The certainty of gene flow from transgenic forests is problematic because neighboring lands are often less intensively managed public and private forest lands. At present, the scale and staggering expense of regulatory oversight alone could drive the political outcome in the absence of risk-benefit analyses. Ecological consequences of investment decisions on private lands deserve closer scrutiny at a national level.

Calls for public deliberation are coming late in the life of the forest product life cycle. I advocate that transgenic conifers be considered separately from agricultural biosafety policy due to the sheer scale and complexity of forest tree gene flow. Biocontainment zones suited to transgenic food crops cannot deter escape of seeds or pollen from transgenic *P. taeda*. Reproductive sterility research for conifers, a complex problem, remains in its infancy and has not received serious consideration as a national research priority.

There is thus an urgent need for policy makers to move on two fronts. First, a gene conservation program should be formalized through the National Forest System. In Region 8 of the southern United States, for example, indigenous *P. taeda* forests need to be protected from the potential impact of transgenic varieties. Widespread use of clonal forests with or without genetic engineering will likely rapidly narrow the numbers of *P. taeda* genotypes, opening the question of how to protect undomesticated germ plasm and close relatives, which remain largely undomesticated.

Second, forestry-specific research programs that address key issues specific to the implementation of transgenic technology in forestry need to be promoted within the existing cadre of national competitive funding programs. We are in dire need of funding for research to gauge the environmental impact of gene flow from trees. At present, we remain ignorant on numerous aspects of tree biology and ecology that affect whether or not we should proceed. Can pine pollen move in the jet stream and, if so, will it remain viable? How does gene flow from transgenic *P. taeda* affect indigenous pine forests or small woodlot or public forest ownership patterns?

A singular priority for forest research is determining the scale of regulatory oversight for transgenic forest trees. Responsible biotechnology governance is indeed questionable for transgenic conifer plantations located within less intensively managed forest ecosystems in the American South. The genetic composition of our nation's indigenous forests is at issue.

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Lost in the woods

To the editor:

In "Struggling to see the forest through the trees" (*Nat. Biotechnol.* **23**, 165–167, 2005), Herrera cites many of the important issues surrounding the state of forest biotechnology, yet at the same time fails to give an accurate impression of the extremely difficult state of the industry worldwide.

First, there are serious technical problems that stand in the way of this industry maturing. Although it is abundantly clear that simple traits like herbicide resistance and insect resistance, when encoded by single genes as in transgenic agricultural crops, can provide major benefits in some species and geographies with responsible use[1], it is not clear that these traits are valuable enough in forestry, given the costs of transformation, integration into breeding programs and associated field testing. For transformation, this is partly a result of the expected need to use new markers in place of antibiotic resistance genes to get broad international regulatory approvals[2], even though the commercially authorized (USA) *nptII* gene for kanamycin resistance used in transgenic agricultural crops has never been shown to be a significant health or environmental risk. In addition, transformation methods must be robust enough to work in the high diversity of germplasm used in most industrial forestry programs—which can include several species and dozens of genotypes. We know of no transformation systems up to this task.

Were there to be a number of companies and/or public sector institutions seriously investing in technological solutions to these problems, we are certain they could be solved. But the reality, in contrast to the impression Herrera gave, is that there is a very low level of industrial activity worldwide. Of the companies listed in Table 1 of his article, only Arborgen in Summerville, South Carolina, is seriously pursuing transgenic breeding science. CellFor in Vancouver, Canada, has ended all transgenic and molecular biology research; SweTree of Umeå, Sweden, works primarily on basic genomics and has never had an applied breeding-related program, and the transgenic breeding research programs in Chile and New Zealand have all been dramatically cut back in recent years. Large, technologically advanced companies like Weyerhaeuser, Federal Way, Washington, have never had their own transgenic research, though they have supported some basic transgenic-related studies in universities, primarily for biosafety and wood quality. Most of the major forestry companies in Chile are effectively turning away from transgenic research because of concerns about activist boycotts and their European markets. Finally, with the high regulatory risks (discussed below), few forestry breeding programs would wish to encumber their efficient programs with transgenic-level regulatory costs and potential liabilities.

Second, and most important, the thorny regulatory environment, designed without regard to the years of scientific consensus from national academies and ecological societies (e.g., see a position paper from the Ecological Society of America[3]), treats genetic engineering itself as dangerous by choosing to regulate every transgenic product in virtually the same way (the so-called 'case-by-case' approach). This extreme 'precautionary' system effectively precludes the use of trial-and-error, empirical methods that characterize all tree breeding programs. It is hard to imagine that changes to growth, wood chemistry or structure that are of significant economic benefit, but that do not also impair tree physiology and adaptation so important in all perennial crops, can be identified mainly in glasshouses and laboratories.

Yet, costly requirements for containment of pollen and seed from trees of commercially relevant sizes, when grown in a representative diversity of environments, make such essential adaptive research virtually impossible to carry out. This is in spite of highly promising small-scale field results from Europe and elsewhere[4], started in the optimistic 1990s. Finally, vandalism has led to local decisions in places such as British Columbia, Canada, to ban all transgenic field research with forest tree species, despite any scientific rationale to do so.

Of course, as Herrera hints, such draconian regulations are in place owing largely to the scare tactics and pressure on government officials from anti-genetically modified organism (GMO) activist organizations, which hope to see all transgenic trees regulated based on imagined worst case scenarios—not based on the increasing interest in modified expression of functionally native genes and pathways enabled by tree genomics. These regulations also ignore the reality that conventional breeding and silviculture, not just genetic engineering, also bring about substantial changes in wood structure, lignin, flowering, growth rate and many other attributes. Yet there is little call for their stringent regulation. It is time that the absurd, anti-scientific (that is, process not product) claims that all *Agrobacterium tumefaciens* or biolistics-delivered genes are somehow capable of causing 'destruction and contamination' of wild forests be identified as the scare-mongering that it is. Instead, lawyers and bureaucrats who have a limited understanding of breeding science or practice are working to insert language into local and national regulations, and into international treaties[5], whose effect will be to completely or effectively (due to cost and liability risk) ban all genetic engineering from forestry and agriculture.

Finally, these same groups, primarily by threat of boycott of retailers and corporations, rather than on advice from the leading scientific societies, continue to pressure companies for adoption of 'green' certification programs, such as the Forest Stewardship Council's (FSC), that ban all field use of transgenic trees, even for contained research. For FSC, any use of transgenic trees is considered a major violation of their 'principles,' even where it involves completely contained field research and is intended to solve a major environmental problem (e.g., to reduce chemical use during pulping, increase the rate of bioremediation or reduce the risk of invasiveness of forest trees when they are exotics[6]). As these programs slowly proliferate under the myth that avoidance of all genetic engineering is somehow an environmental good, companies' willingness to engage in transgenic research understandably dissipates.

These unwieldy social problems (for a review, see ref. 7), combined with the growing anti-commons caused by the fragmented patent estate of technologies important to forest biotechnology, make it a place where most companies understandably fear to tread. It will take strong political leaders and highly engaged scientists empowered by public funds for outreach, to stand-up and prevent green fundamentalist religion from trumping what could be a highly green new tool for breeding practice. Instead of genetic engineering helping to produce more efficient forms of plantation forestry that generate cost-efficient renewable energy and biobased products, we are instead being forced to continue planting more tree farms and harvesting more wild trees than necessary. How green is that?

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