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**GE in Forests: financial considerations**

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**Abstract:**

Anticipation of a biotechnology revolution has led to high expectations. However, one area that has been slow to develop is that of tree biotechnology, particularly genetically engineered or transgenic trees designed for the production of wood for industrial purposes, e.g. lumber and paper. The reasons for the slow development in forest trees appear to be many and include issues of environmental concern by various groups. In addition, the basic financial returns to the commercial application of genetic engineering to forest trees may be lacking also, technical obstacles have impeded the financial viability of certain types of GE trees.

**Key Words:** trees, forest, biotechnology, genetic engineering, lumber, paper, financial, economic.

## GE in Forests: financial considerations

Anticipation of a biotechnology revolution has led to high expectations. However, these may be overly optimistic for a variety of reasons (Nightingale and Martin 2004). One area that has been slow to develop is that of tree biotechnology, particularly genetically engineered or transgenic trees designed for the production of wood for industrial purposes, e.g. lumber and paper. While it is clear that the financial returns to transgenic biotechnology have been adequate to generate a host of new medicinal and agricultural products, the question is open as to whether there are applications of transgenic biotechnology that will generate innovative forest tree products with sufficient incremental market values to justify the total investment costs. In a recent article M.H. El-Lakany, Assistant Director General of FAO and Head of the Forestry Department raise the question of the adequacy of financial returns in forestry when he wrote, “The economic rationale for investing in genetically modified forest trees for commercial application is not directly apparent at present” (2004). The reasons for the slow development in forest trees appear to be many and include issues of environmental concern by various groups. In addition, for a number of reasons, the basic economic returns to the commercial application of genetic engineering<sup>1</sup> to forest trees may be lacking.

This paper focuses on the application of GE to the production of genetically modified organisms (GE) or transgenic trees. It asks “what are the major impediments, financial and other, to its widespread commercial application?”

While the commercialization of transgenic trees has been slow, there has been a large amount of related activity around the world (FAO 2004). Also, at least two transgenic trees have already been commercially deployed. The first was a transgenic fruit tree, the papaya, which was developed, deregulated by APHIS in the U.S. and commercialized specifically to address a disease problem in Hawaii (see Goldman 2003). A second commercialized transgenic is a Bt poplar (*Populus nigra* transformed with the Bt gene cry1Ac) that has been developed in China. It was deployed in pilot plantings as

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<sup>1</sup> The term genetic engineering (GE) is used in preference to genetically modified organism (GMO) since a plant can be genetically modified through traditional breeding practices (sexually) as well as through GE (nonsexual) procedures.

earlier as 1994 and also subsequently. Authorization by the Chinese regulatory authority permitted the establishment of about 1 million trees in 2002 on some 300 ha. This was followed by a smaller release with a hybrid poplar clone transformed with both cry1Ac and API in 2003. (Su et al. 2003, Wang 2004).

The “commercial” deployment of poplar in China at this time appears to be oriented more toward providing environmental “protection” services in parts of China, with difficult physical and climatic conditions and where pests have been a serious deterrent to the establishment of forests, than to commercial wood production. While the distribution of the transgenic as reported has been limited, given the easy vegetative propagation of poplar, the engineered gene is probably distributed beyond the area of the original plantings (Su et al. 2003).

This paper examines some of the financial considerations associated with the development, deregulation, dispersal and commercial utilization of an innovative product such as a transgenic tree used for commercial wood production. New developments and the commercial applications of technology typically involve substantial financial investments over time. In this paper the nature of these investment costs is examined as well as some of the differences between long-lived tree products and annual agricultural crops. It should be noted that while many innovations are technically feasible, often they are not financial viable.

In addition, the paper identifies advantages and limitations faced by selected individual countries in moving toward the commercialization of transgenic trees. Assessing these issues, the paper speculates about which countries are likely to be the early commercial uses of GE trees and how these production might impact the country, with a particular focus on the forest and forest products sectors. Finally, the broader implications of the commercialization of GE trees on the global distribution of production are drawn using a speculative “scenario” type approach.

### **Some Financial Basics**

This section identifies and examines some aspects of the types of investments required for tree innovations. Because of the long-lived nature of most trees and the time

discounting common in financial assessment, trees have certain financial disadvantages compared to, e.g., annual agricultural crops.

In addition, two types of innovations are examined: innovations generated through traditional tree breeding techniques and tree innovations achieved through genetic engineering. Note that the development and successful commercialization of a transgenic tree requires some additional types of investments, e.g., investments in deregulation, not required for trees improved through traditional breeding techniques. Also, there are investment time costs required in forestry that are not required for most agricultural crops.

The financial hurdle for any financial investment is to generate a stream of earnings, adjusted by the appropriate discount rate, which exceed the stream of discounted costs. Alternatively, one might require an investment generate a rate of return in excess of some minimum. This is called the internal rate of return (IRR). For example, the investment might require that an acceptable investment must generate an internal rate of return of at least, e.g., 10 percent.

The Time Value of Planting a Tree: It is well recognized in the financial literature and among most foresters that returns in the near future are preferable to returns in the distant future. For example, suppose an investment (Figure 1) was undertaken that cost \$100 in the initial year, and generated outputs worth \$10 each year for 20 years. The rate or return on this investment would approach 10%.<sup>2</sup> Let us call this the incremental annual crop improvement due to GE innovations.

Now suppose another investment also costs \$100 initially and it generates outputs that could be worth \$10 each year, but that the cumulative outputs and associated revenues could only be collected and marketed at a harvest in year 20, when the total accumulation was worth \$200. The rate of return on this investment would be approximately 3.9%. Let us call this the improvement associated with GE tree with a 20 year harvest rotation.

Note that even though the total cumulative return of both investments was \$200, the rate of return declines markedly due to the delay in the collection of the revenues. The

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<sup>2</sup> The IRR would equal 10% over an infinite time period.

waiting time is a critical element to determining the rate of return and thus the financial viability of an investment. Foresters have understood the financial disadvantages of long rotations since at least Faustmann (1849). An implication of the above discussion is that while for the same initial investment costs many short cycle GMO crops would general acceptable financial returns, tree crops delivering the same total value, but delayed, would not be financially viable. Thus, the hurdles are more difficult for long-lived trees than annual crops, *other thing being equal*.

### **Figure 1: Annual and Cumulative Revenue Collection**

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Annual Crop: Investment of 200 value units (e.g., \$) generates incrementally

10 value units of outputs each year for 20 years. These provide an Internal Rate of Return (IRR) = almost 10%

Tree Rotation of 20 years: Investment of 200 value units (\$) generates incrementally

20 value units each year to an accumulative of 200 value units at harvest after 20 years, which provides an IRR = 3.9%.

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A second implication is that shorter tree-rotations are financially preferable to longer rotations, *other things being equal*. Thus it is not surprising that most tree plantations focus on species with short rotations and tree improvement innovations are directed at increasing tree values or decreasing costs.

Achieving Investment Payoffs in Shorter Time Periods: Although the long tree life appears to put forestry at a financial disadvantage, this need not always be prohibitive. The tremendous expansion of industrial tree planting by the private sector in the latter

decades of the 20<sup>th</sup> Century demonstrates that long-term investments in trees can have returns adequate to attractive financial capital.

Additionally, where GE innovations are involved, not all these innovations need await final harvest to experience a financial payoff. A number of potential innovations have the potential to reduce costs early in the plantation growing cycle. For example, innovations that can reduce establishment costs early in the cycle, such as weeding or pest control cost, will generate benefits early thereby reducing the time costs of the investment. It is worth noting that the two transgenics currently commercialized, disease resistance papaya and Bt poplar both generate benefits early in the growing cycle.

### **Investments in Improved Forest Trees**

Starting with a stock of basic research knowledge, one can think of the development of improved tree products as involving a number of types of investments. These stages are presented in Figure 2, which lays out four investment (cost) stages in the development of a new transgenic forest tree. These are the initial development costs, distribution costs and time costs between planting and receiving financial returns. In addition, if the improved tree is transgenic, deregulation costs are also required and perhaps additional distribution costs to overcome the GE stigma<sup>3</sup> that is present in many markets.

Specifically, investments costs for a innovative transgenic tree typically consist of: 1) the development costs for the new product, e.g., the herbicide resistant gene as applied to, e.g., a eucalypts; 2) the deregulation investment costs for the new transgenic product, given that in most countries a transgenic plant is automatically a regulated article requiring deregulation for commercial use (note these costs are not required for a tree improved through traditional breeding); 3) the costs required for investment in a distribution system for the product, e.g., advertising, sales distributors, etc. (note that overcoming public opposition to a transgenic, its stigma, might require additional cost for a transgenic but not for a tree improved through traditional breeding); and 4) the time costs between when the tree is planted and when be benefits are captured and monetized (an issue common in long-lived trees).

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<sup>3</sup> “Stigma” refers to a decidedly negative view of the product by many consumers.

**Figure 2: Investment Stages for Conventionally Breed and Transgenic Trees**

Stage I	Stage II	Stage III	Stage IV (unique to trees)
<b>development costs</b>	<b>deregulation costs</b> (for transgenics only)	<b>distribution costs</b> (including stigma costs unique to transgenics)	<b>time costs:</b> planting to market

The above comments suggest that, other things equal, the nontransgenic tree would be preferred by the developer because some important investment costs could be avoided. Of course, other things are not always equal. Genetic engineering may allow transformations to be accomplished at lower costs. More importantly, asexual genetic engineering allows certain transformations to be executed that cannot be accomplished with traditional sexual breeding approaches. Hence, despite the extra investment costs, certain products are possible only using the GE technology. This has been true in agriculture as well where, despite substantial deregulation and stigma costs, major GE crop innovations have been successfully commercialized in many countries of the world.

### **Potential GMO Tree Innovations**

There are a host of GE tree innovations currently underdevelopment. Most of these are at universities or private biotech organizations. Table 2 provides a list of traits of interest in forestry. Let us examine a number of prospective GM tree innovations.

**Table 2. Forest Traits That Can Be Improved through Biotechnology**

<b>Silviculture</b>	<b>Adaptability</b>	<b>Wood Quality Traits</b>
Growth rate	Drought tolerance	Wood density
Nutrient uptake	Cold tolerance	Lignin reduction
Crown/stem	Fungal resistance	Lignin extraction

Flowering control	Insect resistance	Juvenile fiber
Herbicide		Tree Form, Branching

Table 3 lists six promising biotechnological innovations with estimates of their likely benefits and operating costs. Of these, the Superior Pine Clone is the only one that is not a transgenic innovation. The pine clone would allow the highest yielding improved trees to be utilized, undiluted by breeding (Pullman et al. 1998). Thus, the highest yield would provide benefits at harvest, but would require high costs at establishment in the form of more expensive clone seedlings.

**Table 3. Possible Financial Gains from Future Biotech Innovations**

<b>Innovation</b>	<b>Benefits<sup>4</sup></b>	<b>Operating Costs</b>
Superior Pine Clone	20 % yield increase after 20 years	\$40/acre or 15%-20% increase
Wood density gene	Improved lumber strength	None
Herbicide tolerance gene in eucalyptus (Brazil)	Reduce herbicide and weeding costs potentially saving \$350 or 45% per ha	None
Improve fiber characteristic	Reduce digester cost potential savings of \$10 per m <sup>3</sup>	None
Reduced amount of juvenile wood	Increase value \$15 per m <sup>3</sup> (more useable wood)	None
Reduce lignin	Reduce pulping costs potential of \$15 per m <sup>3</sup>	None

<sup>4</sup> The actual cost savings experienced by the tree planter will depend on the pricing strategy used by the gene developer and the portion of the savings to be captured by the developer and passed on to the grower.

*Source:* Context Consulting <sup>5</sup>.

The other five listed innovations all involve specialized transgenic imparted traits that involve no additional operating costs and provide benefits either through the growing cycle, as with reduced weeding costs, or in the form of increased or higher quality final outputs. In addition to these traits are traits related to pest and disease resistance, tree form, drought tolerance, salt resistant and so forth. The value of these benefits is less quantifiable in the abstract, but certainly exists for selected applications.

Following find a brief discussion of some of those techniques and traits.

**Cloning and Vegetative Reproduction:** Vegetative reproduction comprises a broad range of techniques involving the manipulation of plant tissue that ultimately allows for vegetative reproduction, that is, reproduction by planting cuttings from a live plant, which are planted and in turn produce a new plant. The development of cloning techniques in forestry is important because if superior trees are available, an approach must be developed to allow for the propagation of large numbers of seedlings with the desired characteristics if these traits are to be transferred into a planted forest.

**Herbicide Resistance:** Planted trees typically require herbicide and, in some cases, pesticide applications for one or two years after planting. The introduction of a herbicide resistant gene can reduce the costs of herbicide applications by allowing fewer but more effective applications without concern of damage to the seedlings. An early assessment indicated that the potential global market for this innovation could be vast (Sedjo 1999).

**Pest Resistant: Bt Gene:** Like the herbicide resistance gene, the Bt gene is expected to provide many of its benefits early in the rotation cycle where it is expected to be a cost saving substitute for pesticides. In general, Bt trees would be developed to reduce the costs of pesticides in forests with serious problems. Apparently, the application of the basic technology to trees is not too difficult. The Chinese have developed and have a limited commercialization of Bt poplars. Thus, at least in China, the regulatory hurdles have been manageable.

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<sup>5</sup> Context Consulting provided information on potential innovations and their likely cost implication based on the best judgment of a panel of experts.

Fibre Improvement: This category includes a host of potential GMs that would increase the amount of usable wood fibre or reduce the costs of its processing in the pulp and paper making processing. Examples include GMOs with reduced juvenile wood, reduced lignin (see Hu et al 1999), or more easily extractable lignin, various fibre quality improvements and or quantity increases, and so forth. The advantages of this innovation are found after the tree is harvested and when the fibre is being processed.

Flowering Control including Sterility: Flowering control allows a delay of several years in flower initiation, nonflowering habit, or sterility. This control may be useful in preventing certain transgenic plants from transmitting genetically modified matter to other plants and/or from migrating into the wild.

### Shorting the Long Time Frames

Where GE innovations are involved, not all these innovations need await final harvest to experience a financial payoff (Table 4 and 5). The user of the herbicide resistance innovation, for example, need not experience the long waiting costs associated with a harvest to receive the financial benefits of the innovation. Rather, financial benefits to the

**Table 4. Timing of the Capture of Financial Returns of Interest in Forestry**

Trait	Early Capture	Captured at Harvest
Herbicide tolerance	X	
Flowering control		X
Fiber/Lignin modification		X
Insect tolerance	X	
Disease tolerance	X	
Wood density		X
Growth		X
Stem straightness		X
Nutrient uptake		X
Cold, wet, drought tolerance	X ?	X ?

tree grower are captured in reduce weeding costs in the establishment phase, years 1-3, of the plantation growing cycle. Similarly, with pest and disease resistant genes, which substitute for the costs of chemical applications and increased mortality, the benefits often occur early in the cycle and thus time costs are reduced.

**Table 5: Period of Benefit Capture**

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<b>Innovation</b>	<b>Financial Benefit</b>	<b>Period of Benefit Capture</b>
Herbicide Resistance	Reduce Weeding Costs	Plantation establishment (1-3 years)
Bt Gene	Reducing pesticide use	Early/mid rotation cycle (1-10 years)
Fibre Improvement	Reducing processing cost improved fibre quantity	Post harvest (harvest 10-40 years)
Sterility or Changes in Reproduction Improved	Reduced Gene flow	May be a condition of planting or product acceptance

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### **Financing Traditional Tree Breeding**

Product Development Costs: Product development costs obviously will vary with the particular product. For conventional tree breeding using a well know already identified species with a short juvenile phase the costs of developing a new forest tree are estimated at about \$400,000 and require 15-20 years to be developed (F&G 2002). Where either traditional or transgenic development approaches can be used for the development of a similar new tree at roughly the same costs, the conventional breeding approach would almost certainly be used since it avoids the costs of deregulation (Stage II) and the costs of overcoming any consumer stigma associated with the transgenic product (part of Stage III).

However, for many transformations using genes not found in the species of interest, a transgenic approach would be required. Also, transgenic approaches may facilitate a much reduced time requirement for some types of transformations.

Figure 3 categorises the five categories of investment costs required for a transgenic tree. For three of the categories the costs appear to be roughly comparable. However, for two categories, deregulation and stigma categories, the costs are likely to be substantially lower in developing countries. This suggests that the developing countries may have some comparative costs advantage in the commercialization of wood trees.

**Figure 3: Comparative Investment Costs: Developed and Developing Countries**

<b>Investment</b>	<b>Developed Countries</b>	<b>Developing Countries</b>
development costs (stage I)	comparable	comparable
deregulation costs (stage II)	high	low
distribution costs (stage III)	comparable	comparable
stigma costs(stage III cont.)	high	low
time costs (stage IV)	comparable	comparable

It is less clear as to which types of countries have the cost advantage with respect to development costs. Often the level of technical and research expertise is greater in developed countries. However, labor costs, even for technical people are likely to be much less in developing countries. Furthermore, knowledge and technology are readily transferable across borders.

### **Towards Commercialization and Location**

Given the above background, where and how might we expect deregulation to occur and transgenic tree commercialization in the future? A number of factors that appear to be relevant to success in commercialization will be examined including prior experience with plantation trees, the market situation for the product, tree type, and ease of deregulation,

Experience and Market Situation: The organizations with the most direct interest in transgenic forest tree development, deregulation and commercialization are the developers and countries/firms that are likely to utilize the innovation and thus be the principal financial beneficiaries of the innovations. These countries/firms are likely to

have had substantial prior success with intensively managed plantation forestry. These include Brazil, Chile, New Zealand, South Africa, China, the U.S. South and perhaps Australia (table 6). These countries all: have had substantial experience with and expertise in intensively managed forest plantations; have large potential markets for innovative trees with substantial commercial potential; have generally low-cost high-yield forests that make them strong competitors; and are in a position to exploit on a large scale this combination of experience, expertise and large domestic markets.

**Tree Type:** Another consideration is the types of species which do particularly well in the various countries and the likelihood that tree will be amenable to useful near-term transgenic innovations (table 6). Any wide spread transgenic program will require a tree type (species) that can quickly replicated or “bulked up” from a few laboratory developed transgenic trees to millions of low cost seedlings that can be deployed. A problem with conifers has been the difficulty with replication. Techniques for clonal reproduction, such as somatic embryogenesis, have been mastered, but they are still quite costly and are as yet not readily for widespread deployment. Thus, countries or regions which depend primarily on conifers are likely to have a delay before the enabling technology, low-cost cloning, is adequately developed.

Many deciduous trees, by contrast, are relatively easy to replicate through vegetative propagation. Thus, one might expect the first large-scale commercial applications of transgenic trees to be in some type of deciduous tree, which can be easily reproduced. Thus, there are distinct technological and financial advantages in planting a tree that has low propagation cost.

**Ease of Deregulation:** Although developing countries do not have a clear advantage in transgenic tree development, at least some developing countries may have a Comparative advantage in deregulation.<sup>6</sup> As demonstrated in the study by Pray et al (2004) a local developer appears to have substantial advantage when it comes to

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<sup>6</sup> Some of the ease of deregulation may reflect the degree of hostility or acceptance within the country toward GE. For a harsh view see: e.g., See the concerns against GE trees of the Institute for Society Ecology <[www.ajc.com/news/content/science/04/05/25gmtrees.html](http://www.ajc.com/news/content/science/04/05/25gmtrees.html)>

**Table 6: Tree Types and Market Size**

<b>Country</b>	<b>Tree Type</b>	<b>Domestic Market</b>
Australia	conifer and deciduous	modest
Brazil	conifer and deciduous	large
China	deciduous	large
Chile	conifer	modest
New Zealand	conifer	modest
South Africa	conifer	modest
US South	conifer	large

achieving fast and low cost deregulation. The optimum approach may well be to form a joint venture between a biotech development company in the developing world with a partner in the countries of interest. The partner can then become the major agent in the deregulation process with both partners sharing the proceeds from the revenues of the deregulated transgenic.

Where developing countries have the expertise for the applied stages of the transgenic innovation, the role of the developed country firm might be smaller or non existence. In China, for example, the role of the foreign firm in the development of the transgenic poplar appears negligible, although some foreign scientists do appear to have played a role.

Finally, there are ecological concerns such as gene escape, that could effect the timing of deregulation. For example, serious concerns have been raised about the implications of gene escape from a transgenic indigenous species, such as loblolly pine in the U.S. to the wild forest population (Williams 2004). Such concerns could delay to deregulation of transgenic pine in the U.S., but may raise little concern with an exotic, such as transgenic eucalyptus in Brazil, since there are no native forest trees of the same or related genus (DiFizio et al. 2004).

The global market for tree germplasm: In concept trade in transgenics can involve two different types of goods: the transgenic tree and its live germplasm, which is available for planting and reproduction, and the commodity wood and products made from that commodity. The commodity produced by the transgenic plant might be transgenic corn or industrial wood. Thus, there are two possible industries and two possible markets: that of the tree transgenic produce developer, and that of the tree grower. Access to international markets is likely to be different for the two industries.

In general, the commodity is not likely to be eligible for international trading restrictions unless deemed to be a health or safety hazard, which has often been the argument against transgenic crops. In the case of wood, however, the commodity would be either raw wood in the form of logs, or wood products such as lumber, pulp or paper. In none of these cases does it appear a serious argument can be made for trade restrictions based on health, safety or concerns of initiating environmental damages in the importing country related to the transgenic nature of the tree, since the wood cells would be dead. By contrast, the living germplasm, e.g., the living modified organism (transgenic) plant or its live seed, can be regulated by virtue of the general regulation most countries place on transgenic plants.

Summary: The above suggests that GE trees are most likely to become commercial first in countries that a) already have large areas of well functioning plantation forestry and areas for expansion. Additionally, these countries b) will have access to large markets, either domestically or abroad. Furthermore, c) foreign markets are unlikely to provide any barriers directed at the transgenic character of the wood being utilized. Also d) the tree types most likely to be genetically engineered are likely to be non conifers, due to the high replication costs with conifer. Furthermore, e) the countries that initiate large scale commercial transgenic plantation are likely to have a friendly deregulation process and a population that is not overly concerned about transgenic issues and particularly transgenic trees. Finally, f) the ease of deregulation may depend on the extent of concerns of gene escape to wild forest populations. These concerns may be greater in developed countries.

### **The Tale of Two Countries: China and Brazil**

Two countries, China and Brazil, appear to have most or all of the preconditions that would make them early deregulators and commercializers of transgenic trees. China has most of the preconditions for tree deregulation. In fact, as noted, China has already deployed limited amounts of transgenic poplars, with a Bt gene to resist insects. However, due to their easy vegetative reproduction properties, these may be more widely distributed than generally recognized. China has been establishing very large areas of tree plantations for decades for both protection and commercial industrial wood production purposes. It has markets for industrial wood and has had large rehabilitation and protection efforts underway for some time. China has chosen to commercialize the poplar, a tree whose genome has been well studied. The tree is also very easy to propagate vegetatively. The transgenic tree was largely developed in China and apparently was deregulated without inordinate difficulty. The only feature in conflict with the criteria listed above is that gene escape could be transferred fairly readily to the wild poplar population. However, this could be viewed positively in China as this could confer pest resistance upon much of the wild trees under insect stress.

**Table 7: The Tale of Two Countries: China and Brazil**

	<b>China</b>	<b>Brazil</b>
<b>market size</b>	<b>large</b>	<b>large</b>
<b>tree experience</b>	<b>abundant</b>	<b>abundant</b>
<b>deregulation procedures</b>	<b>modest costs</b>	<b>likely? Modest costs</b>
<b>tree type (ease of propagation++)</b>	<b>poplar</b> ++	<b>eucalyptus</b> ++
<b>Public acceptance</b>	<b>widespread</b>	<b>widespread</b>
<b>current transgenic trees</b>	<b>yes</b>	<b>no</b>

Although the Brazilian situation is different in many respects, Brazil meets all the preconditions for transgenic trees. Brazil has large areas of plantation forest and has become a major world supplier of certain types of forest products, e.g., market pulp. Although the tree types in these plantations vary substantially, large areas are in

eucalyptus which has been greatly improved through traditional breeding and it is the eucalyptus that is likely to be the first transgenic forest tree in Brazil. The innovations are likely to be of the fiber improving type further enhancing Brazil's competitive position in the fiber and pulp markets. Although Brazil only recently began to allow transgenic crops, deregulation could be achieved fairly easily. Domestic concerns about transgenics appear to be minor and, since Eucalyptus is an exotic in Brazil, gene escape constitutes little threat to native forests.

Finally, we might note here that although the U.S. has been a leader in the development, deregulation, deployed and commercialized transgenic crops, deregulation of a transgenic forest tree may be sometime off. Although the U.S. has already deregulated the papaya, a fruit tree, this deregulation may be more of an exception than a sign more tree deregulation soon to come. Much of the transgenic research in the US is oriented to loblolly pine. As noted, pine will need a facilitating low-cost technology in the development of clonal pine. Progress is being made but low-cost applications require further improvements. In addition, wild loblolly stands raise questions about the implications of gene escape. Although these issues may subsequently be determined to be minor, substantial field research will likely need to be undertaken before deregulation is achieved. It may be that the first applications of the deregulated transgenic pine will occur in countries without native pine, e.g., South America or New Zealand.

### **Some Possible Future Scenarios**

Although there are substantial concerns about the release of deregulated GE trees (see Campbell and Asante 2001), the fact is that some transgenic trees have already been released, and more are likely to be deregulated soon. As suggested above, the most likely countries involved in GE tree commercialization are likely to be China and Brazil.

No country in the world has more land in planted forests than China. China has planted large areas in poplar, pine as well as exotic species. In western China a "Great Green Wall" of forest is being established to help control impending desertification. It is difficult to imagine China not making use of transgenic trees that offer serious advantages even given some international opposition. Once developed, the incremental costs of the transgenic poplar are likely to be negligible. Also, transgenics can provide

insect resistance services without requiring large doses of expensive and often environmentally harmful pesticides. If a pest resistant Bt transgenic poplar is used effectively, there is little reason to expect that other transgenic trees will not also be introduced. These may be introduced to enhance industrial wood production and wood properties. Given the large demands of the Chinese economy for industrial wood, however, it is unlikely that China will use any advantages gained from transgenic trees for industrial wood production in foreign markets in the foreseeable future.

Brazil, by contrast, is likely to look toward transgenic trees to enhance its already formidable advantage in certain types of industrial wood production, particularly pulpwood. While it has been anticipated that the expansion of Brazil's domestic market will eventually draw a large portion of its production out of the international market and into the domestic market, this has yet to occur. Indeed, given the high yields and the large areas of land suitable for plantations, there is no physical reason why Brazil could not produce large volumes of industrial wood for both domestic and international markets.

Research is currently underway on developing a transgenic eucalyptus with about a 30-40% increase in fibre<sup>7</sup>. The most likely scenario may be that the transgenic eucalyptus becomes deregulated and commercially planted in Brazil within the next few years. The ecological implications of such a transgenic are likely to be minimal in that the eucalyptus is an exotic and therefore gene escape is unlikely to impact native species anywhere in the western hemisphere. Additionally, a eucalyptus with greater fibre content will almost surely not provide additional "fitness" in the wild to the transformed tree. Thus, ecological objections to the use of the tree in Brazil are likely to be weak and non compelling.

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<sup>7</sup> Personal conversation, Sharman MacRay, Quebec City Canada, September 27, 2003.

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