Genetic Dialectic

The Biological Politics of Genetically Modified Trees

THE
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HOUSE

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The attempt to engineer trees genetically belongs to a centuries-old tradition of state and corporate efforts at drastic simplification of large wooded landscapes for specialized purposes. Fraught with internal contradictions, this tradition is under challenge from interests defending local diversity. An effective response to the dangers of genetically modified (GM) trees will go beyond exposes of their biological effects by contributing to alliance-building among these interests.

Most contemporary forest stewardship systems of established and sustained productivity, fertility and value to local people are based on diversity. Such systems, which outsiders usually find difficult to interpret or administer, often include a mixture of forests, woodlands, agricultural fields, and gathering or hunting grounds arranged in changing and seemingly-irregular patterns matching local topography to local concepts or convenience. They typically feature trees planted or maintained for a variety of purposes including food, shade, erosion control and protection for livestock; fruit, vegetables and wood for humans; and water, nutrients and protection for crops. This diversity of uses generally reflects a local politics in which no single production interest is able to exclude all others. It has a number of beneficial effects — for example, shielding insect species from the monolithic selection pressures they would encounter in a monoculture, which often turn them into devastating pests.[1] (*See* Box: "A Contemporary Diversity-Based Forestry System", p.2.)

In enduring tension with such systems (and with itself) is a forestry tradition, at least two centuries old, of centralized control which attempts to create large, simplified wooded landscapes. These are designed to be easy to administer from possibly distant offices for single, specialized purposes.[2] This tradition stems from the efforts of both early modern European states and large commercial concerns to calculate probable yields from timber extraction, using techniques such as statistical field surveys of the species and sizes of forest trees. This narrow focus on quantifying sustainable wood volume led naturally to attempts to create, as if from a blueprint, a more uniform forest that was both more legible to bureaucrats and their employees and more "efficient" in producing a single commodity. Systematic seeding, planting and cutting brought into being the ideal bureaucratic or commercial "forest", with its grid pattern of similar trees supposedly manageable according to globally-applicable techniques and free of "extraneous" vegetation or human activity. Such "forests" — and the industrial plantations which followed on became rigidly separated off from agriculture (*see* Box, "The Industrial Pulpwood Plantation Tradition", right) The multiple functions of ordinary forests were reconceptualized as symptoms of untidiness and disorder. Non-wood uses of forests were recast as, at best, "minor forest products", while trees whose growth rates had ceased to justify their survival in economic terms were dismissed as "overmature". Flora and fauna which reduced timber output were classified as weeds or pests.

This redefinition of forests was accompanied by a redefinition of rights, as forest societies were also partly disassembled. Complicated webs of local rights of access to woods and their varied contents — firewood, mushrooms, fodder, nuts, gravel, peat, game, poles, moss and so on — were curtailed as authorities and firms sought to gain

A Contemporary Diversity-Based Forest System

Among at least 400 modern "community forest" systems in the hilly upper Northern region of Thailand is that of Mae Khong Saai village in Chiang Dao district of Chiang Mai province. The system features 57 hectares of agricultural fields in which at least 10 different types of paddy rice are grown in stepped fields in the valley bottoms. Some 10 varieties of dryland rice are also cultivated in hill fields, which rotate on a cycle of 3-5 years.

Some 643 hectares of community use forest are carefully distinguished from 980 hectares of protected forest, between them encompassing six different native forest types. Some 58 herbal medicines on which villagers depend are locally cultivated, some in a protected pharmaceutical garden in the middle of the forest. Altogether, forest food and medicine yield the equivalent of US$700 per year for each of the village's 22 households. As well as providing wood for local use, the forests also help preserve the nature of the streams that lace the area, which provide water for agriculture and drinking as well as the 17 carefully-conserved species of fish which supplement the local food supply.

All aspects of the system – agriculture, community-use forest, protected forest, fisheries – are interdependent. The whole pattern, meanwhile, relies for its survival on local villagers' protection. For example, the use of fire is carefully controlled by locals so that devastating blazes don't strike the local forest, as they often do the surrounding region's monoculture tree plantations. Regular monitoring, together with a newly-formalized system of rules and fines covering forest, stream and swidden use, helps maintain the local biotic mosaic. Political vigilance is also crucial. In 1969, locals teamed up with concerned government officials to stave off a threat by commercial loggers to devastate the area. Today, Mae Khong Saai villagers are fighting a 1993 government decree ordering them out of the Wildlife Sanctuary which was established in 1978 on the land they inhabit and protect.

Mae Khong Saai's insistence on local stewardship is obviously good for the area's biodiversity. A recent rapid wildlife survey in and around the village resulted in sightings of many species – including a flock of Oriental Pied Hornbills (*Anthracoceras albirostris*) – that indicate that the area is one of the most biologically diverse in Thailand. Animals including bear, dear, gibbon, boar and various wild cats, as well as over 200 species of birds, take advantage of the tapestry of local ecosystems.

In constant interaction with lowland economies, polities and cultures, Mae Khong Saai could not be further from the romantic cliché of a completely isolated, self-sufficient community. As well as marketing forest products, many community members periodically take jobs far outside the community, some in distant cities. In their defence of local livelihoods and the biodiversity they rely on, moreover, Mae Khong Saai's residents depend partly on alliances they have fashioned not only with similar communities across Thailand's northern mountains but also with urban-based NGO movements. It is in fact through the experience of alliances attempting to defend local forest stewardship in front of state officials that the term of art "community forest", which lumps together a variety of land-use systems, has been invented. Arguably, Mae Khong Saai owes even its current identity and way of life on the periphery partly to the history of uneasy relations between the Karen people who inhabit it and the modern, nationalistic, racialist Thai state which has developed over the past century. Whatever successes its forest stewardship system achieves will owe much to the way it is able to converse and negotiate with lowland and international powers in renewing its strategies for local control.

Sources: Environmental Improvement Department et al., *Raayngaan Phol Kaan Wijay Rueang Khwaam Laaklaai Thaang Chiiwaphaap lae Rabop Niwet nai Khat Paa Chum Chon Phaak Nuea Tawn Bon*, Chiang Mai, 1997; Turton, A. (ed.) *Civility and Savagery: Social Identity in Tai States*, Curzon, London, 2000.

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1. *See*, for example, Vandermeer, J. and Perfecto, I., *Breakfast of Biodiversity*, Food First, San Francisco, 1995; Shiva, V. and Bandyopadhyay, J., *Ecological Audit of Eucalyptus Cultivation*, Research Foundation for Science and Ecology, Dehra Dun, 1987; Groome, H., "Conflicts Caused by Imbalances in Forest Policy and Practice in the Basque Country", *Progress in Rural Policy and Planning* 1, 1991; and Wolvekamp, P. et al., (eds.) *Forests for the Future*, Zed, London, 1999.
2. Scott, J.C., *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed*, Yale University Press, New Haven, 1999, Chapter 1; Maser, C., *The Redesigned Forest*, Miles, San Pedro, CA, 1988.

The Industrial Pulpwood Plantation Tradition

The factory-like order of industrial pulpwood plantations, with their ranks of even-aged trees of the same species marching over large landscapes, is closely tied to the political development of the factory itself. The basic design for the paper machine used today was developed in the 1790s largely as an attempt to transfer control over paper-making knowledge from restive artisans to factory owners. The new device encouraged increased plant scale, increased consumption and increased physical centralization. It also encouraged the use of wood — which was more easily stored, more available and more easily transportable than agricultural wastes or rags, as well as being less labor-intensive — as raw material. Reliance on wood in turn encouraged the already-existing trend toward state control over forests. It also helped foster reliance on large, heavily-mechanized and -capitalized, water- and energy-intensive mills. One outcome was large-scale deforestation and the creation of vast, simplified catchment areas of uniform raw materials — industrial plantations, or "fields of fibre". Increasingly sited in the South, where land is cheaper, growth rates faster, and regulation less restrictive, such enclaves are intolerant of other land uses such as agriculture, gathering, grazing or wildlife preservation. Requiring centralized legal, political and biological control, they also provide few jobs for local people and have provoked local resistance in countries ranging from Indonesia and Thailand to Portugal and Chile.

The grand scale of pulp and paper operations makes state subsidies indispensible, whether in the form of free infrastructure, tax breaks, cheap land, suppression of local opposition, or low-cost university research services. The enormous size of each factory added to the sector, meanwhile, fosters savage boom-and-bust cycles which encourage periodic increases in demand. Paper executives insist that this scale is necessary for "efficiency". But even if one disregards the issue of whether or not any industry so subsidized can be regarded as "efficient", obvious questions remain. Who or what is this "efficiency" for? A typical US citizen uses 60 times more paper than an average Vietnamese, yet the literacy rates of the two countries are virtually the same. (*See* Table: "For Whom Is Paper Produced? Is Paper Consumption Correlated with Literacy?" p.4.) In fact, some 58 per cent of current world paper production has nothing to do with writing and printing, but is used instead in packaging, tissues, and other uses; and even a large proportion of writing and printing papers go toward junk mail and other types of advertising. The scale of the industry and its associated need to simplify landscapes and entrench high demand are products not of some disembodied need for "efficiency" but of a wider politics and culture.

Sources: Carrere, R. and Lohmann, L., *Pulping the South: Industrial Tree Plantations and the World Paper Economy*, Zed Books, London and New Jersey, 1996; Kerski, A., "Pulp, Paper and Power: How an Industry Reshapes Its Social Environment", *The Ecologist* 25 (4) 1995, pp.142-9; *Pulp and Paper International*, August 2000; World-Watch, *Vital Signs*, Washington, 1994.

more sweeping legal controls over their productive domains. As seeding, planting, nutrients, growth rates, dates of harvest and access to the land itself came increasingly under the control of landowners and industry, a backlash, both biological and social, became evident. Growth rates dropped after first rotations of trees had been harvested; pest infestations increased as genetic diversity dropped; wildlife vanished, and local farmers deprived of part of their livelihoods resisted. In Prussia, the birthplace of scientific forestry, a full 150,000 of 207,478 prosecutions brought in 1836 were for wood-stealing and other forest offences.[3] After second rotations of conifers had been planted, pests proliferated and thinner and less fertile soils and reduced mycorrhizal interactions led to production losses and increased storm damage.

All of these, however, were played down as problems which could be "mitigated" through the application of further centrally-administered techniques. Examples included chemical fertilizer and pesticide application; distribution of nesting boxes to replace the hollow trees which birds had previously used; and state and corporate repression.

Enter Genetically Modified Trees

Politically and institutionally, the genetic engineering of trees is directed mainly at shoring up this beleaguered tradition of giant-scale industrial operations, corporate power over the countryside, and biologically homogenized landscapes.

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3. Linebaugh, P., "Karl Marx, the Theft of Wood, and Working-Class Composition: A Contribution to the Current Debate", *Crime and Social Justice*, Fall-Winter 1976, p.13.

Two trends are in evidence. The first aims at industrial quality control at a new, molecular level. Papermaking offers one example. As long as papermakers were dependent on diverse types of wood waste for raw materials, they had to rely mainly on manufacturing processes to ensure uniform paper quality. With pulpwood plantations, however, variability in the raw material itself could be reduced through choice of species, site, inputs, spacing, and breeding techniques encompassing provenance, hybridization, cloning, macro- and micro- propagation, and DNA analysis. The genetic engineering of trees is merely another step in this standardizing "process of linking genes to tree, pulp and paper characteristics".[4] Robotics systems developed by the Australian biotech company ForBio (currently in liquidation) provide one way of producing the large numbers of cloned GM trees necessary. Pulp and paper industrialists now envisage vast plantations of trees not only of single species, but also genetically identical.

One of the most important targets of current research is lignin — the strengthening and protective substance of woody plants. In the production of high-quality paper from cellulose fibres, lignin gets in the way and must be removed with a high expenditure of chemicals and energy. By manipulating the genes which instruct woody plants to manufacture the building blocks of lignin, biotechnologists hope to reduce the proportion of the substance in pulpwood trees, or change it to a less "troublesome" type. Reducing lignin by as little as one per cent would result in savings of many millions of dollars for the industry and would also be useful environmental public relations, since less water, energy and chemicals could be used in pulp recovery.[5] Several US patents have been taken out on GM low-lignin trees.

For Whom Is Paper Produced?
Is Paper Consumption Correlated with Literacy?

Country	*Apparent Paper Consumption 1999 kg/person*	*Pulp Production 1999 kg/person*	*Approximate Literacy Rate*
USA	347	209	95
Japan	239	87	100
Taiwan	231	17	95
Italy	179	10	95
Malaysia	107	7	90
Portugal	98	176	85
Chile	53	193	95
South Africa	40	49	80
Thailand	31	14	95
China	28	13	80
Bulgaria	19	6	100
Indonesia	15	18	85
Egypt	15	1	50
Viet Nam	6	2	95
Nigeria	4	<1	55
Nicaragua	3	0	65

Sources: Pulp and Paper International, Asia Week, UNESCO

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4. Fernandez Carro, O. and Wilson, R.A., "Quality Management with Fibre Crops," *TAPPI Journal*, February 1992, pp.49-52.
5. Most high-quality wood pulp is manufactured by boiling wood chips in a caustic soda solution to separate lignin from cellulose. Making one tonne of bleached chemical pulp requires 120,000 or more litres of water. See Grant, J., Young, J.H. and Watson, B.G., *Paper and Board Manufacture*, British Paper and Board Industry Foundation, London, 1978.

Genetic engineers also aim to increase the wood density of trees destined for construction materials or paper pulp manufacture; to curb the tendency to branch in trees grown for furniture; to boost growth rates in fuelwood trees; and to engineer fruit trees for altered taste,[6] different ripening characteristics[7] or pharmaceutical production.[8] One biotech company has been set up to market a caffeine-free GM coffee bush which is billed as a means of avoiding certain industrial processes in the manufacture of decaf coffee.[9]

The second tweak which tree biotechnologists give the monoculture tradition is to try to repair some of its inherent contradictions without questioning its nature or the power relationships that sustain it. For example, large monoculture plantations are notoriously vulnerable to insect and disease infestations, since they offer a gigantic feast all in one place to any insect or microorganism able to evolve to exploit them. Applying pesticides may ultimately make the problem even worse, since they cull the target organism's natural enemies while simultaneously causing it to evolve resistance.[10] Instead of addressing these problems at their root, however, genetic engineers are applying the Band-Aid of trying to make trees manufacture their own insecticides.

Among the first genes forest biotechnologists exploited were those encoding insecticidal toxins from the soil bacterium *Bacillus thuringiensis (Bt)*. *Bt* genes have been engineered into a wide range of species, including poplar, European larch, white spruce and walnut. Other genes that have been selected to confer insecticidal properties on trees include protease inhibitor genes from rice and potatoes that result in disruption of insect digestion.[11] In order to counter diseases that cut into the yield of fruit tree plantations, meanwhile, biotechnologists are attempting to engineer resistance to plum pox and papaya ringspot viruses.[12] Researchers are also exploring the possibility of creating GM trees that are resistant to fungal disease, such as leaf rust and leaf spot diseases that affect poplar and white pine plantations.[13]

In the same way, genetic engineering is being applied to the problem of soil salinisation associated with industrial plantations, particularly those in Australia. Instead of attempting to decrease salinisation, scientists are adjusting plantation trees' genomes in a way which allows them to survive on the spoiled land.[14]

One of the areas of greatest current interest for forest biotechnologists, finally, is the engineering of broad-spectrum herbicide resistance. Industrial tree monocultures are typically established by ploughing up existing vegetation – an expensive process which also results in soil erosion. If broad-spectrum herbicides could be used to clear land without affecting plantation species, and to keep it free of understorey, business could save an estimated US$975 million per year.[15] Biotechnologists are thus racing to create herbicide-friendly plantation trees, particularly hardwoods, which tend to be more vulnerable to herbicides commonly used in forestry than pines. Among the trees that have already been grown in field trials are chestnut, sweetgum and poplar engineered with genes to confer resistance to glyphosate, chlorosulfuron and glufosinate-ammonium. A number of patents have also been taken out.

Promising to bypass the need for conventional breeding (a particularly long and costly process with trees due to their long life cycles), genetic engineering is also attractive to wood industries in that it extends the breeder's palette to include a range of previously-

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[6] Hasegawa, S., Suhayda, C., Omura, M. and Berhow, M., "Creation of transgenic citrus free from limonin bitterness", ACS Symposium Series 637, 1996, pp.79-87; Suhayda, C.G., Omura, M., Hasegawa, S., "Limonoate dehydrogenase from *Arthrobacter globiformis*: the native enzyme and its N-terminal sequence", *Phytochemistry*, 40 (1), 1995, pp.17-20.

[7] Stiles, J.I., *T-STAR Summer Newsletter*, Tropical and Subtropical Agriculture Research Program, USDA, Washington, 1997.

[8] Kobayashi, S., Nakamura, Y., Kaneyoshi, J., Higo, H. and Higo, K., "Transformation of kiwifruit (*Actinidia chinensis*) and trifoliate orange (*Poncirus trifoliata*) with a synthetic gene encoding the human epidermal growth-factor (hegf)", *Journal Of The Japanese Society For Horticultural Science* 64 (4), 1996, pp.763-69.

[9] Wayne Brown Institute, "Investors' Choice" venture capitalist conference, Maui, Hawaii 20 May 1999. Naturally caffeine-free varieties of coffee exist (although their taste does not suit the consumer market) as well as water-based, low-chemical systems for removing caffeine. Caffeine in coffee plants, however, gives a degree of protection against insects.

[10] Raffa, K.F., "Genetic engineering of trees to enhance resistance to insects", *Bioscience* 39 (8), 1989, pp.524-35.

[11] Klopfenstein, N. B. et al., "Transformation of *Populus* hybrids to study and improve pest resistance", *Silvae Genetica* 42, 1993, pp.86-90, cited in Mullin, T.J. and Bertrand,.S., "Environmental release of transgenic trees in Canada - potential benefits and assessment of biosafety", *The Forestry Chronicle* 74 (2), 1998, p.203.

[12] Ravelonandro, M., Scorza, R., Labonne, G., et al., "Resistance of Transgenic *Prunus domestica* to Plum Pox virus infection", *Plant Disease* 81(11), 1997, pp.1231-35; Gonsalves, D., "Control of papaya ringspot virus in papaya: A case study", *Annual Review of Phytopathology*, 36, 1998, pp.415-37.

[13] Seguin, A., "Transgenic trees resistant to microbial pests", *The Forestry Chronicle* 75(2), 1999, pp.303-4.

[14] Pulp & Paper Information Centre, *Genetic modification of trees: FactSheet*, Pulp & Paper Information Centre, Wiltshire, UK, 1999.

[15] Sedjo, R., *Biotechnology and Planted Forests: Assessment of Potential and Possibilities*, Resources for the Future Discussion Paper 00-06, Washington, 1999, p.24.

unavailable traits from other species. Genes from bacteria, for example, can be used to boost trees' resistance to insects, and genes from pine to increase nitrogen uptake and growth rates in poplar.[16] This is another reason why genetic engineering is biased against biodiversity: it may lead to the conclusion that native genetic resources traditionally used by breeders are inessential. This argument could cut support for forest conservation.

Following the Money

A glance at who is instigating, funding, patenting and testing the genetic modification of trees confirms that the technology is strongly biased in favour of the conflict-plagued industrial monoculture tradition — and against more progressive diversity-based systems of forest livelihood and stewardship.

Tree biotech is biased in favour of monocultures.

Some research is being carried out directly by transnational corporations committed to the industrial plantation tradition. One of the biggest efforts toward making genetic engineering in forestry a reality was a US$60 million joint venture announced in April 1999 between Monsanto and pulp and paper manufacturers International Paper, Westvaco and Fletcher Challenge.[17] The last three companies all have miserable reputations, particularly among environmentalists and affected people, for their forestry operations, toxic releases, or both,[18] while Monsanto is a well-known promoter of large agribusiness monocultures worldwide. The objective of their alliance was to make wood easier to pulp. Although Monsanto, plagued by European hostility to genetically-modified crops and a falling share price, backed off six months later, restricting its role in the deal to that of a technology provider, the other partners remain in the hope that the new "designer trees" will reduce mill costs. In January 2000 they were joined by the New Zealand company Genesis Research and Development (which specializes in pharmagenomic drug discovery and therapeutic vaccines as well as forestry genomics). Fletcher Challenge and Genesis have been in partnership for five years to develop herbicide tolerance in plantation trees such as eucalyptus, poplar and pine.[19] The two firms have also been granted a US patent to alter the lignin content of trees. Japanese paper and car firms are also carrying out research into the genetic manipulation of trees. In addition, transnational corporations are stumping up money to pay university researchers in a number of countries to carry out investigations into tree biotech.

The bulk of basic research, however, is likely to be funded by corporate-friendly government agencies working together with industry associations and universities. This better suits the conservative orientation of many wood industries, who favour the time-tested corporate strategy of shifting research costs off on the public sector wherever possible.

In the mid-1990s, for example, the American Forest and Paper Association, an industry group dominated by giant transnationals with control over vast areas of land, launched a "collaborative research effort" with the United States Department of Energy to increase US wood production.[20] Under the scheme, the US government provides tax dollars to government laboratories or universities for genetic engineering research which the corporate sector can then take advantage of, with supplementary support from companies such as Georgia-Pacific, Rayonier, Union Camp and Westvaco.

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[16] Canovas, R.F., Gallardo, A.F. and Kirby, E.G., "Transgenic trees having improved Nitrogen metabolism", patent WO 0009726 (2000).

[17] *Independent on Sunday*, London, 16 May 1999.

[18] Carrere, R. and Lohmann, L., *Pulping the South: Industrial Tree Plantations and the World Paper Economy*, Zed Books, London and New Jersey, 1996.

[19] Genesis web site: http://www.genesis.co.nz/science3.ast.

[20] Wright, L. L. and Berg, S., "Industry/Government Collaborations on Short-Rotation Woody Crops for Energy, Fiber and Wood Products", Proceedings of the Seventh National Bioenergy Conference, Nashville, 1996. *See also* http://www.agenda2020.org/sustain.htm.

Researchers at the Tree Genetic Engineering Research Cooperative (TGERC) based at Oregon State University are responsible for researching and testing trees genetically modified for improved fibre production, herbicide tolerance and resistance to fungus and insects. They receive funding from the US Department of Energy Biofuels Program, the US Department of Agriculture, and the US Environmental Protection Agency; paper and timber companies such as International Paper, Weyerhaeuser, Boise Cascade, Georgia-Pacific, Union Camp and MacMillan Bloedel; the Electric Power Research Institute, a utility industry association; other firms such as Monsanto and Shell; and Oregon State University itself. Providing technical and logistical support are the US and Canadian Forest Services, Mycogen, the University of Washington, and Washington State University. This wide collaboration, in TGERC's own words, results in a "leverage factor of nearly 40-fold for individual industrial members".[21]

Many biotech research costs are shifted onto the public.

Tree biotechnologists at Michigan Technical University, meanwhile, have benefited both from money from the state of Michigan and from collaboration with plantation companies such as Champion.[22] Their colleagues at the University of Washington have received funding from not only the US Departments of Agriculture and Energy but also the National Science Foundation, as well as various wood corporations and universities.[23] The Department of Energy and the National Science Foundation are also bankrolling research on genetic manipulation of organisms to alleviate global warming[24] and a Plant Genome Research Program which could lay the groundwork for GM pines.[25] In Canada, too, although a joint venture called Arborgen has been formed by transnational forestry companies to work on GM trees, the government is playing a central role in developing tree biotech through the Canadian Forest Service.[26]

The more money is available for tree biotech research, of course, the less incentive foresters will have to study other areas — a heavy irony, given that while the complexity of forest ecology and tree genetics is well recognised, they are poorly understood and starved of research funding.

Genetic Colonisation

Nowhere are the contradictions of the GM "fix" clearer than in the controversy over how to prevent genetic modifications from spreading from industrial to neighbouring ecosystems.

The need to prevent GM trees and their genes from invading native ecosystems is clear. Low-lignin trees have the potential to disrupt the forest composting cycle responsible for unique soil structures and nutrient cycling systems. An influx of low-lignin trees vulnerable to damage from insects and other herbivores, moreover, could result in pest population explosions. Insect-resistant GM trees have the potential to disrupt insect population dynamics and also are likely to enjoy an invasive advantage over forest tree species. More generally, invasions of GM trees could threaten the diversity of the forest gene pool from which trees are selected for conventional breeding — a reservoir already reduced by selective logging practices.[27] Because trees are even more genetically compatible with their wild relatives than highly-bred agricultural crops, GM "escapes" are especially worrisome in forestry.[28]

Although the need to separate GM and non-GM trees meshes neatly with industrial incentives for simplifying land use to a single species

[21] Strauss, S. and Meilan, R., "Overview of TGERC: Tree Genetic Engineering Research Cooperative", Oregon State University, 1998, http://www.eesc.orst.edu/agcomwebfile/magazine/00Winter/OAPWinter2000/OAPWIN0006.html. In all, Oregon State University has $50 million in long-term grants from federal, state and private sources to finance its genetic engineering research, much of which goes into transgenic trees.

[22] Podila, G.K. and Karnosky, D.F., "Fibre Farms of the Future: Genetically Engineered Trees", *Chemistry and Industry*, 16 December 1996; Campbell, F.T., "Genetically Engineered Trees: Questions without Answers", American Lands, Washington, 2000, http://www.americanlands.org/Getrees.htm; Struzik, E., "Genetically Altered Trees No Longer 'Pulp Fiction'", *Edmonton Journal*, 27 July 1999.

[23] Campbell, F.T., op. cit. 22.

[24] US Department of Energy, Office of Fossil Energy, Office of Science, draft *Working Paper on Carbon Sequestration Science and Technology*, Washington, February 1999.

[25] Campbell, F.T., op. cit. 22.

[26] Ibid.

[27] Raffa, K.F., op. cit. 10.

[28] Tzifira, T., Zuker, A. and Altman,A., "Forest-tree biotechnology: genetic transformation and its application to future forests", *Trends in Biotechnology* 16, 1998, pp.439-446; Mullin, T.J. and Bertrand, S., op. cit. 11, p.203.

The Technofix Dilemma

The genetic engineering of new traits into trees can be expected only to deepen the familiar environmental and social contradictions of the industrial monoculture tradition:

Lignin-reduced trees

Lignin-reduced trees are likely to have multiple deleterious effects given that lignin functions in forests in so many ways. Lignin reduction may weaken trees structurally (although it may also lead to an increase in strengthening cellulose fibre), and some researchers have reported stunted growth and collapsed vessels, leaf abnormalities or an increase in vulnerability to viral infection.

Because lignin protects trees from feeding insects, low-lignin trees are also likely to be more susceptible to insect damage, leading to pressures to increase pesticide use. Low-lignin trees will also rot more readily — affecting soil structure, fertiliser use, and forest ecology — and will release carbon dioxide more quickly into the atmosphere.

Insecticide-producing trees

GM trees that produce their own insecticide are virtually certain to cause non-pest species to evolve into pests as GM pesticides eradicate their competitors. The target insects themselves, meanwhile, will evolve resistance to the GM pesticide, leading straight back to the application of conventional pesticides. In addition, some newly-resistant insects could simultaneously evolve a capability to expand their feeding range to previously less-susceptible plant species.

Unexpected pesticide contamination of ecosystems is also possible. The insecticidal *Bt* which certain agricultural crops have been engineered to produce, for example, has unexpectedly been found to be capable of being exuded through roots and binding with soil particles, persisting in the soil for 243 days and remaining toxic for very long periods. Non-target insects essential to healthy ecosystems may also be vulnerable to the GM insecticides.

Finally, as long as they enjoy an advantage over trees susceptible to insect feeding, insecticide-producing trees will be able to invade wilder systems with ease, disrupting their insect population dynamics.

Disease-resistant trees

Trees genetically engineered for resistance to disease, especially when deployed in simplified landscapes, are likely to cause fresh epidemics. For one thing, genetic diversity within stands is well-recognised as essential to tree health in sustainable forestry. Yet with the advent of cloned GM trees, genetic diversity will be lower than ever in commercial plantations. Extreme vulnerability is bound to engender extreme methods of disease control.

Second, 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 form mycorrhizal interactions essential for nutrient uptake and soil structure.

Third, GM virus resistance may accelerate the evolution of new diseases. Biotechnologists have engineered several tree species, including plum and papaya, with genes from viruses which instruct the trees to make viral proteins. For reasons not fully understood, these proteins confer some resistance to infection by that particular virus and often its close relatives. Yet infecting viruses can acquire and use viral genetic information carried on some GM plant chromosomes in a process known as viral recombination. In the absence of genetic engineering, viral recombination will occur only on the rare occasions when two similar viruses have infected an organism simultaneously, but because every cell of GM virus resistant plants contains viral genetic material, any viral infection can be considered as in effect a simultaneous infection. Laboratory experiments have confirmed that viral recombination involving engineered viral genes in plants can indeed increase viruses' virulence and expand the range of hosts they are capable of attacking.

Herbicide-resistant trees

Trees genetically engineered to be tolerant of herbicides will further entrench the use of the chemicals in corporate and state attempts to create wooded landscapes free of "extraneous" species.

The consequences will be multiply detrimental. Broad-spectrum herbicides damage soil structure and fertility through changes in root systems, soil insect populations and soil food webs. As bacteria and fungi which promote soil health decline, vegetation-damaging bacteria and fungi move in. Ultimately, the use of other pesticides to combat fungal diseases may increase.

Herbicides are also dangerous to birds and other animals that rely on a diversity of plants for food and shelter. Their use over prolonged periods diminishes food sources for the species dependent on them and provides ideal conditions for the evolution of herbicide-tolerant plants and the need for higher doses and even more hazardous chemicals.

Herbicide use has also been shown to increase agricultural crops' susceptibility to disease. Despite manufacturers' claims of 'environmental friendliness', moreover, glyphosate, the active ingredient of favoured plantation herbicides (including Round-Up), binds to soils in the same way as inorganic phosphates and may remain undegraded for years, endangering, through runoff, aquatic life.

Glyphosate also disrupts the healthy balance of soil life and kills beneficial insects including wasps, lacewings and ladybirds. GM glyphosate-tolerant trees have been grown in field trials throughout the 1990's, in USA, Europe and South Africa.

Faster-growing trees

Trees genetically modified for faster growth are likely to use up water even faster than the fast-growing trees currently used in industrial plantations, exacerbating problems of dryout and salinification which undermine the agricultural or fisheries livelihoods of people living on adjacent land. Such trees will also suck up nutrients at a higher rate, necessitating the application of an ever-increasing volume of chemical fertilisers. Hence fast-growing GM trees may speed up the process by which previously rich land is impoverished — thus increasing, not reducing, plantations' demand for land and their threat both to agricultural livelihoods and to native forests. Trees genetically modified for fast growth will also be highly invasive of ecosystems for which they were not intended, quickly overtaking slower-growing non-GM trees in the competition for light and nutrients. They will thus threaten not only wild and endangered tree populations but also the plants, insects, fungi, animals and birds that have evolved to fill specialist niches dependent on those populations.

For example, Swedish researchers engineered aspen with a gene from oats which controls the response of plants to day length. The resulting tree was able to grow in winter daylengths (with as little as six hours of daylight daily) as well as summer (when daylight may extend to 15 hours or more). Had the GM aspen not lost its ability to withstand cold, it would have had a huge advantage over other trees in extreme latitudes where day length limits tree growth.

Fast-growing trees with improved ability to take up nitrogen compounds from soil can also be an invasive ecological threat. A (non-GM) nitrogen-fixing tree introduced to Hawaii provides one cautionary example. The tree has pumped a normally nutrient-impoverished lava ecosystem so full of nutrients that a number of diverse and specially-adapted native plant communities have been driven out.

Carbon-absorbing trees

Recent proposals by the US Department of Energy and others to use carbon-dioxide absorbing GM trees to counter climate disruption highlights in another way the complex connections between genetic engineering and the attempts of central authorities to re-engineer large landscapes for single purposes. At their most grandiose, such proposals call for genetically "manipulating" terrestrial ecosystems so that they can temporarily store several times more carbon than at present, in order to make possible "continued large-scale use of fossil fuels". One result could be the creation of vast plantations of trees genetically engineered for both faster growth (to absorb more carbon dioxide from the atmosphere) and higher lignin content (for more stable storage of the sequestered carbon). The consequences would include not only the social effects associated with the seizure and degradation of huge areas of forest lands and their soils, but also the entrenchment of a wasteful energy economy elsewhere. If allowed to decay or used for fuel or paper, of course, the trees would quickly release the carbon they had temporarily sequestered back to the atmosphere.

Sources: Hu, W.J., Harding, S.A. et al., (1999) "Repression of lignin biosynthesis promotes cellulose accumulation and growth in transgenic trees", *Nature Biotechnology* 17 (8), 1999, pp.808-12; Piquemal, J., Lapierre, C. et al., "Down-regulation of Cinnamoyl-CoA reductase induces significant changes of lignin profiles in transgenic tobacco plants", *The Plant Journal* 13 (1), 1998, pp.71-93; Muary, S., Hoffman, L. et al., "Abstract", Forestry Biotechnology Conference, Keble College, Oxford, UK, April 1999; Raffa, K.F., op. cit. 10; Saxena, D., Flores, S. and Stotsky, G., "Transgenic plants: insecticidal toxin in root exudates from Bt corn", *Nature* 402 (6761), 1999, p.480; Malone, L.A., Burgess, E.P.J. et al., "*In vivo* responses of honey bee midgut proteases to two protease inhibitors from potato", *Journal of Insect Physiology,* 44 (2), 1998, pp.141-47; Burgess, E.P.J., Malone, L.A. et al., "Effects of two proteinase inhibitors on the digestive enzymes and survival of honeybees (*Apis mellifera*)" *Journal of Insect Physiology* 42 (9), 1996, pp.823-28; Seguin, A., op. cit. 13; Simon, A.E. and Burjaski, J.J., "RNA, RNA-recombination and evolution in virus-infected plants" in *Annual Reviews of Phytopathology* 32, 1994, pp.337-62; Zhou, X., Liu, Y. et al., "Evidence that DNA-A of a geminivirus associated with severe cassava mosaic disease in Uganda has arisen by interspecific recombination" *Journal of General Virology* 78, 1997, pp.2101-11; Király, L., Bourque, J.E. et al., "Temporal and spatial appearance of recombinant viruses formed between cauliflower mosaic virus (CaMV) and CaMV sequences present in transgenic *Nicotiana bigelovii*", *Molecular Plant-Microbe Interactions* 11 (4), 1998, pp.309-16; Greene, A. and Allison, R.F., "Recombination between viral RNA and transgenic plant transcripts", *Science* 263, 1994, pp.1423-1425; Schoelz, J.E. and Wintermantel, W.M., "Expansion of viral host range through complementation and recombination in transgenic plants", *Plant Cell* 5, 1993, pp.1669-79; Vance, V.B., Berger, P.H. et al., "5'-proximal potyviral sequences mediate potato-virus-x potyviral synergistic disease in transgenic tobacco", *Virology* 206, 1995, pp.583-90; Lecoq, H., Ravelonandro, M. et al., "Aphid transmission of a non-aphid transmissible strain of zucchini yellow potyvirus from transgenic plants expressing the capsid protein of plum pox potyvirus", *Molecular Plant-Microbe Interactions* 6, 1993, p.403; Asins, M.J., Monforte, A.J. et al., "*Citrus* and *Prunus* copia-like retrotransposons, *Theoretical and Applied Genetics*, 99 (3-4), 1999, pp.503-10; Smiley, R.W., "Influence of glyphosate on *Rhizoctonia* root rot, growth and yield of barley", *Plant Disease* 76, 1992, pp.937-42; Holmes, M.T., Ingham, E.R. et al., "Effects of *Klebsiella planticola* SDF20 on soil biota and wheat growth in sandy soil", *Applied Soil Ecology* 326, 1998, pp.1-12; Cummins, R., "GMO crops fail to live up to flagged benefits", *Farming Independent* (UK), 6 October 1998; Mekwatanakarn, P. and Sivasithamparam, K., "Effect of certain herbicides on soil microbial populations and their influence on saprophytic growth in soil and pathogenicity of take-all fungus", *Biology and Fertility of Soils* 5, 1987, pp.175-80; Johal, J.S. and Rahe, J.E., "Glyphosate hypersensitivity and phytoalexin accumulation in the incompatible bean anthracnose host-parasite interaction", *Physiological and Molecular Plant Pathology* 32, 1988, pp.267-81; Jewell, T., "Glyphosate", *Pesticides News* (UK) 33 (5), 1996; Bidwell, J.R. and Gorrie, J.R., "Acute toxicity of a herbicide to selected frog species", prepared for the Western Australian Department of Environmental Protection, Perth, 1995; Hassan, S.A., "Results of the fourth Joint Pesticide Testing programme carried out by the International Organisation for Biological Control/WPRS-working group 'Pesticides and beneficial organisms'", *Journal of Applied Entomology* 105, 1988, pp.321-29; Carrere, R. and Lohmann, L., op. cit. 18; Olsen, J.E., Junttila, O. et al., "Ectopic expression of oat phytochrome A in hybrid aspen changes critical daylength for growth and prevents cold acclimatization", *Plant Journal* 12(6), 1997, pp.1339-50; Rutgers University patent WO 0009726; Crawley, M.J. (ed.), *Plant Ecology*, Blackwell Science, Oxford, 1997, pp.595-632; US Department of Energy, op. cit. 24.

Pollen and seeds from GM trees can travel long distances.

or variety of tree, the problem is that isolation is virtually impossible in practice. For one thing, plantations often border wild forest systems, and indeed are often set up on land cleared of old-growth forest. For another, tree pollen can travel vast distances. On the treeless Shetland Islands, pollen was found from forests more than 250 kilometres away across the sea.[29] In Northwest India, windborne pollen was found 600 kilometres from the pine trees where it had originated.[30] Crucial forest pollinators including flies, butterflies, ants, beetles, aphids, bumblebees and honeybees are also notably indifferent to posted boundaries between GM and non-GM domains. Seeds are equally difficult to limit to a single geographical area, some being carried around by fruit-eaters while others are wind-borne or water-borne. In fact, it is seed or vegetative fragments which feature in the best-documented cases of long-distance gene flow, for example the establishment of plants on new continents.[31] Many trees can also spread through the distribution of broken twigs, while others send suckers up from their root systems. A single aspen in Utah, for example, boasts 47,000 trunks springing from its root system, and covers 42 hectares.[32] Trees can also grow from stumps left after felling.[33] In sum, trees may be even more adept at spreading their progeny than crops, and once in the wild, a single GM tree could survive for hundreds (perhaps thousands) of years.

A Cascade of Higher-Order Technical Fixes

One measure of the power of the tradition of industrial landscape simplification is that for each fresh contradiction created by attempts to "fix" one of its problems, there is always funding to research yet further, higher-order fixes. The result is a continuous cascade of ingenuity-absorbing technical tweaks fated to generate still further contradictions.

Thus one "solution" to the dilemma of genetic invasion is to attempt to engineer trees for sterility (*see* Box "GM Sterility"). Making GM trees sterile, the reasoning goes, will prevent gene flow. Predictably, however, this second-order fix leads immediately to difficulties requiring a third-order fix, and so on. GM sterility, for example, cannot be guaranteed to be permanent over generations and through environmental changes and disease stresses.[34] Nor does engineered sterility prevent gene flow through horizontal transfer (for example to bacteria and fungi), or through vegetative propagation, such as twig and stump re-growth or suckers. Moreover, stands of sterile trees devoid of birds, insects or mammals that rely on tree seeds, pollen or nectar for food could disrupt population dynamics (pollinators are of particular concern), with severe repercussions for neighbouring wild systems.

Current regulatory requirements for risk assessment constitute a further example of an attempt at a higher-order technical fix. This fix is, once again, quickly beset by its own limitations and dilemmas.

First, much of the data which adequate risk assessment of GM trees demands is unobtainable. For instance, in practice it is not possible to measure accurately to what extent GM plants or their genes might spread, simply because of the sheer size of the area which would need to be thoroughly examined for migrants. Studying small-scale, short-term experimental GM releases, moreover, holds few lessons for the large-scale, long-term releases to which GM forestry is committed, and long-distance migration and its effects will be different for every release.

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30. Singh, G., Chopra, S.K. and Singh, B., "Pollen-rain from the vegetation of North-West India", *New Phytologist* 72, 1973, pp.191-206.
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Second, serious risk assessment would exclude GM trees from precisely those uses for which they are being principally developed. Kenneth Raffa at the University of Wisconsin's Forestry Department suggests, for example, that risks of evolution of insect resistance can be limited if large or homogenous plantations are avoided. But this recommendation is inherently at odds with the requirements of the large-scale forestry industry.[35] Raffa's team also recommends close monitoring of plantations for a rise in insect resistance, but such monitoring is expensive and difficult in the remote locations in which plantations are often established.

It is unlikely that risks can be contained.

Third, the long life cycles of trees and the range of seasonal and other environmental stresses that they have to withstand entail that any genetic modifications made to them may be unstable. This too militates against reliable risk assessment.[36] Each stage of a tree's life cycle sees previously unused genes or gene combinations being activated — those that act in concert to direct flower formation or fruit ripening, for example. Determining how these interact with the engineered gene could take several years to ascertain — entailing delays unacceptable to shareholders or even many risk assessors. Unforeseen results are common. Aspen, for instance, will usually not flower before its seventh year, and German authorities gave consent for a five-year open field trial of GM aspen trees on the assumption that they would not flower during the trial. Yet one of the GM trees started flowering in its third year, despite pre-trial findings hinting that GM aspen would grow even more slowly than non-GM aspen. Although all the trees were derived from the same gene clone, in other words, they did not all flower at the same time.[37] Even in agricultural crops, engineered genes have been shown to be less stable than originally expected.[38]

Given the threat to the development of forestry biotech which thoroughgoing and rational assessment would pose, it is small wonder that proponents such as Simon Bright of Zeneca Agrochemicals are driven on occasion to articulate the defensive, unscientific demand that questions about GM trees be "framed in a way that gets a positive answer, or that a positive answer is allowed".[39] The agencies currently undertaking risk assessment of GM trees are often the ones with a vested interest in supplying just that "positive answer". Thus in Canada the Canadian Forest Service both promotes GM research and checks for risks, while Oregon State University's TGERC program, whose future lies in promoting GM trees, is precisely the body the US Environmental Protection Agency has chosen to assess the dangers of the technology.[40] This pattern hardly bodes well for forest ecosystems and the people whose livelihoods depend directly on them.

GM Sterility

Tree sterility can be engineered in several ways: manipulating hormonal messaging systems, altering flower- and pollen-related enzyme production, using cell ablation technology, and so forth. For example, genetic triggers can be engineered together with a gene for, say, diphtheria toxin, under the control of a promoter that instructs the tree to use the gene only in cells destined to become reproductive structures. Production of the toxin in these cells leads to their death.

One happy side effect of preventing flowering and seed production, biotechnologists suggest, might be to divert trees' energy and nutrients to timber production, thus increasing financial returns. Another effect would be to reduce the costs of removing seedlings of unwanted plants. A third would be to prevent the timber of some commercially important pine species from being marked by indentation and formation of cone stems.

Source: Mouradov, A. and Teasdale, R. D., "Genetic engineering of reproductive incompetence in radiata pine", *Protoplasma* 208, 1999, pp.13-17.

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[35] Raffa, K.F., op. cit. 10.
[36] Finnegan, J. and McElroy, D., op. cit. 34.
[37] Schiermeier, Q., "German transgenic crop trials face attack", *Nature* 394, 1998, p.819.
[38] Finnegan, J. and McElroy, D., op. cit. 34.
[39] 3C Associates, *Genetic engineering in Forestry. A business briefing for pulp and paper professionals*, 3C Associates, Oxon, UK, 2000, p.15.
[40] http://www.fsl.orst.edu/tgerc/index.htm; The Pulp & Paper Information Centre, op. cit. 14.

Conclusion

The processes through which genetically engineered trees are being developed are profoundly biased against social arrangements which promote and rely on biological diversity. These processes are also riven by dilemmas and destructive tendencies which chains of technical refinements, no matter how long, are likely to be powerless to overcome. Tackling the challenge GM trees pose means tackling the industrial and bureaucratic tradition which seeks the radical simplification of landscapes. That entails alliance-building with groups working against or outside that tradition, from seed savers to communities battling encroachment of industrial tree farms on their land.

In these respects, the issues raised by GM trees are similar to those raised by GM crops. Yet in many ways, genetic modification in forestry is an even more serious issue than genetic engineering in agriculture. Trees' long lives and largely undomesticated status, their poorly understood biology and lifecycles, the complexity and fragility of forest ecosystems, and corporate and state control over enormous areas of forest land on which GM trees could be planted combine to create risks which are unique. The biosafety and social implications of the application of genetic engineering to forestry are grave enough to warrant both an immediate halt to releases of GM trees and renewed attention to the social, historical and political roots of the tree biotech boom.

Prudence requires an immediate halt to GM tree releases.

The Corner House is a research and solidarity group which aims to support the growth of a democratic, equitable and non-discriminatory civil society in which communities have control over resources which affect their lives and livelihoods, as well as power to define themselves rather than be defined only by others. Contact details are on p. 1.

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