenic aspen had reduced root carbon and greatly reduced soil carbon accumulation compared to unmodified aspen. The trees accumulated 30% less plant carbon and 70% less new soil carbon than unmodified trees.*[19] *This makes the transgenic tree highly undesirable in terms of reducing carbon in the atmosphere, hence defeating the whole purpose of switching from fossil fuels to biofuels."*[20]

In addition to reducing the lignin in trees, researchers are investigating altering the structure of lignin to enhance its digestability to microbes. In one line of research, proteins are being introduced into plant cell walls to create protein-lignin linkages that could be digested using protease enzymes. In another scheme,

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[16] Allison Snow, *"Transgenic crops—why gene flow matters"*, *Nature Biotechnology* Vol. 20, p. 542, June 2002.
[17] David Schubert, *"Regulatory regimes for transgenic crops"*, *Nature Biotechnology* Vol. 23, pp. 785 – 787, July 2005.
[18] Allison Wilson, *et al.*, "*Genome Scrambling - Myth or Reality? Transformation-Induced Mutations in Transgenic Crop Plants"*, Brighton, UK: Econexus, October 2004, at www.econexus.info. See also Jonathan R. Latham, et al., *"The Mutational Consequences of Plant Transformation"*, *Journal of Biomedicine and Biotechnology*, Vol. 2006, pp. 1-7, 2006.

[19] Hancock J.E., et. al., *"Plant growth, biomass partitioning and soil carbon formation in response to altered lignin biosynthesis in Populus tremuloides," New Phytol.*, 2007, 173(4), 732-42.
[20] Cummins J. and Ho, Mae-Wan, *"Unregulated Release of GM Poplars and Hybrids"*, report submitted to the USDA APHIS in response to a permit application (06-250-01r) from Oregon State University for field tests of transgenic Populus Alba and Populus hybrids, August, 2007.

researchers are looking at incorporating a particular plant protein called expansin into trees, as well as cellulase enzymes that would essentially enable the tree to begin to digest itself prior to harvest.[21]

Once again the threat of these traits escaping into forest ecosystems, is dire. Assessments of the risks posed, however, are not being done.

Disease and Insect Resistance

Because lignin naturally protects trees from insects and disease, trees with modified lignin will probably have to be engineered with additional traits for disease and insect resistance, which leads to additional concerns, should these genes escape.

The UK research organization, The Corner House, notes that *"trees genetically modified for resistance to disease are likely to cause fresh epidemics"*[22] by encouraging the survival of other diseases resistant to the genetic modification. They go on to assert that *"fungicide production engineered into GM trees to help them counter such afflictions as leaf rust and leaf spot diseases may dangerously alter soil ecology, decay processes and the ability for the GM trees to efficiently take up nutrients…"*. Mycorrhizal fungus and other soil fungi are a critical part of forest ecology. Fungicides engineered into trees are likely to be exuded by the roots into the soil, killing beneficial soil fungi and damaging soil ecology.

Another significant concern is that the evolution of new, more pathogenic viruses may be accelerated by GE tree viral resistance traits. Ricarda Steinbrecher elaborates on the potential for genetically engineered viruses to recombine with other viruses to create new and 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."*[23]

Insect resistance also conveys serious concerns. In China, the problem of desertification was tackled through the planting of huge monoculture plantations of poplars. These poplars, however, fell victim to predation by caterpillars, and great numbers of them died. With the help of the UN FAO, insect resistant poplars were then introduced. These GE poplars were genetically engineered for the production of the *Bacillus thuringiensis* (Bt) toxin, an insecticide that targets the caterpillars of *Lepidoptera* (butterflies and moths). The project was started in 2002 and today more than one million GE poplars have been planted across ten provinces. However, no one knows exactly where they are.[24] The Nanjing Institute of Environmental Science in 2004 reported that the Bt poplars were already contaminating native poplars,[25] but it is not known how far this contamination has spread.

The escape of the Bt trait into native forests is problematic for numerous reasons. Insects have evolved with forest ecosystems for millions of years and the ecological implications of eradicating certain species of insects has not been assessed. These impacts, however, are likely to be wide-ranging. For example, the insects targeted by Bt trees are an important food source for nesting songbirds, as well as other wildlife. At least one study has found that Bt-toxin remains active and lethal after ingested and can make its way up the food chain

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[21] David Pacchioli, *"Researchers at the new biomass energy center are homing in on future fuels"*, Penn State University, State College, Pennsylvania release 9/24/07 http://www.rps.psu.edu/indepth/bioenergy1.html

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

[23] Ricarda Steinbrecher, *"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.

[24] Huoran Wang, "The state of genetically modified forest trees in China", Preliminary review of biotechnology in forestry, including genetic modification, UN FAO, December 2004

[25] F. Pearce "Altered Trees Hide Out with the Poplars", *New Scientist*, 9/19/04, P.7

and will actually bind to the intestines of non-target organisms, causing *"significant structural disturbances and intestinal growths"*.[26]

The Bt trait is expressed in every cell of the modified tree, including the pollen. This is a major concern in relation to pollinators such as bees and butterflies. Bee populations in some regions have recently experienced serious decline. Deployment of Bt trees on a large scale could devastate pollinator populations.[27] A study released late in 2007 demonstrated that pollen and other plant tissues containing Bt toxins are washing into streams near Bt cornfields, and that the toxin is killing caddisflies, the most diverse order of aquatic insects and an important food source for fish and amphibians.[28]

Bt-toxin also exudes from the roots of GE plants and into the soil, where it can affect organisms present in the soil or the soil community as a whole. It can thus impact on beneficial soil microbe and pathogen interactions, nutrient cycling and uptake, and other little-understood soil processes. Little is known about the way in which Bt-toxin production alters the rotting process of dead Bt trees. Use of Bt-toxin also raises concerns about the creation of *"super-pests"*[29] and killing of beneficial insects,[30] as well as the displacement of insect pests from GE trees to more vulnerable species.

Beyond the impacts on forests and wildlife, however, are the impacts of Bt pollen on humans. Airborne Bt pollen may be toxic when inhaled.[31][32][33] This could have serious ramifications for communities living in the proximity of GE tree plantations. This potential health impact has not been adequately studied.

In summary, the long-term consequences of the use of Bt trees or the escape of this trait into forests have not been adequately assessed.

Genetically modified poplars used in biofuel plantations may also be engineered to become sterile. Proponents of genetic engineering claim that adding a sterility trait to GE trees would help prevent contamination of non-engineered trees. This argument is being used to attempt to reverse the moratorium on so-called "Terminator Technology." Because of the complex nature of plant reproduction and gene regulation, however, and the genetic changes trees experience as they age, it is highly unlikely that any sterility in trees can be reliably sustained. This means that contamination by seed or pollen would continue to be a threat. It also means there is the potential for stands of native trees themselves to become partially sterile through cross-pollination, or become impaired in their development of flowers or seeds. Sterile trees would also be able to spread their transgenes through vegetative propagation.

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[26] C. Brown, S. Connor and M. McCarthy, "The End for GM Crops: Final British Trial Confirms Threat to Wildlife," 3/22/05, http://news.independent.co.uk/ low_res/story.jsp?story=622479&host=3&dir=58

[27] J. Losey et. al., "Transgenic pollen harms monarch larvae," Nature 399, 1999, p. 6733; and Hansen L. and Obrycki, J., "non-target effects of Bt-corn pollen on the Monarch butterfly (Lepidoptera: Danaidae), Abstract, North Central Branch meeting of the Entomological Society of America, March 1999; and Malone, L.A. et al., "In vivo responses of honey bee midgut proteases to two protease inhibitors from potato," *Journal of Insect Physiology* 44(2), 1998, pp. 141-147.

[28] E. J. Rosi-Marshall, et al., "Toxins in transgenic crop byproducts may affect headwater stream ecosystems," Proc. Nat. Acad. Sci. USA vol. 104 no. 41, October 9, 2007, pp. 16204 –16208.

[29] F. Gould, cited in J. L. Fox, *"Bt Cotton Infestations Renew Resistance Concerns"*, *Nature Biotechnology* 14, 1996, p. 1070

[30] A. Hilbeck 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.

[31] Kleter, G.A. and A.A.C.M Peijnenburg. 2002. Screening of transgenic proteins expressed in transgenic food crops for the presence of short amino acid sequences identical to potential, IgE-binding linear epitopes of allergens. *BMC Structural Biology*, 2: 8. At www.biomedcentral.com/1472-6807/2/8

[32] 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

[33] Vazquez-Padron RI, et.al. 1999b. *Bacillus thuringiensis* Cry1Ac protoxin is a potent systemic and mucosal adjuvant. *Scandinavian J Immunology* 49: 578-584

Furthermore, the sterility modification itself has ramifications. Foremost are the likely impacts on native wildlife. Sterile trees do not provide food (seeds, pollen, nectar) for insects, animals or birds, which means that large monocultures of GE trees will displace a wide variety of native species. In addition, the trees themselves may be toxic.[34]

Introduction of Non-Native Invasive Plants for Cellulosic Agrofuels

"Eucalyptus is the perfect neoliberal tree. It grows quickly, turns a quick profit in the global market and destroys the earth." —Jaime Aviles, *La Jornada* [35]

GE tree escape, via seed or vegetative propagation, is possible even from non-native species without wild relatives. The case of bentgrass contamination is instructive here, as it describes contamination resulting from seed dispersal. GE eucalyptus is one non-native tree being proposed by tree engineers as a potential feedstock for cellulosic ethanol plants.

Eucalyptus, native only to Australia, is a favorite species for pulpwood plantations worldwide. It is a notoriously invasive tree species that often out-competes native plant species. In the US state of California, eucalyptus was introduced in 1856, and is now widespread throughout the coastal and southern regions of the state. Because eucalyptus is also extremely fire-prone, California spends millions of dollars every year trying to eradicate these invasive plants.

The *Introduced Species Summary Project* of Columbia University found eucalyptus to be a great threat to ecosystems: *"The loss of biodiversity and habitat is a great threat from the … eucalyptus. It creates virtual monocultures and can rapidly take over surrounding compatible areas, completely changing the ecosystem. That monoculture creates a loss of habitats for many species that relied on the previous system. Due to its great capacity for taking over a wide variety of habitats, the … eucalyptus could possibly spread to a great range of systems where there is enough water content and create huge monocultures."*[36]

The US Forest Service also reported concerns about the ability of eucalyptus to suppress the growth of other plants: *"The leaves of … eucalyptus release a number of terpenes and phenolic acids. These chemicals may be responsible for the paucity of accompanying vegetation in plantations. Natural fog drip from … eucalyptus inhibits the growth of annual grass seedlings in bioassays, suggesting that such inhibition occurs naturally. At least one leaf extract has been shown to strongly inhibit root growth of seedlings of other species."*[37]

While eucalyptus has been a favorite species for monoculture tree plantations throughout the tropics and subtropics, their temperature requirements have made other cooler climates, as well as higher altitudes, off limits.

The company ArborGen, however, is currently engineering eucalyptus for cold tolerance so that it could survive at temperatures as low as -20ºc, which would greatly expand its potential range.[38] This transformation of eucalyptus into a species that can survive in colder climates creates significant threats to forests in those climates. Extending the range of eucalyptus also makes it possible for companies to replace slower-growing (but carbon rich) native forests with fast-growing (but carbon poor) eucalyptus plantations, considered more valuable for the production of cellulosic agrofuels. In his 2006 year-end report to stockholders, Rubicon CEO

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[34] J. Cummins et. al.,

[35] John Ross, *"Big Pulp vs. the Zapatistas: Cellulose Dreams in Southern Mexico"*, *Multinational Monitor*, April, 1998, p.9

[36] Introduced Species Summary Project, Tasmanian Blue Gum (*Eucalyptus globulus*Labill.) http://www.columbia.edu/itc/cerc/danoff-burg/invasion_bio/inv_spp_summ/Eucalyptus_globulus.html

[37]Lora L. Esser 1993. Eucalyptus globulus. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/ [2007, November 5].

[38]Stephen Kasnet and Luke Moriarty, *"Rubicon Interim Report"*, Rubicon. 02/28/07 (Rubicon is a joint owner of ArborGen)

Luke Moriarty explains the economic potential of the cold tolerant GE eucalyptus: *"The excellent results of the best performers in the field trials would suggest that the level of cold tolerance can be extended even further, thus offering a broader geographic market for this new hardwood product than originally anticipated."*[39]

Besides wiping out native forests for eucalyptus plantations, the commercial use of cold-adapted eucalyptus could result in the escape of these GE trees (via seed or asexual vegetative reproduction) into ecosystems and forests where they could out-compete native vegetation and displace wildlife. Furthermore, the southern US, where establishment of commercial GE eucalyptus biofuel feedstock plantations is now being considered, is known to be subject to strong storms, including tornadoes and hurricanes, which have the potential to distribute eucalyptus seeds over very large areas from tens to hundreds of kilometres.

Development of second generation biofuels in Brazil is also a concern. Efforts are currently focusing on the use of bagasse—the biomass left over from the production of sugar cane-based ethanol. Denmark-based Novozymes is cooperating with Centro de Tecnologia to develop facilities to utilize all parts of the sugarcane plant for ethanol production. Novozymes CEO Steen Riisgaard explained, *"the research agreement is part of our efforts to identify economically profitable processes within the development of biofuels from plant waste and other biomass."*[40] While these facilities may be developed under the guise of reducing "waste" in the production of ethanol, they are also a step towards acceptance of other cellulosic feedstocks as well.

ArborGen is already developing GE low-lignin eucalyptus in Brazil, as is pulpwood giant Aracruz Cellulose. The emergence of cellulosic ethanol in Brazil opens up another market for their reduced lignin trees and ArborGen forsees millions of dollars in profits from sale of its GE low-lignin eucalyptus pulp, due to the fact that it is projected to be less expensive to process.[41] Eucalyptus is already a serious problem in Brazil, where plantations have replaced vast stretches of the *Mata Atlantica* coastal forest ecosystem. Increasing demand for eucalyptus for cellulosic agrofuels, in addition to paper pulp, will most probably lead to the expansion of these eucalyptus plantations as well as the use of GE low-lignin eucalyptus, posing yet further threat to ecosystems.

GE Jatropha and Oil Palm

Beyond genetically engineering trees for cellulosic agrofuels production, researchers are also exploring ways to engineer Jatropha and oil palm trees to improve the quality and quantity of their oil, to resist herbicides and/or to kill insects.

African oil palm is native to tropical Africa, where it grows from the Congo to Sierra Leone, while American oil palm is native to Central and South America. However, it is now widely cultivated in tropical areas around the world. Jatropha is native to Central America and the Caribbean; and it too is being cultivated or planned for cultivation in huge monocultures in India, China, Africa, Latin America and elsewhere.

BP is investing US$76 milion in Jatropha cultivation. India has identified eleven million hectares of land for future jatropha plantations. China is moving forward with plans for more than 13 million hectares of jatropha and other biofuel feedstocks, on sensitive, biologically rich native forestlands in southwestern China.[42] In western Australia, however, Jatropha has been banned due to the fact that it is extremely invasive and highly toxic to animals and people (ingesting three untreated seeds can be fatal to humans).[43]

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[39] ibid.
[40] Michael Shirek, *"Novozymes concludes agreement in Brazil regarding second-generation biofuels"*, *Ethanol Producer Magazine*, September 2007.
[41] ibid.
[42] Yingling Liu, *"Chinese Biofuels Expansion Threatens Ecological Disaster"*, Worldwatch Institute, March 13, 2007, http://www.worldwatch.org/node/4959
[43] Ben Macintyre, *"Weed moves from bowels to biofuel"*, *The Australian*, 07/30/2007.

Scientists are engineering these two trees for a variety of traits. Oil palm is being modified in Indonesia and Malaysia to change the composition of its oil. Food industry researchers are seeking to modify it for reduced saturated fatty acid content. Others are working to make the oil adaptable to new uses, as a source of biodegradable plastics, for example, and other products currently manufactured with petrochemicals. They also want to increase the oil content of the seeds. Because of its susceptibility to some insects, oil palm is also being engineered for insect resistance (with all of the potential consequences previously mentioned); and is being engineered for resistance to the herbicide glufosinate.[44] Jatropha is being engineered to increase production and improve the oil content of the seeds.[45]

Conclusion

The pursuit of a global energy strategy that features wood as a major agrofuel feedstock clearly poses a variety of potential problems. Use of genetically engineered trees for agrofuel production would significantly increase this risk, with serious implications for the world's forests and forest-dependent peoples.

In the US, for example, efforts are underway to use the monoculture loblolly pine plantations of the Southeast US for cellulosic ethanol production. A company called Range Fuels is developing an ethanol production facility specifically for this purpose, with funds from the US Department of Energy. The US state of Georgia has been quoted as seeking to become the *"biofuels Saudi Arabia",* using their pine plantations as the feedstock.[46] These same plantations, however, are the world's largest source of paper pulp.

Taking these plantations out of paper production and transitioning them into agrofuels production will have global implications. As the raw materials to feed the world's increasing appetite for paper are no longer available from existing plantations, they will increasingly come from the world's remaining forests. In addition, the rapidly rising demand for wood, triggered by cellulosic agrofuels production, will accelerate the conversion of native forests into fast-growing monoculture tree plantations and escalate rates of illegal logging. This skyrocketing demand for wood will also further the pressure to commercially develop genetically engineered tree plantations, which will in turn threaten the ecological integrity of native forests.

With current rates of deforestation contributing 20% of global carbon emissions annually, the massive increase in deforestation that will accompany the rise of wood-based agrofuels production will have significant impacts on climate, belying the argument that cellulosic agrofuels will be part of the solution to global warming.

In conclusion, the massive increase in logging and the planned use of genetically engineered trees that will accompany the production of wood-based "second generation" agrofuels make this so-called "alternative energy" one of the foremost threats to forests and forest-dependent peoples across the globe.

To get involved with the STOP GE Trees Campaign and support the Campaign's goal of a global ban on genetically engineered trees, visit www.globaljusticeecology.org/stopgetrees.php

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[44] UN FAO GMO registry.

[45] Qing Liu, Surinder Singh & Allan Green, "Genetic Modification of Vegetable Oils for Potential Use as Biodiesel," CSIRO Plant Industry presentation, May 2007, http://www.thaijatropha.com/9.pdf

[46] David Adams, *"Biofuel Push May Take Root in Georgia"*, *St Petersburg Times*, 02/08/07.