Biotechnology in the Forest?
Policy Options on Research on GM Trees

**David Humphreys, Jorrit Gosens, Michael J. Jackson,
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EXECUTIVE SUMMARY

Biotechnology is one of the most controversial and intensely debated subjects of our age. The subject of genetic modification (GM) has been a politically contentious subject with respect to agriculture, and it seems likely that the issue of GM trees will, at some stage, become a live political issue. Given this, forest research institutes should be able to demonstrate that this subject has been seriously considered, and that policy in this area can be justified and supported.

The subject of GM trees is a relatively new one in world forestry, although some policy trends have already become apparent. First, most major international environmental NGOs, stressing the scientific uncertainties involved with GM trees, have tended to oppose GM trees, or at a minimum to urge extreme caution in their use. Second, most major intergovernmental organisations have avoided taking a policy position on the GM issue. This is not due to indifference, however, but to differences on the subject between member states. For example, the World Bank has not issued a policy statement on GM due to the different views of its shareholders in Europe and North America. Third, most international forestry organisations and networks, including the International Union of Forest Research Organisations (IUFRO) and the Center for International Forestry Research (CIFOR), have yet to formulate a clear policy position on the use of GM trees. This reflects the differing approaches to the issue within the international forestry community.

This paper presents a set of possible policy options on the subject. It provides some analysis of the possible benefits and potential disadvantages of GM trees with respect to five clusters of argument: scientific and environmental, legal, economic, social and ethical. No clear, unambiguous arguments emerge either for or against GM trees. On the one hand there are potential environmental and economic benefits. For example, the enhanced productivity and/or improved quality (e.g. for pulping) that genetic modification may provide could reduce the pressures on natural forests. GM trees can be made more resistant to certain pests. But on the other hand there are potential risks to the environment from genetic contamination of natural stands, the economic costs of which could be significant. The social costs of GM plantations could be severe, especially in developing countries. The legal situation is also unclear: while the Cartagena Protocol on Biosafety provides some guidance, it is open to differing interpretations.

The paper provides eight policy options for the consideration of forest research organisations such as the EFI, ranging from full and active support for GM trees to complete opposition. The policy that is chosen will depend on how the various risks and benefits are assessed, how the current body of international law is interpreted, and which ethical arguments are considered most persuasive. Should an organisation choose to

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support research into GM trees it is suggested that it should also adopt a contingency plan for disengaging from this area should evidence emerge that the risks are unacceptable or that GM trees are causing serious and irreversible damage to nature.

PREFACE

Over the past decade, the genetic modification of food crops has proven to be a contentious subject. It is likely that the genetic modification of trees will also prove politically controversial. In 2004, the Scientific Advisory Board (SAB) of the European Forest Institute (EFI) suggested to the EFI Board that the Institute should consider adopting a policy on research on GM trees. The view was expressed in the SAB that EFI, as a major actor in Europe on forest research, has a responsibility to itself, its member institutions and other stakeholders to ensure that its policy on GM trees has been thoroughly considered and well founded. As a result of these discussions the EFI Board asked the SAB to invite competent authors to write a discussion paper on GM trees, including an evaluation of the current policy context and a distillation of the available research policy options. It was understood that providing an exhaustive state-of-the-art on GM trees was outside the scope of this work, and that the main contribution of the paper would be in introducing the various types of arguments related to GM trees, and options for policy choice.

The paper was first drafted following a collaboration between colleagues at The Wageningen University, Netherlands and The Open University, United Kingdom. EFI is thankful to the authors, who responded to the call and whose views – as presented in this discussion paper – will be valuable when EFI will be considering its position to the issue.

I believe that this paper will help in encouraging discussion on this topic, and that the discussion will be useful not only to EFI but also to its members if they see it necessary to formulate their own policies on the research of GM trees.

On behalf of EFI and the authors, I would like to express our special gratitude to Catherine Bastien, Jan-Erik Hällgren, Ted Farrell and Antoine Kremer for their constructive and detailed comments. Comments by Eeva Hellström, François Houllier, Jari Kuuluvainen, Davide Pettenella, Göran Ståhl, Hubert Sterba and Victor Teplyakov were also most valuable to the current work.

Joensuu, Finland
August 1, 2005

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Director, EFI

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1 INTRODUCTION

1.1 GENETICALLY MODIFIED TREES AS AN ISSUE: POLICY AND POLITICS

Genetic engineering, which first developed on a large scale in the 1980s, is a form of biotechnology that introduces a gene-character into a recipient host organism. The genetic code of a living organism defines its possible characters and consists of deoxyribonucleic acid (DNA) or ribonucleic acid (RNA)[1] Note, however, that there are several natural ways for DNA/RNA transfer to take place between organisms of the same species, or between species, including trees. These natural mechanisms are part of the evolutionary processes that take place on Earth.

A genetically modified (GM) tree (sometimes referred to as a genetically engineered tree or a transgenic tree), can be defined as a tree that "through human intervention in a laboratory, has had its genome, or genetic code, deliberately altered through the mechanical insertion of a specific identified sequence of genetic coding material (generally DNA) that has been either manufactured or physically excised from the genome of another tree".[2] The new genes are passed on to future generations. Genetic modification may be used to alter or introduce a wide range of traits, including insect and disease resistance, herbicide tolerance, tissue composition, and growth rate.

The first GM tree trial was carried out in Belgium in 1988.[3] Since that time many tree species, both for fruit and timber production, have been genetically modified and tested in field trials. Trials have been conducted in Europe, North and South America and New Zealand, principally for facilitating pulp production and for increasing productivity. In China the State Forestry Administration has approved GM poplar trees for commercial planting and one million insect resistant GM poplars have been planted.[4] Appendix 1 provides a list of some GM trees grown in field trials.

At present the subject of GM trees can be seen as a *policy issue*, in other words an issue on which individual actors make decisions more or less free from external political pressures and influences. It has tended so far to avoid becoming a *political issue*, that is, an issue subject to lobbying, campaigning and pressure group activities in which different political actors declare, or are pressured to declare, a "for" or "against" stance. However, this situation could change very fast. GM trees have all the ingredients of a political issue: genetic modification of trees could have profound social, environmental and economic

1 Arborea, http://www.arborea.ulaval.ca/en/public-corner.php#q3 (accessed 9 November 2004).
2 Alberta Forest Genetic Resources Council, http://www3.gov.ab.ca/srd/forests/fmd/genetics/gmo.html (accessed 9 November 2004).
3 This section draws from Asante Owusu, R. 1999. GM Technology in the Forest Sector: A scoping study. http://www.mindfully.org/GE/Forest-GM-TechnologyNov99.htm (last accessed 19 July 2005).
4 World Rainforest Movement, http://www.wrm.org.uy/bulletin/85/China.html (accessed 9 November 2004).

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ramifications; it invokes serious ethical debate; and it could already be the subject of international law and regulations. It could rapidly become a political issue at the national and international levels.

If GM trees should become an issue of *national* political debate it will do so in some countries before others. For example, in the late-1990s GM crops was the subject of an intense political debate in some European countries, such as the United Kingdom, yet it attracted hardly any political debate in others. While no European country has yet to introduce an outright ban on genetically modified organisms (GMOs), several regional level governments have done so. Countries outside Europe to have introduced a complete ban on GMOs include Algeria, New Zealand, Peru and El Salvador.[5]

If GM trees should become an issue of *international* political debate it will do so in some policy arenas before others. For example, at the fourth session of the United Nations Forum on Forests (Geneva, May 2004) environmental NGOs, including the People's Forest Forum, lobbied delegates arguing for a complete global ban on GM trees, the risks of which, it was argued, "extend over national borders and across generations and are irreversible".[6] The NGOs had no impact on these negotiations only because the issue of GM trees is not a UNFF agenda item. However, the UNFF is currently negotiating a new international institutional arrangement on forests that may, or may not, include GM trees. While there is no international legislation that specifically focuses on GM trees, the Cartagena Protocol on Biosafety could be interpreted to apply to GM trees,

This paper is based primarily on an analysis of the existing literature on GM trees. Section 2 provides a brief overview of the policy positions of some major international actors on GM trees. Section 3 evaluates the arguments for and against the use of GM trees in forestry under five headings:

- Scientific and environmental
- Legal
- Economic
- Social
- Ethical

Based on these arguments, section 4 presents a menu of some possible policy options that the EFI, its member organisations and other organisations engaged in forestry research may wish to consider when deciding their policy on GM trees.

1.2 GM TREES IN FORESTRY[7]

Forest ecosystems provide different goods and services that humans depend on, such as water reservoirs, biodiversity and wildlife habitats, carbon sequestration, timber, recreation and other social and spiritual values. About a quarter of the world's land surface

5 Lang, C. 2004. World Rainforest Movement Bulletin 88, November.
6 "Open Letter for Country Delegations in Fourth Session of the UN Forum on Forests, 14th May 2004 in Geneva".
7 This section draws from Salwasser, H. 2004. Future Forest: Environmental and Social Contexts for Forest Biotechnologies. In Strauss, S.H. and Bradshaw, H.D. (eds.). The Bioengineered Forest: Challenges for Science and Society. Washington DC: RFF Press. Pp. 3–11.

is covered by forest.[8] Forests are transformed by management activities such as livestock grazing, recreation, water diversions, roads, and the harvesting of trees.

One of the main arguments deployed in favour of GM trees is that their use will increase the productivity of timber producing forests and reduce the environmental impacts associated with intensive management. Improved pulping quality will reduce the usage of chemicals used for bleaching and will cut down on waste from pulp factories. The FAO predicts that between 1996 and 2010 there will be a 25% increase in wood demand.[9] This demand cannot be met solely by natural forests. It is estimated that 35% of timber comes from plantations, which made up just 5% of total forest cover in 2000. It is predicted that 10–15% of wood production forests will meet up to 80% of the world's industrial wood needs by 2050.[10] It can be argued that in economic terms, more efficient use of wood producing forests through the effective use of GM trees would reduce further the pressure on natural forest reserves, which are managed not for the extraction of forest products but in order to sustain native species and ecosystems. According to this view, the use of GM trees has both economic and environmental advantages. Furthermore, GM trees that have been genetically engineered for pest resistance can help in the restoration of native species that are endangered by pests. Again, so it is argued, GM trees have both economic and environmental benefits by optimising the multiple functions of forests through increasing productivity and protecting native species.

Besides their potential use in operational forestry, GM trees offer interesting perspectives in research and particularly in gene expression and tree improvement programmes. The creation of transgenic plants is the most straightforward way to determine gene function. Large scale genomic research on intensively cultivated trees (e.g. poplars, pines) will lead to the identification in the near future of candidate genes (i.e. genes that may control phenotypic traits of ecological or economic value).[11] One way to validate these candidate genes is gene transformation. Once their phenotypic effects have been verified, these genes can be introduced in elite genotypes by traditional crosses, and propagated in seed orchards for their future use in plantations. In this case the use of gene transformation is restricted to research activities, but the final outcome of the research (improved varieties) in some cases makes use of GM trees, albeit under circumstances such as closed laboratories whereby risk is minimized.

8 FAO – Food and Agriculture Organization of the United Nations. 2002. Global Forest Resources Assessment 2000. FAO Forestry Paper 140. Rome: FAO.

9 FAO press statement on GM trees. 2003. http://www.fao.org/english/newsroom/ focus/2003/gmo6.htm (accessed 17 November 2004).

10 Sedjo, R. and Botkin, D. 1997. Using Forest Plantations to Spare Natural Forests. Environment 39(10): 14–22 and Victor, D.G. and Ausubel, J.H. 2000. Restoring the Forests. Foreign Affairs 79(6): 239–257.

11 Wullschleger S.D., Jansson S. and Taylor G. 2002. Genomics and forest biology: Populus emerges as the perennial favorite. The Plant Cell 14: 2651–2655.

2 POLICY PRECEDENTS

Several large international forestry research institutes and businesses have become directly involved in research in GM trees, including carrying out field trials. One example is ArborGen, a joint venture formed in 1999 between Monsanto and three major forestry corporations: International Paper, Westvaco and Fletcher Challenge. This has become the world's biggest GM tree company. Monsanto pulled out of ArborGen six months after its formation. In January 2000, Genesis Research and Development, New Zealand's biggest biotechnology company, joined the joint venture.[12] ArborGen's vision is "to create products that benefit consumers, sustain the environment, and provide value to the forest industry through the application of genetics and enhanced trait technology. The application of research provides an additional tool in the sustainable forestry toolbox."[13]

The French organisation INRA, which participates in the IUFRO Task Force on Forest Biotechnology,[14] is involved in research on GM trees and cooperates with researchers from other laboratories. The Finnish research institute METLA also carries out research on forest genetics and the application of biotechnology to tree breeding.[15] The Swedish University of Agricultural Sciences and Umeå University have created the Umeå Plant Science Centre (UPSC) that, amongst other things, carries out tree breeding using GM poplars.

There now follows a brief review of the policy positions on GM trees of some international actors in forestry and forest policy:

People's Forest Forum

The Peoples Forest Forum is coordinating an international petition for a total global ban on GM trees. The petition is available on their website. It was presented to the 10th session of the conference of parties to the United Nations Framework Convention on Climate Change (UNFCCC) at its 10th session in December 2004.[16] By 4 January 2005, 304 environmental groups had signed the petition including the Gaia Foundation (UK) Global Forest Coalition (Paraguay), Friends of the Earth International, Third World Network (Malaysia) and Sierra Club (USA).[17]

12 Lang, *op.cit.*
13 Arborgen "Improving Forestry Through Genetics and Technology", http://www.arborgen.com (accessed 1 December 2004).
14 INRA: http://www.inra.fr (accessed 10 December 2004).
15 Metla: http://www.metla.fi (accessed 10 December 2004).
16 People's Forest Forum: http://elonmerkki.net/forestforum/uk/index.html (accessed 16 November 2004).
17 People's Forest Forum: http://elonmerkki.net/forestforum.uk.signed1.html (accessed 4 January 2005).

World Rainforest Movement

The World Rainforest Movement (WRM) is a global network of NGOs and forest peoples' groups with headquarters in Montevideo, Uruguay. It has signed the petition for a global ban on GM trees from the Peoples' Forest Forum. The WRM's November 2004 bulletin expressed the WRM's firm opposition to GM trees, principally on the grounds that this would inevitably lead to the genetic contamination of wild relatives.

Forest Stewardship Council

The Forest Stewardship Council (FSC) specifies the basic requirements that timber harvested at the forest management unit level must meet if it is to be certified as "well-managed" according to FSC principles. The FSC's standard of October 2004 prohibits the use of any GMO's in certified forestry operations.[18]

Programme for the Endorsement of Forest Certification Schemes

In distinction to the FSC, the Programme for the Endorsement of Forest Certification Schemes (PEFC, formerly Pan-European Forest Certification) has not taken an oppositional stance against GM trees. Most PEFC national schemes do not limit the use of GM trees, although exceptions include the United Kingdom and France.[19]

World Wide Fund for Nature

In November 1999 the WWF formulated a position statement on GMOs that called for a halt to the use or the release of GMO's until "all ecological interactions are fully researched; [including] transparent comprehensive environmental impact assessments of planned releases; and properly regulated monitoring and control of gene technology."[20] In other words, the WWF is not necessarily against GM, but it is urging further assessment of their effects. This was made clear in a statement on GM trees in which a WWF spokesperson declared "We are not against genetically modified trees in principle, but we want more research and above all openness about what is planned. We need to know the pros and cons, about the dangers of cross fertilisation of native species and sterilising large areas of the landscape".[21]

International Union of Forest Research Organisations

IUFRO's Task Force on Forest Biotechnology is currently working on a publication on forest biotechnology to be presented to the 2005 IUFRO World Congress (8–13 August 2005, Brisbane).[22]

Center for International Forestry Research

CIFOR has not adopted any formal policy position on GM trees.

18 Forest Stewardship Council 2004. FSC standard for forest management enterprises supplying non FSC-certified controlled wood. http://www.scscertified.com/PDFS/forest_COCStandard_30_%20010%20FM_100104_1.PDF (accessed 1 December 2004).

19 Cashore, B. Auld, G. and Newsom, D. 2004. Governing Through Markets: Forest Certification and the Emergence of Non-State Authority. New Haven: Yale University Press. 18 p.

20 Asante Owusu, *op.cit.*

21 Francis Sullivan of WWF, cited in The Guardian, 10 November 1999.

22 As reported in African Conservation Forest: http://www.africanconservation.org/dcforum/DCForumID35/20.html (accessed 2 December 2004).

World Bank

The World Bank's 2002 Forest Strategy makes no mention of GM trees, and neither does its operational policy on forests, which states that the Bank will only fund plantations that are "environmentally appropriate, socially beneficial, and economically viable."[23] According to an interpretation from the World Rainforest Movement this would exclude GM tree plantations, which are neither "environmentally appropriate" nor "socially beneficial".[24]

World Conservation Union (International Union for the Conservation of Nature, IUCN)

In November 2004 a major IUCN meeting took place in Bangkok, Thailand. Its purpose was to debate 114 motions on the future direction of IUCN. Among these motions was the question of GMOs, in particular whether the IUCN should encourage a halt on genetically modified organisms, or help establish a sound body of knowledge on their environmental risks and impacts. Delegates from both governments and the NGO sectors voted for a halt by a wide margin.[25]

23 World Bank 2004. Operational Policy OP4.36, "Forests", November 2002 (revised August 2004), para.2.

24 Lang, *op.cit.*

25 As reported in African Conservation Forest: http://www.africanconservation.org/dcforum/DCForumID35/20.html (accessed 2 December 2004).

3 ARGUMENTS FOR AND AGAINST GM TREES

In this section we briefly explore and consider five clusters of arguments for and against research on GM trees, namely scientific/environmental, legal, economic, social and ethical.

3.1 SCIENTIFIC AND ENVIRONMENTAL ARGUMENTS

Most debate on GMOs to date has focused on crops. Yet trees are different from annual crops, and forests are very different ecological entities to farmers' fields. There are genetic modification issues that are specific to forestry. Genetic modification could bring many advantages, but there are many long and short term uncertainties on the risks to the environment of using GM trees, as well as on the potential benefits. For example, use of GM trees could enable the percentage of land used to produce a given volume of timber to decrease, with the percentage of cut natural forest also decreasing. However, the risks of GM trees may in many respects be more serious than those of GM crops. Trees live longer than agricultural crops, which means that changes in their metabolism might occur many years after they are planted. At the same time, trees are different from crops in that they are largely undomesticated, and scientists' knowledge about forest ecosystems is poor compared to their knowledge of agricultural ecosystems. The ecological and other potential risks associated with GM trees could be greater than those of GM crops.

Application of GM technology to trees

Lignin is an important component of the cell wall of woody species. It gives trees strength and a defence mechanism. In nature, a great variety in lignin content exists between trees, sometimes within the same species. For the paper and pulp industries, lignin is undesirable. Removing the lignin is an expensive and polluting process. Modifying the lignin content of trees by genetic modification changes the composition and processing properties of the wood. These properties reduce the energy inputs to, and the pollutants released by, the pulping industry, which is an environmental as well as an economic benefit. At the same time the use of bleaching chemicals can be reduced resulting in an environmental benefit. But environmental benefits must be seen in the context of the whole production cycle. First, when the amount of lignin in trees decreases, the resistance of trees to attack by disease might also decrease. Second, the strength of the wood decreases, so that the forests may become less resistant to wind stress. Third, when wood has a lower lignin content it may decay faster, which could have an effect on soil composition and biology. Finally, the genes of trees with lowered lignin content may cross with wild species.[26] This could over the long term result in an overall reduced lignin content throughout the gene pool, resulting in weaker trees that are increasingly unable to cope with natural stresses. However there is no scientific evidence that these varieties are more or less vulnerable to wind or insect attacks, hence at present no firm conclusions can be drawn.

One claimed advantage to using GM trees is that faster growth can result in higher carbon sequestration, and thus help fight global warming. The United Nations Framework Convention on Climate Change, which oversees the Kyoto Protocol, has agreed that genetically engineered trees could be used in industrial tree plantations to take up carbon emissions. However, arguments for the use of GM tree plantations to sequester carbon have been heavily discounted by environmental groups.[27]

An increased growth rate is one goal of forest biotechnology. There are several methods for this, but the most reliable results so far have been obtained by introducing plant sterility. Part of the plant’s energy that goes into producing flowers and fruits can be redirected towards tree growth. Field trials to date have shown that GM plantations can lead to increased yields, which can allow for more wild forest to be left undisturbed.[28] In the short term this has a positive environmental effect, because less land is used to grow the same amount of timber. However water and nutrient use increases, which may have a degrading effect on the land. Again the risk of GM species invading natural forests exists (unless, of course, the GM species are sterile).

The use of GMOs to create insect resistant crops has already been successful. The crops have been genetically modified to contain the *Bt* (*Bacillus thuringiensis)* insecticide. *Bt* is a bacterium that produces insecticidal chemicals. This bacterium has been used in field trials with pine, spruce, walnut and apple. The use of *Bt* has several advantages. *Bt* insecticide could reduce the use of pesticides. *Bt* insecticide decomposes quickly in sunlight, so it does not pollute water or soil. The bacterial toxins are said to be species specific and could therefore be safe for non-target species (although this is disputed). However, insects could become resistant to *Bt* through selection pressures, in a not dissimilar way that weeds can become resistant to herbicide pressures.[29] Finally, and once again, undesirable side effects could result if the genes were to spread in the natural environment, especially into water.

An economic problem with the production of wood is that it comes in different sizes and shapes. Plantations, including GM plantations, can ameliorate wood uniformity. Tree height, diameter and the number of branches can all be influenced by forestry interventions. But such interventions are expensive. The use of GM to produce trees that grow more uniformly, perhaps through cloning, would eliminate the need for such interventions, which would be of huge commercial benefit. However, and as with non-GM plantations, the structure of the forest would be simplified, and would be somewhat removed from that of a natural ecosystem.[30]

26 Asante Owusu, *op.cit.*

27 World Rainforest Movement: http://www.wrm.org.uy/bulletin/85/China.html (accessed 9 November 2004).

28 *Ibid.* and Hu, W.J., Harding, S.A., Lung, J., Popko, J.L., Ralph, J., Stokke, D.D., Tsai, C.J. and Chiang, V.L. 1999. Repression of lignin biosynthesis promotes cellulose accumulation and growth in transgenic trees. Nat. Biotechnol. 17: 808–812.

29 Asante Owusu, *op.cit.*

30 *Ibid.*

Although flowering control is not yet fully understood, the combination of genetic modification and DNA sequence information could speed up breeding considerably. Furthermore, landscape that is damaged by pests, for example, could be restored a lot faster. Trees that are modified to master harsh conditions could, in theory, be used to prevent land degradation and to restore forest cover on degraded land.[31] This technique is already used by selecting varieties that are more tolerant to, for example, heavy metals, and which have a higher metal uptake capacity and associated soil remediation ability.

There are other possible advantages. There is the possibility of producing valuable pharmaceuticals from GM trees. Cleaning up environmental pollution using GM trees has potential. Restoring contaminated land sites reduces risks to the environment and greatly enhances the value of these sites. Considerable progress has been made with both heavy metals and organic pollutants.[32] The use of GM trees might also enable the manipulation of wood-quality traits, improved photosynthetic efficiency and tolerance to abiotic stresses such as drought.[33]

Possible environmental effects

It should be noted that many of the anticipated side effects of GM trees also apply to other activities related to traditional genetic tree improvements that are based not on gene transformation but on clonal forestry. For example, selection for stem growth may result in reduction of wood density due to a negative correlation between these two traits. Similarly artificial selection for insect pest resistance by traditional means (based on quantitative genetics) may generate new selection pressures to the pest and contribute to a faster evolution of the pests.

A considerable environmental risk from the use of GM trees is the potential for long-distance pollen spread. This is compounded by the fact that, compared to GM crops, GM trees are long lived so that pollen spread will continue for decades. There have been attempts to genetically modify trees so that they do not produce pollen. This would protect against pollen transfer into other species and invasiveness into the modified species. But scientists have not been able to guarantee that pollen formation can be prevented in every individual GM tree. This illustrates the problems of scientific uncertainty that surround GM trees: there is no real proof of damage, because it is almost impossible to measure and track the effects of a small amount of genetically modified tree pollen escaping into the wild. Plants, including trees, have been exchanging genetic material for millions of years within and between species on a large scale. Up until now there is no evidence that this has resulted in large scale ecological problems.[34] It can be argued that when the problem of flowering GM trees is detected, it could be avoided by using short rotation forestry with limited flowering potential. When it is necessary to use longer rotation periods, the risk

31 FAO press statement on GM trees. 2003. http://www.fao.org/english/newsroom/ focus/2003/gmo6.htm (accessed 17 November 2004).
32 Gartland K.M.A., Crow, R.M., Fenning, T.M. and Gartland, J.S. 2003. Genetically modified trees: production, properties and potential. Journal of Arboriculture 29(5).
33 From a pulp and paper industry in India report: http://www.ciionline.org/Common/313/paperind.pdf (accessed 5 November 2004).
34 Gartland et al., *op.cit.*

should be kept in mind. It also needs to be noted that pollen flux is only one aspect of gene flux. Seed flux is also important too.

It will be clear from the discussion so far that because trees have a long lifespan there is, relative to crops, increased potential for unexpected and undesirable effects once genetically modified species are released in the natural environment. Furthermore, when a new gene is inserted into the genome of a tree, the side effects, which may be visible only after many years, can be hard to detect and address. Effects like gene silencing could occur, when specific genes are "switched off". The opposite can also happen. Genes that have been silent could suddenly be reactivated. Particularly worrying are stress-activated genes, the effects of which cannot be anticipated until the stress response is triggered.[35] Because trees live longer, the risk that they will be subjected to stressful circumstances could be higher. For example, the chances increase of stresses such as temperature extremes, insect attack or climate change. Overall, the range of stress conditions becomes larger with increasing lifespan, and problems may go undetected for longer.

Changing the genome of a species could decrease the biodiversity of GM forest ecosystems. Making trees sterile, which is an important safeguard for releasing GM material into the environment, could have a negative effect on biodiversity. Trees with no reproductive features might result in reduced diversity of the birds and insects that feed on them.

3.2 LEGAL ARGUMENTS

There are three categories of use of GMOs: contained testing in closed laboratories; field trials, and general release onto the market. With respect to the third category, GMOs released onto the market, there is a difference between GMOs used in industrial products and GMOs used in food or feed.

These three categories of use can have very different effects and have attracted different legislative approaches. Providing that the proper safeguards are in place, contained testing is likely to be safe, although it raises ethical questions. The natural environment might be at risk with field trials, and increasingly so with commercial crops. When used as food products, human health might be affected, although it can be argued that the risks must be regarded as very small. This is just a very brief explanation of the different levels of effects, each of which is subject to different legislation.

European Legislation on GMOs

The first piece of legislation on the release of GMOs is the 1998 European Commission moratorium on the sale of genetically modified food and the use of genetically modified crops.[36] As the EU moratorium applies to "crops" it could be interpreted to refer to tree

35 Asante Owusu, *op.cit.*
36 European Parliament Newsroom online: http://www.elections2004.eu.int/highlights/en/709.html (accessed 4 November 2004).

plantation. Such an interpretation would restrict the use of GM trees in plantations established by pulp producers based in EU member states.

Following the introduction of the moratorium no new GM crops were authorised for planting or use in the EU. The moratorium blocked the import of all kinds of GM agricultural crops, primarily from US sources, and has been opposed by large biotech seed producers. These producers have been backed by the US government, which argues that the moratorium on GM products is a non-tariff trade barrier intended to protect national markets from outside competition, and is thus illegal under the terms of the World Trade Organisation (WTO). The response of the EU has been that the moratorium was introduced to prevent the release of GM material into the environment without prior scientific assessment of the risks to humans and environmental health. In 2003 the US government filed a formal complaint at the WTO, arguing for an end to the moratorium. (Appendix 2).

On a technical point: some sources argue that the EU ban should not be called a moratorium, presumably because of the legal significance of this term within the WTO (Appendix 2).[37] However it should be noted that official European Union sources cited in this section use the term. Other sources prefer to call the ban a "de facto moratorium".[38]

The EU moratorium no longer applies to all GM species. In November 2003 new EU legislation was agreed for products containing GMOs to be clearly labelled to that effect. If implemented, consumers would be able to judge for themselves whether or not to use such products. This legislation has created a political climate in which the moratorium could be dropped, given that many of the EU's "moratorium states", including Denmark, France, Germany, Greece and Italy, have indicated that they will not agree to a lifting of the moratorium until there is legislation on the traceability and labelling of GMOs.[39] Also in 2003 an EU amendment was passed allowing any member state to pass legislation to protect conventional non GM-crops and organic crops from contamination by introducing restrictions on the growing of GM crops.[40] Regions to have declared themselves "GMO-free zones" under the labelling law include upper Austria, Salzburg, Wales and the Basque country.[41]

After the labelling law was passed, the European Commission began approving the use of GM crop food varieties on a case by case basis. A recent example is the Commission's approval of Monsanto's NK603 maize for use in food for a ten-year period from October 2004. It should be stressed that this law allows NK603 to be imported into the EU, and not commercially grown inside the EU.[42]

It is not clear whether EU legislation allows the importing into the EU of forest products from GM sources, although the legislation that allows the importation of GM maize makes it more likely. However, this also depends on the outcome of the current deliberations on the moratorium at the WTO.

37 European External Trade website: http://europa.eu.int/comm/trade/goods/agri/pr170603_en.htm (accessed 6 November 2004).
38 For example: "The scientist online": http://www.biomedcentral.com/news/20031211/03/ (accessed 13 November 2004).
39 "The EU's moratorium on GMOs": http://www.foeeurope.org/GMOs/Moratorium.htm (accessed 5 January 2005).
40 European Parliament Newsroom online: http://www.elections2004.eu.int/highlights/en/709.html (accessed 4 November 2004).
41 For a map of regions that are "GM free zones" see the Friends of the Earth website, http://www.foeeurope.org/GMOs/gmofree/ (accessed 8 November 2004).
42 The Sacramento Bee online news: http://www.sacbee.com/24hour/business/story/1769942p-9619173c.html (accessed 5 November 2004).

Current status of possibilities in EU member countries

A number of EU countries have carried out field trials involving the deliberate release of GMOs into the environment, including Belgium, Finland, France, Germany, Italy, Netherlands, Spain, Sweden, and the UK.[43]

By 29 September 2004, 27 products containing GMOs had been approved for sale throughout the EU.[44] The products include cotton for clothes, maize for animal feed and colorants for foodstuffs. The EU countries in which these products have been marketed are the Belgium, Denmark, France, Germany, Netherlands, Spain, Sweden and the UK. These are all countries in which field trials have been carried out.

Since the start of debate on GMOs in the WTO, the European Commission has approved the use of several GM varieties of food products, but it has not lifted the moratorium altogether. Opponents to the labeling law argue that it is a non-tariff trade barrier that makes competition unfair, since labeling and tracking costs make GM products more expensive (by approximately 12% to similar products that do not contain GMOs). Opponents also argue that for the EU to approve products that contain GMOs, thus implying that they are safe, and then to insist that these products be labeled, sends out mixed signals and causes confusion among consumers.[45]

The Cartagena Protocol[46]

The Cartagena Protocol on Biosafety was agreed in 2000 under the auspices of the Convention on Biological Diversity.[47] The protocol, which has been used by the EU as a guideline for European legislation, deals with *living* genetically modified organisms (or LMOs). It has applicability, therefore, to GM trees, but not to products from GM trees that have been felled. Timber from GM trees would not, therefore, be covered by the protocol. The main objective of the protocol is “to contribute to ensuring an adequate level of protection in the field of the safe transfer, handling and use of living modified organisms resulting from modern biotechnology that may have adverse effects on the conservation and sustainable use of biological diversity, taking also into account risks to human health, and specifically focusing on transboundary movements.”[48] There are two guiding principles to the Cartagena Protocol, the precautionary principle and the “right to know” principle.

The precautionary principle was included in the Rio Declaration on Environment and Development, which states that “In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation”.[49] As there are strong reasons to believe that the environmental effects that

43 “Biotechnology & GMOs”: http://gmoinfo.jrc.it/gmp_browse_geninf.asp (accessed 8 November 2004).
44 *Ibid.*
45 Food Navigator, http://www.foodnavigator.com/news/news-ng.asp?id=40992-eu-gmo-labelling (accessed 18 November 2004).
46 This section draws from material published in MacKenzie, R. et al. 2003. An explanatory guide to the Cartagena Protocol on Biosafety. IUCN Environmental Policy and Law Paper 46.
47 A protocol is a separate instrument that is individually negotiated, signed and ratified.
48 Cartagena Protocol on Biosafety, article 1.
49 Rio Declaration on Environment and Development, June 1992, principle 15.

result from the release of living modified organisms can lead to irreversible damage, prevention can be seen as the best strategy.

The right to know principle can be found in articles 7 and 8 of the protocol on the advanced informed agreement (AIA) procedure. This requires that living modified organisms that have been identified as likely to have “adverse effects on the conservation and sustainable use of biological diversity” are handled and transferred after advance written notification that states that the product is a GM variety.

Both principles are reflected in EU legislation. The EU has adopted the precautionary approach for a broad range of environmental problems, including GM organisms, while the labelling law reflects the right to know principle.

The protocol contains further obligations to member countries, such as the obligation to create competent national authorities that monitor movements of LMOs, as well as the guidelines and rules that national legislation should contain. Where there are unintentional transboundary movements of LMOs states are obliged to notify the governments of other states that are potentially affected, as well as the Biosafety Clearing House.[50]

While the Cartagena Protocol applies to GM trees, its precise meaning is open to different interpretations. For example, according to a strong interpretation of the precautionary approach, GM technology, including GM trees, can be seen as a violation of international law. However a weaker interpretation is that the development of GM trees is permissible, although care should be exercised until scientists have fully assessed the possible adverse effects. This then leads onto a contradiction in the precautionary approach: how can scientists fully assess the risks of GM technology unless they are permitted to carry out research, including controlled field trials? While contained laboratory research would prevent the spread of genes into the natural environment, it does not allow the measurement of all effects. Only field trials will permit this.

3.3 ECONOMIC ARGUMENTS

The industrial forestry sector mainly focuses on the production of wood. Due to an increasing global population future demand for wood is predicted to increase at a time when the forestry sector will experience uncertainties such as competing demands for land use. In such circumstances the genetic modification of trees will, it is claimed, enable the industrial forestry sector to meet future demands for wood while simultaneously reducing the pressures on forests.[51]

Economic benefits

Industrial forestry increasingly resembles industrial agriculture, with trees managed by regular human interventions and harvested periodically. Forestry is now adopting innovations, such as genetic modification, that have been previously used in agriculture.

50 Cartagena Protocol on Biosafety, article 17.
51 Lucier, A.A. Hinchee, M. McCullough, R.B. 2004. Biotechnology and the Forest Products Industry. In Strauss, S.H. and H.D. Bradshaw (eds.) 2004. *op.cit.* Pp.12–22.

Table 1. Possible financial gains from innovations in GM trees

Additional Innovation	Benefits	Operating Costs
Clone superior pine	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 fibre characteristic	Reduce digester cost potential savings of $10 per m^3	None
Reduced amount of juvenile wood	Increase value $15 per m^3 (more useable wood)	None
Reduce lignin	Reduce pulping costs potential of $15 per m^3	None

Source: Context Consulting

As a result the potential economic benefits of GM trees have been understood to be comparable to those in GM agriculture. The introduction of GM trees has the potential to produce great economic benefits. It is argued that the introduction of GM trees will reduce production costs and increase the availability to consumers of wood products at more competitive prices.[52]

The improvements generated by GM technology can take many forms. The particular ways in which GM technology will be applied to trees will depend on the type of wood that is wanted by industry and consumers. Possible financial gains may be realised through production-cost savings and increased wood quality and volume (Table 1). It should be noted that most genetic traits are controlled by several genes, and not by individual genes acting alone, as Table 1 could be read as suggesting.

Economic disadvantages

While there are advantages, GM trees may also entail economic disadvantages. One disadvantage compared to traditional forestry arises from the technology itself. The production and commercialization of GM trees involves the development of the transgene, and its introduction into tree cells. Because this is an expensive and highly specialized process, if the use of GM trees becomes popular and widespread the forestry sector itself is likely to become increasingly dependent on biotechnology companies and GM seed companies. Furthermore, the patents involved in scientific discoveries can raise the seed price and make GM trees expensive. This phenomenon has already taken place in the agricultural sector, and has resulted in many small farmers going out of business due to the extra costs involved, including paying annual royalties to GM companies for seeds.

52 Sedjo, R.A. 2004a. Biotechnology and the Global Wood Supply, in *ibid.* Pp. 23–35. See also Sedjo, R.A. 2004b. Genetically Engineered Trees: Promise and Concerns, Washington DC: Resources for the Future.

The second potential economic disadvantage is that substantial economic costs could result from environmental risks. The use of GM trees could, over the long term, seriously damage the forestry sector itself due to genetic contamination that results in weaker forests that are increasingly unable to fend off natural stresses, such as attacks from pests that have become resistant to the insecticides produced by GM trees (section 3.1 above). Where the introduction of GM trees might result in only slight environmental degradation the forestry sector would incur the time and expense of restoring its resource base. Where the environmental degradation is severe, restoration will not be possible. The costs incurred thus depend on the magnitude of the risks. The problem is that these risks are difficult to assess and quantify.

The third potential economic disadvantage relates to market dependency. If consumers have a low acceptance of GM trees this will result in low demand that will eventually lead to higher costs per unit. The increasing demand from consumers in Europe for timber that is certified and labeled as sustainable or well-managed indicates growing consumer intolerance of environmental risks, which suggests that large scale development of GM trees may not be profitable.

3.4 SOCIAL ARGUMENTS

The social consequences of GM trees are those that affect the welfare, status and positions of different groups in society. Like other new social developments, the introduction of new technology generates its own winners and losers in society. In the previous section we noted that the winners from the use of GM technology in the agricultural sector include large GM and seed corporations, while the losers include many small farmers.

One of the social arguments against the introduction of GM maize runs as follows. GM varieties are often made sterile, ostensibly to prevent spread to the natural environment. But sterility requires that farmers need to purchase new seed each crop cycle, rather than gathering seeds from the previous crop, and the new seeds are more expensive than previously, because they include an additional element, namely royalties to the companies that developed the GM species. The net result is a revenue flow from poor Southern farmers to rich Northern corporations, with many small agricultural producers going out of business. Should the social consequences of introducing GM trees parallel those of GM maize, then many small scale foresters could be forced into insolvency while, again, Northern biotech companies gain financially.

It seems probable that if GM tree plantations are going to be established for commercial use, this will be most likely to happen in Asia and Latin America.[53] Furthermore, “there is a clear North-South division concerning the nature of the trials and the type of institutions involved. In North America and the European Union research is typically under the auspices of government and academia while in the countries of Latin America, Africa and South-east Asia, research is being driven by the private sector.”[54] Already field trials,

53 San Francisco State University: http://online.sfsu.edu/~rone/GEessays/GMtrees.html (accessed 21 November 2004), and Nativeforest: http://www.nativeforest.org/pdf/GM_TREE_REPORT.PDF (accessed 21 November 2004).

54 Thomas, S. 2001. Ethical and social considerations in commercial uses of food and fiber crops. In Strauss, S.H. and Bradshaw, H.D. (eds.). Proceedings of the first international symposium on ecological and societal aspects of transgenic plantations. Pp. 92–98.

including those by Monsanto, Fletcher Challenge Forests, and International Paper, are on a scale that is almost appropriate for economic exploitation. The field trials have been carried out in countries such as Brazil, China and Indonesia. Consequently the possible ecological risks will be borne by the inhabitants of these countries, and not by the countries whose industries are developing the technology. The result is likely to be a social inequality, both in the division of risk, which will fall mainly on developing countries, and in the division of the financial benefits, which will accrue primarily to the developed world.[55]

There are other effects that will potentially damage the natural environments and livelihoods of people in the South. Large conventional (non-GM) tree plantations in the South are known to have had damaging effects on the local environment due to the large inputs of water, fertiliser and pesticides that are needed for successful production. It is to the advantage of the forest industry to use GM species with faster growth rates, but this too would require increased inputs, leading to further negative effects on surrounding environment and livelihoods, such as reduced water availability for local agriculture. Conventional plantations may leave local inhabitants with no other choice than to over-exploit adjacent lands or forests, leading to soil erosion and forest destruction.[56] Similar social consequences can be expected if large-scale GM tree plantations are introduced in the South.

If GM trees have the economic advantages over natural trees that are projected, then GM plantations will outcompete conventional plantations. This will leave local populations with little choice other than to become further dependent on foreign companies. The technology and the capital needed to set up such plantations would likely be out of the reach of most local small scale forest producers, many of which would be likely to go bankrupt. As Jason Ford has argued GM trees "are merely the latest symbol of a much greater problem: a system based in global trade liberalization where short term profits are valued above all else."[57]

Even if the social effects posited above do not occur, they are causing anxiety among large groups in society. When GM technology is introduced into a local environment people are put into a situation that they do not desire. There is no possibility of excluding oneself from the risks of GM products simply by choosing not to consume them. And with field trials the natural environment, and to a large degree society itself, becomes a testing laboratory. The fact that the long term effects are not yet known is an added source of uncertainty and fear.[58]

3.5 ETHICAL ARGUMENTS

Ethics is an area of study that addresses controversial and socially sensitive issues and their normative dimensions. It asks questions such as what should people do and not do, what is

55 *Ibid.*

56 Petermann, A. Effects of GE tree plantations on indigenous people. In: From native forests to Franken-trees; the threat of genetically engineered trees. Action report for social & ecological justice (year of publication unknown).

57 Ford, J. "The perfect neo-liberal tree: GE, free trade, & industrial forestry in the global south": http://www.gene-watch.org/genewatch/articles/14-2neoliberal.html (accessed 13 December 2004).

58 "The politics of GM food: risk, science & public trust", ESRC Global Environmental Change Programme: http://www.sussex.ac.uk/Units/gec/gecko/gm-brief.htm (accessed 25 November 2004).

right and just, and what policy should be adopted from a moral standpoint. Ethical principles provide standards for the evaluation of policies and practices. The application of GM technologies on trees is a highly controversial issue in many European countries and other parts of the world. This section provides a brief overview of the ethical considerations of implementing genetically modified crops, particularly GM trees. These considerations are broken down into three categories: religious and metaphysical concerns, social and political ethics, and professional ethics.[59] The boundaries between these categories are not always clear, and consequently there is some overlap between them.

Religious and metaphysical concerns

The first issue that can be addressed in the subject of ethics in genetic modification is whether this whole area of science and technology crosses some sort of moral boundary or enters a prohibited area. Is it morally right for genes to be taken from one species and spliced into another, thus creating new species that did not evolve through natural selection? A related concern of the public is the "unnaturalness" of trees that are genetically modified. GM trees are the result not of evolution, or even of cross breeding of species, but of technology, which gives a whole new dimension to nature and how it is perceived and experienced by the public.

Some religious organizations have explicitly argued for a ban on GMOs. An example is the Religious Campaign for Forest Conservation (RCFC), which has support from several churches and Jewish groups in the US.[60] The position of the Vatican on GM foods is harder to judge. In a speech on World Food Day 2004, Pope John Paul II said "to reach the goal of adequate food security, a proper management of biological diversity is essential in order to guarantee the survival of the different animal and plant species. This effort demands ethical and not merely technical and scientific considerations, although the latter are indispensable to assure the preservation of these resources and their use in accordance with the practical needs of the world population."[61] A later passage in the same speech can be interpreted as a veiled statement against GM foods: "The mandate that the Creator gave to human beings to have dominion over the earth and to use its fruits (cf Gn 1: 28) considered in the light of the virtue of solidarity, entails respect for the plan of creation through human action *that does not imply challenging nature and its laws, even in order to reach ever new horizons*, but on the contrary, preserves resources, guaranteeing their continuity and availability to the generations to come" (emphasis added).[62]

Social and political ethics

In the public debate on GM trees, four main groups of actor are involved: environmental NGOs, consumers, the private sector and scientists. According to one observer "NGOs are

59 Thompson, P.B. 2001. The ethics of molecular silviculture. In Strauss, S.H. and Bradshaw, H.D. (eds.) 2001. *op.cit.* Pp. 85–91.
60 Religious Campaign for Forest Conservation: http://www.creationethics.org (accessed 6 January 2005).
61 Message of John Paul II to Mr Jacques Diouf on the Occasion of World Food Day 2004: http://www.fao.org/wfd/holysee_2—4_en.htm (accessed 6 January 2005).
62 *Ibid.*

actively campaigning against the introduction of GM crops because of their potential harm to the environment. They act by capturing public sympathy and focus on the negative effects of GMOs". [63] Consumers are informed, and to a degree influenced, by media coverage of GM, much of it negative. The public has the power to influence the industry by ignoring their products or by demanding a ban on these products. Multinational companies play a significant role in the debate. They are agents for the development of new technology and often have allies in government. In the UK and the US government regulatory agencies on GMOs have often included representation from businesses.[64] This in itself raises an ethical issue: should the regulated also be the regulators? In other countries, such as Sweden, regulatory bodies have included NGOs.

There are also concerns over issues relating to the ownership of and access to biotechnology. In particular, is it legitimate for particular social groups and actors to "own" species through patents, and then to charge other groups and actors royalties for access to these species? Whereas the seeds of nature can be seen as a common or public good, the seeds of crops, plants and trees produced using GM technology, as well as conventional tree-breeding techniques, have been appropriated by patent holders. This amounts to a form of privatisation of nature, with local communities being the losers and major corporations the beneficiaries.[65]

Another ethical question is whether the (unknown) risks of GM species are justifiable given the promises of such species. GM species promise to substantially reduce hunger and improve nutrition in the South, and to improve wood production, thus relieving pressure on the world's remaining natural forests. Should the risks be accepted? Critics respond that GM species will benefit primarily the producers and patent holders, rather than consumers and other social actors. Genetic modification and the associated patent rights are tools for increasing the control that a few corporations exercise over world crop production. Furthermore, it is argued that no risk of harm can possibly be justified when the costs will fall on future generations.

Professional ethics

All scientific disciplines, including life science, uphold the ideal of scientific objectivity. Scientific objectivity is crucial to the credibility of scientific disciplines and, irrespective of whom scientists work for, it is important that the objectivity and credibility of science is not undermined. To ensure this, independent ethical boards may be established to provide the rules of conduct for handling controversial issues, such as genetic modification. This is important as many people rely on scientists for impartial advice, on GM and other issues.

A serious dilemma is that genetic risks cannot be scientifically judged if GM trees are not first produced and tested under realistic conditions. To be able to act as an objective and credible scientist, data from field trials must be produced and openly scrutinized, which implicitly accepts a priori the risk of the trial itself. Hence restrictions based on a

63 Thomas, S. 2001. Ethical and social considerations in commercial uses of food and fiber crops. In Strauss, S.H. and Bradshaw, H.D. (eds.) 2001. *op.cit*, Pp. 92–98.
64 See, for example, George Monbiot 2001. Captive State: The Corporate Takeover of Britain, London: Macmillan. Pp.225–251.
65 Vandana Shiva. 2001. Protect or Plunder? Understanding Intellectual Property Rights, London: Zed Books.

continuous application of the precautionary principle may preclude a final risk assessment needed for the required judgement.

The ethical problem, which does not apply solely to GM trees but to other areas of applied science too, arises because scientists do not owe allegiance solely to their profession. They are also socially positioned actors with allegiance to an employer, such as the public sector, a NGO or a corporation. Most scientists with expertise in GMOs are employed by research institutes and industrial corporations. These scientists, it can be argued, have a vested interest in emphasising the benefits of biotechnology, and in minimising the associated risks. While the work of scientists may, epistemologically, be value free and neutral, many scientists, it can be claimed, are located within social structures that are inherently biased in favour of GM technology. A professional ethical dilemma may exist if an individual scientist is paid to carry out work for a GM corporation that he or she believes may have unacceptable environmental implications. Another example of an ethical dilemma may exist if a scientist is publicly asked a question to which an honest answer may be detrimental to his or her employer.

3.6 SUMMARY OF SECTIONS 3.1 TO 3.5

Scientific

There are possible advantages to GM trees. Trees that are subject to a particular threat in a particular location, such as from insects, can be genetically engineered to resist the threat. The improved wood production that may result from GM trees could reduce the demand to convert remaining natural forest to production forest. Creating trees with a uniform shape would reduce economic costs. Reducing lignin content can reduce the use of pollutants and energy used for production. However, there are some worrying environmental arguments against GM trees. The spread of modified genes in the wild is a severe risk given the long distance pollen spread of trees. The long lifespan of trees could lead to long term unexpected adverse effects, such as altered resistance to attack from pests. Negative effects on forest biodiversity are likely, but at this stage difficult to judge.

Legal

The main international legal instrument is the Cartagena Protocol on Biosafety, although its practical relevance is somewhat unclear. The Cartagena Protocol is founded upon the precautionary principle, a strict interpretation of which could rule out all GM tree projects. A weaker interpretation would allow for GM tree projects, although with precaution being exercised until all possible adverse effects have been fully assessed. Within the EU permission has been granted for individual research projects and GM crop varieties for commercial sale, although for most species a moratorium on the growth or import of new GM crops has been in force since 1998. The WTO is likely to play an important role in the debate on whether countries can legitimately ban the import of GM crops, or whether a ban would constitute a trade restraint. There have been research projects on GM varieties of trees in several countries, including Finland. Any new GM research project proposals must include a risk analysis, and must be authorised by the EU.

Economic

GM trees could reduce forestry's production costs and increase availability to consumers of wood products. Reduced costs would result from increased productivity, and would lead to more competitive prices. The benefits of GM trees could be a 20% yield increase over 20 years, improved lumber strength, reduction of herbicide and weeding costs, increased value of wood by the reduction of juvenile wood, and reduced lignin levels leading to reduced production costs for the pulp and paper industry. The economic disadvantages are the management of uncertain environmental risks and the increased dependency of the forestry sector on the biotech sector as a result of the increased costs due to patents. Long term tree breeding could lead to the possible reversal of GM induced characteristics, resulting in the loss of the associated economic benefits.

Social

In the past GM varieties of commercial crops have increased the gap between rich and poor, in particular between seed producing companies and poor southern farmers. Pulp tree plantations in the South have tended to overuse available land and water resources, and to pollute the surrounding environment with fertiliser and pesticides. GM tree plantations can be expected to place even greater demands on the environment, since GM varieties are engineered for faster growth. Small forest enterprises using GM trees may struggle to remain solvent. Local agriculture will suffer because of the decreased availability of high quality soils and water. Other effects on local welfare include the hiring of local people only for simple and poorly paid jobs.

Ethical

While GM trees are certainly technically possible, the key question is whether they are socially and ethically justifiable. Does this whole area of science cross an ethical boundary? Should humans be interfering with nature? There is public unease at the "unnaturalness" of GM trees, and on the question of private actors being able to "own" life through patents. However any ethical discussion of this subject must consider the complex question of whether the risks of GMOs are justifiable given the possibility that they may contribute to solving some significant global problems. The role of scientists in answering these ethical questions is especially important, yet scientists themselves may face an ethical dilemma, with loyalties both to their profession and to their employers.

4 CONCLUDING REMARKS AND POLICY OPTIONS

From the preceding discussion it will be clear that no obvious and unambiguous policy emerges that forest research organisations can adopt on GM trees. There are considerable economic and environmental benefits to GM trees, but also potentially serious economic and environmental disadvantages. The anticipated social effects of introducing GM trees are overwhelmingly negative. The legal situation on GM trees is unclear. The whole question of introducing GM trees raises serious ethical questions to which there are no obvious answers.

Below eight main policy options are presented for consideration by forest research organisations engaged in, or considering becoming engaged in, research on genetically modified trees. The options range from full support for GM trees to total opposition.

1. As any written statement will inevitably be controversial due to the nature of the subject, the "policy" should be to issue no public policy statement at all on GM trees. The organisation will support research and projects on GM trees that meet its internal project evaluation standards. (Organisations that adopt this option may find it advisable to develop a list of internal criteria by which GM projects are assessed and evaluated.)
2. Research into GM trees is actively endorsed, with no internal limitations to the organisation's interest in GM trees, or the projects it will fund in this area. The organisation will seek to position itself as a market leader in GM technology. Based on the assumption that there are no significant risks to GM trees, the organisation will not engage in the monitoring of their long term effects.
3. Research into GM trees is actively endorsed. The organisation should seek to position itself as a market leader in GM technology. However, given that the risks to GM trees are uncertain the organisation may impose some internal limitations to its interest in GM trees, and the projects it will fund in this area.
4. Research into GM trees is endorsed, with some internal limitations. As well seeking to attain a leadership role in the development of the technology, the organisation also seeks a leadership role in the monitoring of the long term effects of GM trees, perhaps through helping to establish a major pan-European data base on the long term effects of GM trees.
5. The organisation does not actively endorse research on GM trees and does not seek a leadership role in this area. However its policy is to support GM research if risk analysis indicates the research is safe enough. The organisation is prepared to support both closed laboratory research and carefully controlled field trials.
6. The organisation does not actively endorse research on GM trees. However it supports on a selective and occasional basis closed laboratory research if risk analysis indicates the research is safe enough. Due to the irreversible risks from spreading genes in the natural environment the organisation refuses to support field trials, at least until the risks of GM trees have been more thoroughly assessed.

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7. Due to the uncertain risks and the possibility of serious long-term irreversible damage to the environment the organisation does not support any GM research or related activities, including laboratory work. However the organisation does not adopt an advocacy position, that is, it does not seek to influence other actors.
8. The organisation is firmly opposed to any involvement on GM trees. It adopts the role of a policy advocate against research in this area, using its position as a policy actor to influence other actors, possibly pressing for a European-wide ban on GM trees.

The policy choice that forest research organisations make in this important area of research cannot be a purely scientific one, given the many scientific uncertainties that surround this area. Neither can the choice be a purely legal one, due to the different interpretations that can be drawn from the current body of international law. While there are strong ethical arguments against GM trees, there is also an ethical argument, albeit one that is currently not well developed, in favour of GM trees. The economic and social cases are not clear, either for or against.

Policy selection will involve assessing the merits of these different sets of arguments. Whichever policy is chosen will, inevitably, be the result of some arguments being considered as more important or persuasive than others. As a general rule, those policy options inclined towards *support* for GM trees will tend to be supported by the following arguments:

- the various risks are negligible and manageable
- the benefits to society as a whole are tangible and are likely to be significant
- a weak interpretation of the precautionary principle should apply
- the ethical case against GM trees is not convincing, indeed there are some ethical reasons why we should research GM trees

Those options inclined towards *opposition* to GM trees will tend to emphasise the following arguments:

- the various risks are significant and are likely to prove unmanageable and irreversible
- the benefits to society have yet to be demonstrated. Those benefits that do materialise will accrue only to some actors rather than to society as a whole, and are likely to be short lived.
- a strong interpretation of the precautionary principle should apply
- the ethical case against GM trees is overwhelming

The weight given to the various arguments may also depend on the research context and organisation type (e.g. private/governmental/NGO). Moreover, the environments within which GM trees are implanted may vary, from industrial plantation forests to trees planted in semi-natural forests. A research organisation will, presumably, wish to take into account all these factors when selecting its GM policy.

APPENDIX 1. GENETICALLY MODIFIED TREES GROWN IN FIELD TRIALS

The information in this appendix is taken from a 2004 source[66] and makes no claims to exhaustiveness or completeness. Other tree species have been genetically modified and grown in laboratories and greenhouses, but comprehensive information is not available.[67]

Common name	Species	GM trait
Silver birch	*Betula pendula*	Marker genes
American chestnut	*Castanea dentata*	Blight resistance
European sweet chestnut	*Castanea sativas*	Herbicide tolerance (glyphosate)
Eucalyptus/Red River Gum	*Eucalyptus camuldensis*	Marker genes Herbicide tolerance (glyphosate) Insect resistance (*Bt* toxin)
Rose gum/Flooded gum	*Eucalyptus grandis*	Marker genes Herbicide tolerance (glyphosate)
Tasmanian blue gum	*Eucalyptus globulus*	Marker genes
Swetgum	*Liquidambar spp*	Herbicide tolerance (2,4-D)
Norway spruce Scots pine	*Picea abies* *Pinus sylvestris*	Insect resistance (*Bt* toxin) Marker genes
Poplars/Aspen/Cottonwood	*Populus spp* Including: *Populus nigra* *Populus* *Tremuloides* *Populus deltoides* *Populus tremulata*	Herbicide tolerance (glufosinate, sulphonyl urea, glyphosate) Insect resistance (*Bt* toxin) Disease resistance Altered lignin content Male sterility Female sterility Increased growth rate Bioremediation Marker genes

66 Data produced in this section is reproduced from OECD Biotrack: http://www.oecd.org//ehs/bioabout.htm; European Union database of releases, http://www.jrc.int: US field trial database, http://www.nbiap.vt.edu/, in Strauss, S.H. and Bradshaw, H.D. (eds.) 2004. *op.cit.* Pp.23–35.

67 A more recent, comprehensive preliminary review of biotechnology applications in forestry was published by FAO, 2004: Preliminary review of biotechonology in forestry, including genetic modification. Forest Genetic Resources Working Paper FGR/59E. Forest Resources Development Service, Forest Resources Division, Rome, Italy, 118 p. (see: http://www.fao.org/newsroom/en/news/2005/104906/index.html)

Common name	Species	GM trait
Apple	*Malus domestica*	Marker genes Improved rooting Disease resistance (scab and blight) Altered flowering time Insect resistance Altered fruit ripening Altered sugar content
Crab apple	*Malus sylvestris*	Insect resistance Fungal disease resistance
Plum/Cherry	*Prunus spp* *Prunus domestica*	Disease resistance Altered morphology Altered ripening Marker gene
Orange	*Citrus spp*	Marker gene
Kiwi	*Actinidia deliciosa*	Fungal disease resistance
Olive	*Olea europea*	Fungal disease resistance
Papaya	*Carica papaya*	Virus resistance Delayed ripening
Walnut	*Juglans spp*	Insect resistance (*Bt* toxin) Improved cutting rootability Disease resistance Altered flowering time

APPENDIX 2. THE DEBATE WITHIN THE WORLD TRADE ORGANISATION

The debate in the WTO has been polarised between the US and the EU. The EU is the biggest importer (and net importer) of agricultural products globally. When the European Commission introduced a full ban on genetically modified agricultural products, it faced opposition from the American agricultural industry, in particular producers of new varieties of seeds such as Monsanto, which argued that the ban was scientifically unfounded. The argument from US corporations is that there is no difference between GM and non-GM varieties. The US government, influenced by its agricultural and biotechnology corporations, has argued at the WTO that GM and non-GM varieties are very similar products that are merely produced in different ways. Hence, according to the US, the ban is discriminatory according to WTO rules; it is a non-tariff barrier that discriminates between similar products on the basis of their manufacture. The US has also argued that there is no evidence that there is any danger in the growing or use of GM products.

Citing the precautionary principle, the EU view is that care should be taken when meddling with DNA. The long-term effects of consuming crop products from GM sources are not known, and effects of growing GM crops might prove to be irreversible. The EU view has taken the position that GM and non-GM varieties are not similar products produced in different ways, as the US claims, but that they are fundamentally different products. Hence, according to the EU, the ban is not discriminatory according to WTO rules.[68]

Since the debate in the WTO has started, the European Commission has approved use of several GM varieties of food products, but not lifted the moratorium altogether.

68 Newell, P. 2002. Biotechnology and the politics of regulation. IDS Working Paper 146, Institute of Development Studies, University of Sussex, Brighton, UK