The Global Status of Genetically Engineered Tree Development

A Growing Threat

cban Canadian Biotechnology Action Network

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Acknowledgments

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This report is available in Spanish, Portuguese, and is forthcoming in Japanese.
stopGEtrees.org/global-status-report

Please share your information about genetically engineered trees with us or comment on the report. Contact: trees@cban.ca

To take action with The Campaign to STOP GE Trees visit stopGEtrees.org or contact action@stopgetrees.org

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Executive Summary

The global release of genetically engineered (GE or genetically modified) trees is closer than it has ever been.

Risks

Using genetically engineered trees in plantations, and even releasing GE trees into the wild, is being proposed despite the serious risks and vast uncertainties.

The processes of genetic engineering often result in unanticipated changes. The potential for unexpected genetic outcomes and environmental effects would increase and multiply over the long life of trees, because of the environmental extremes trees face, and because so many species interact with trees. The ability of trees to spread pollen and seeds over long distances increases the range of potential environmental and social impacts, across borders and in violation of Indigenous sovereignty.

The release of genetically engineered trees would be a threat to forests and forest ecosystems, with impacts on many local communities and Indigenous peoples. The potential negative impacts could be profound and irreversible.

Current status

China planted the first GE tree, an insect-resistant poplar, in 2002, but there is little information about this release. These GE poplars are the only commercially planted GE forest trees in the world. GE tree research is currently concentrated in the US and Brazil, and these countries may be the next to plant GE trees commercially. *There are also two other GE trees – a loblolly pine and eucalyptus – that are legal to be planted, in the US and Brazil, as of 2015, but have not been planted.*

A few key companies and university research teams are now leading the development and promotion of GE trees: Principally, pulp and paper company Suzano and its subsidiary FuturaGene; tree biotechnology company ArborGen; and research centres at the Oregon State University and State University of New York.

Most current GE tree research is focused on eucalyptus, along with pine and poplar, and is driven by the pursuit of more profitable plantations for industrial purposes such as pulp and paper production, timber and biofuel production. The most common traits being genetically engineered into forest trees are herbicide tolerance; cold and drought tolerance; pest and disease resistance; faster growth; and altered wood quality.

Regional summaries

Locations of field tests are one main indication of regions at most immediate threat of GE tree introduction, although very few GE field tests will lead to commercialized products.

LATIN AMERICA

In November 2021, Brazilian company Suzano, through its biotechnology subsidiary company FuturaGene, obtained approval in **Brazil** to plant GE eucalyptus trees that are genetically engineered to be tolerant to the herbicide glyphosate. This follows the earlier 2015 approval of FuturaGene's GE faster-growing eucalyptus tree, which has not been planted commercially. Brazil is the only country in Latin America where field tests of GE plantation trees appear to be currently taking place. However, there is ongoing GE tree research taking place in **Chile**, particularly at the University of Concepción.

AFRICA

There are no field trials of GE forest trees in Africa, and **South Africa** is the only African country where research into GE trees is taking place. Research is taking place at the University of Pretoria, funded by the pulp and paper companies Sappi and Mondi, as well as other timer companies and public institutions.

NORTH AMERICA

The **United States** is home to the most research and field testing of GE trees globally, as well as to two of the most prominent GE tree researchers globally. In 2020, university researchers asked the US to allow the release of a genetically engineered blight-tolerant American chestnut tree into the wild. This decision is pending.

NEW ZEALAND AND AUSTRALIA

There are current, long-term field tests of GE radiata pine in **New Zealand**, run by the government-owned forest research institute called Scion. These tests were approved in 2010 and will run for 25 years. There have been several past GE tree field trials in New Zealand, accompanied by protests. There are no field trials of GE plantation trees in **Australia**.

ASIA

Two varieties of GE insect-resistant poplar trees were widely planted in **China** in the early 2000s, but the planting was not closely monitored. There is a huge amount of laboratory research on various species in China and field tests are likely being conducted, but there is no public information available. **India** and **Malaysia** are both home to current field tests of GE rubber trees. There have been field tests of GE eucalyptus and poplar in **Japan**.

EUROPE

There are current field tests of GE trees – mostly poplar – in **Sweden**, **Finland** and **Belgium**. These field tests are conducted by universities and by the Swedish forest biotechnology company SweTree.

Glyphosate-Tolerant Eucalyptus

Aside from the Chinese release of a GE poplar tree in 2002, a GE herbicide-tolerant eucalyptus in Brazil may soon be the first GE plantation tree to be released commercially. On November 16, 2021, Brazil approved the planting and commercial use of a GE eucalyptus tree that is genetically engineered to survive spraying with the herbicide glyphosate. Use of this GE tree will likely result in increased glyphosate use on eucalyptus plantations that already negatively impact the environment as well as many local communities and Indigenous peoples. This GE tree was developed by the company FuturaGene, a subsidiary of the Brazilian pulp and paper company Suzano, and it follows a 2015 approval in Brazil of Suzano's GE fast-growing eucalyptus tree, which has also not yet been commercially released.

GE American Chestnut

Researchers at the State University of New York College of Environmental Science and Forestry (SUNY-ESF) have genetically engineered an American chestnut tree to be blight-tolerant, and are asking the US government to approve it for unrestricted planting in the wild. The American chestnut is an endangered species but researchers argue that releasing this GE tree will "restore" it to the forests of Eastern US and Canada. If approved, this GE tree would be first-ever GE plant released with the purpose of spreading freely through wild ecosystems. Its release would be a large-scale experiment, and there will be little or no potential to track or reverse its spread.

Living Carbon

The small US venture capital company Living Carbon is experimenting to genetically engineer poplar trees to capture and store more carbon. Field tests started in 2021 but the company is already selling uncertified carbon credits. The company promotes a wide range of intentions and ideas that do not appear to have any substantial research behind them. Living Carbon's GE tree is not proven to work and yet the company has raised $15-million USD from investors hoping to profit from it. Even without a GE tree, Living Carbon is already making money.

While research into GE trees has been accompanied by protest around the world, a few companies and a coalition of GE tree researchers have been actively campaigning for weaker regulation at the national and international levels, and for forest certification programs to allow the use of GE trees. In response, the Forest Stewardship Council has begun a process that could see them directly oversee some GE tree field tests and move them towards allowing certified companies to profit from GE trees. Such decisions by certification schemes could pave the way for the use of GE trees globally.

At the same time, national regulations are changing rapidly around the world. Many governments are removing their oversight over some plants developed with the new genetically engineering techniques of gene editing. These political developments could result in many unrecorded and unregulated field tests, as well as the release of some GE trees without government risk assessments or even notification to governments. This expansion of corporate self-regulation could speed up the introduction of some of the riskiest applications of genetic engineering, such as GE trees.

Introduction

The global release of genetically engineered (GE or genetically modified) trees is closer than it has ever been. This advancement is a significant concern because the release of GE trees would pose serious threats to forests and other ecosystems, as well as to many local communities and Indigenous peoples. The environmental impacts could be irreversible.

This report examines the current global reality of GE trees. It documents the status of GE tree development around the world, in order to identify where the risk of GE tree release is most immediate. It also outlines some of the risks and discusses some of the most prominent proposed uses. Due to changes in national regulations, this report may be the last opportunity to get a snapshot of GE tree field testing around the world.

The information in this report benefits from decades of monitoring and research by groups and movements around the world who oppose the application of genetic engineering to tree species. This opposition – and the analysis in this report - is grounded in commitments to environmental and social justice, which are under direct threat from the introduction of genetically engineered trees.

GE FOREST TREES

This report focuses on the genetic engineering of trees that are used for wood products such as timber and pulp. These GE trees are distinguished from fruit and other food trees because of their unique environmental risks and economic and social-cultural threats. Trees such as poplar, pine, and eucalyptus are larger, longer-lived organisms than most fruit and nut trees in agricultural cultivation. These tree species also have a shorter history of domestication, with more wild relatives.

We use the term **plantation trees** and **forest trees** when referring to these species, even though most are used in large-scale monoculture plantations in regions where they are exotic species (such as the use of eucalyptus in plantations in Brazil). These plantations often replace diverse forests.

> "A forest, in all languages, is not planted. In fact, it is scientifically erroneous to claim otherwise. A plantation can never be a forest, not even a biological or legal category of it. Forests are formed by natural vegetation and a high level of biodiversity. They perform various ecological functions, including as water catchment systems. They shield wildlife, fishes and microorganisms. Plantations are large monoculture farms of crops, disastrous for water catchments, rivers, entire ecosystems and their biodiversity."
>
> — Friends of the Earth Malaysia, 2020[1]

The research and development of genetically engineered trees is focused on a few important tree species around the world. **Most GE plantation tree research focuses on eucalyptus**, which is the second largest plantation species in the world, after pine. A lot of research also uses poplar trees, which serve as a popular model for genetic research that can be applied to other species. Wherever there is commercial use of plantation species, along with research tools such as genome mapping of those species, GE research could follow.

This report includes information on research into GE oil palm because of the intensive use of oil palm in plantations (including for non-food uses such as biofuels), and the role of these plantations in deforestation. It also mentions research into GE bamboo, which is a grass but also an important forest resource with similar uses to plantation trees, including for paper and construction material.

THE STATUS

What? Genetically Engineered Trees

Genetic engineering (also commonly called genetic modification) is a collection of laboratory techniques used to create genetically engineered (genetically modified) organisms, often abbreviated to GMOs. It is sometimes referred to as modern biotechnology, but this is a broad term that also includes non-genetic engineering techniques.

Genetic engineering directly changes the genetic makeup (DNA) of an organism, bypassing normal plant or animal reproduction to create new characteristics. Genetic engineering includes techniques that make changes to DNA by inserting genetic material from the same, similar, or totally unrelated organisms, or, with genome editing (also called gene editing), by introducing genetic material that acts as an "editor" to change DNA.[2]

Genetically engineering trees is technically challenging and is fraught with serious environmental and social risks. It is also hugely controversial and the research has consistently been met with opposition and protests. Despite these major challenges, GE tree development continues.

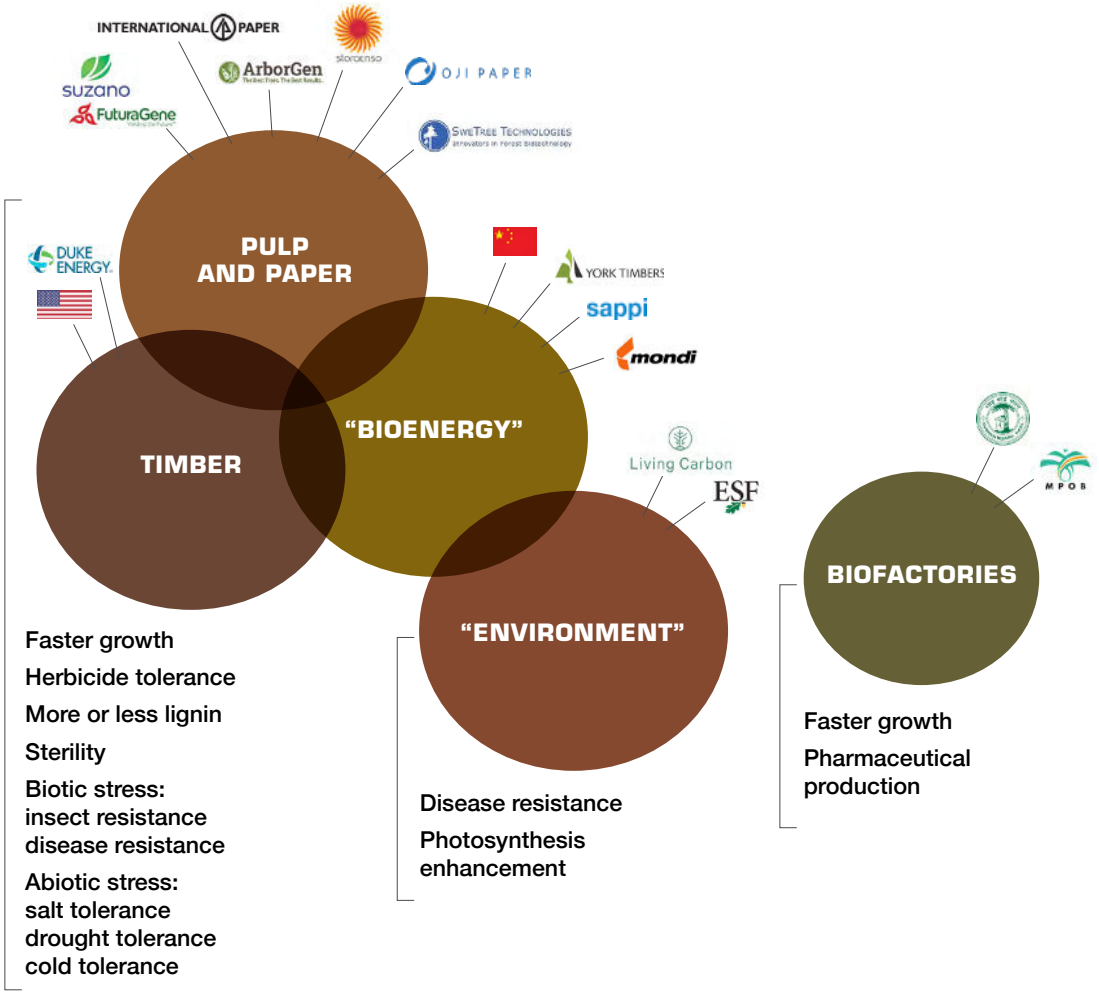
While the development of GE trees is less advanced than that of GE food crops, it is catching up rapidly. A small number of companies have invested in GE tree development and there are a few key researchers working on GE tree projects at universities across the world. There are also some recent technical and political developments that are bringing GE trees closer to commercialisation.

As with most novel, unproven technologies, research into GE trees is accompanied by many promises of benefits. The history of similar promises made for GE agricultural crops warns that promises for GE trees may never be fulfilled. In reality, proposed GE traits may not be possible to create and, if they are planted, may fail over time as insects, weeds and viruses, for example, evolve in response.[3]

The hype over GE trees started with a promise to genetically engineer trees to grow faster, tolerate herbicides, and resist insect pests, in order to make them more profitable for industrial plantations. These commercial purposes are still the focus of research, however, there is rising promotion of the idea that GE trees could be used as climate and conservation solutions. This includes research to genetically engineer trees to be more easily converted into fuel and other materials currently made from petroleum. These are dangerous proposals that not only threaten forests with GE trees but also threaten to expand plantation production and distract from the real change needed to address the global climate and biodiversity crises.

Today, some GE tree projects are closer to reality than others, but experience shows that even commercially-approved GE trees may never come to market. However, at this point in the trajectory of the technology, the commercial planting of one GE tree would set a global precedent that could increase and broaden the commercial interest in GE trees and lead to other GE trees being developed and released. This could mean various genetically engineered tree species being imported and exported for planting in industrial tree plantations in many regions around the world, including in regions that do not currently have large-scale tree plantations.

Why? Purposes/Industrial Sectors



This graphic represents the industrial sectors that are exploring GE trees, for what purposes, and with which GE traits. It also refers to those companies, institutions and universities that are identified in this report as developing GE trees or investing in GE trees.

Most GE tree research is focused on increasing the productivity of plantation trees, for a number of **industrial purposes**. These purposes include the production of pulp, paper, and timber; as well as using trees as "bioenergy" crops - to produce biomass (wood pellets, for example) to burn for electricity and liquid "cellulosic biofuel."[4] There is also some interest in genetically engineering trees to produce other industrial materials such as pharmaceuticals (using trees as "biofactories"). There is also some experimentation with GE trees to sell carbon credits and proposals to release GE trees into the wild to "restore" endangered species.

The most common **traits** being genetically engineered into forest trees are herbicide tolerance, cold and drought tolerance, pest and disease resistance, faster growth, and altered wood quality which includes engineering lower lignin. Lignin is one of the main structural substances in plants. It makes processing wood into pulp for paper, for example, difficult and expensive, and it impedes the process of making liquid fuel from wood.

"In addition to the traditional uses of wood products, cellulose from trees is being used as a feedstock to the chemical and pharmaceutical industries, currently supplementing, but in the future possibly replacing fossil fuels."

Forest Biotechnology Working Group at the State University of New York College of Environmental Science and Forestry (SUNY-ESF)[5]

THE STATUS OF GE TREE COMMERCIALISATION:

- In 2002, the People's Republic of China planted the first-ever GE tree: two types of GE insect-resistant poplar trees were planted, which **remain the only commercially planted GE trees in the world**.
- There are two GE trees that are legal to be released but are not yet planted: a cold-tolerant loblolly pine and a fast-growing eucalyptus. Both were legal to plant as of 2015 in the US and Brazil, but the companies say they never commercially planted them.
- In November 2021, the Government of Brazil approved the commercial planting of a GE herbicide-tolerant eucalyptus tree from pulp and paper company Suzano. **This GE eucalyptus tree in Brazil could soon be the first commercially planted GE tree in the world since the GE poplar was planted in China**.
- There is a GE blight-tolerant American chestnut tree currently being reviewed for approval by the US government, for deliberate release into the wild.

GE poplar in China was the first and, so far, is the only GE tree planted commercially in the world. However, this could change soon. There are GE trees in the US and Brazil that are legal to plant but have not yet been commercially released. Meanwhile, field testing on potential new GE trees continues in many countries around the world.

Who? Corporate Developers

Suzano is the largest pulp producer in the world, and one of the world's largest manufacturers and exporters of eucalyptus pulp. The company is based in Brazil and has five international offices, in Argentina, Austria, China, Switzerland and the US. In 2021, Suzano announced construction of a new factory in Brazil that is set to be the largest single-line pulp plant in the world.[6] Suzano runs over half of all the field tests of GE trees in Brazil. It has approval in Brazil to plant two GE eucalyptus trees, but these have not yet been released. **FuturaGene** is Suzano's biotechnology research and development unit. It has been a subsidiary of Suzano since 2010. FuturaGene's research activities are concentrated in Brazil, with some research and development in China and Israel.

ArborGen was founded in 1999 as a tree biotechnology company, in a $60-million joint venture of Monsanto, International Paper, Westvaco (later MeadWestvaco and now WestNorth), and Fletcher Challenge Forests (later Rubicon, which bought ArborGen in 2017, and then changed its name to ArborGen).[7] ArborGen is licensing its technology to other companies to produce genetically engineered pine trees[8] and, in 2021, announced a licensing agreement with an unnamed company that is developing trees to better capture and store carbon.[9] ArborGen is now a major supplier of non-GE loblolly pine and eucalyptus seedlings in the US and Brazil. In 2021, it sold its Australian and New Zealand business to focus on markets in the US and Brazil.[10] It is not growing any GE trees commercially but has approval in the US (2015) to plant a GE loblolly pine. ArborGen runs almost half of all the field tests of GE trees in Brazil.

Stora Enso is a Finnish-Swedish company that produces packaging products, wood and paper products, including those aimed at replacing materials made from fossil fuels ("biomaterials").[11] It is Europe's biggest paper maker and has mills across Europe, as well as in Brazil, Uruguay and China. Stora Enso owns or leases over 2 million hectares of land in Sweden, Finland, Brazil, Uruguay, and China, as well as in Estonia and Romania.[12] In 2018, Stora Enso joined 23 other Finnish and Swedish companies to form a joint project named Combient focused on artificial intelligence, deep learning, big data and automation.[13] Stora Enso has conducted field tests of GE eucalyptus in Brazil.

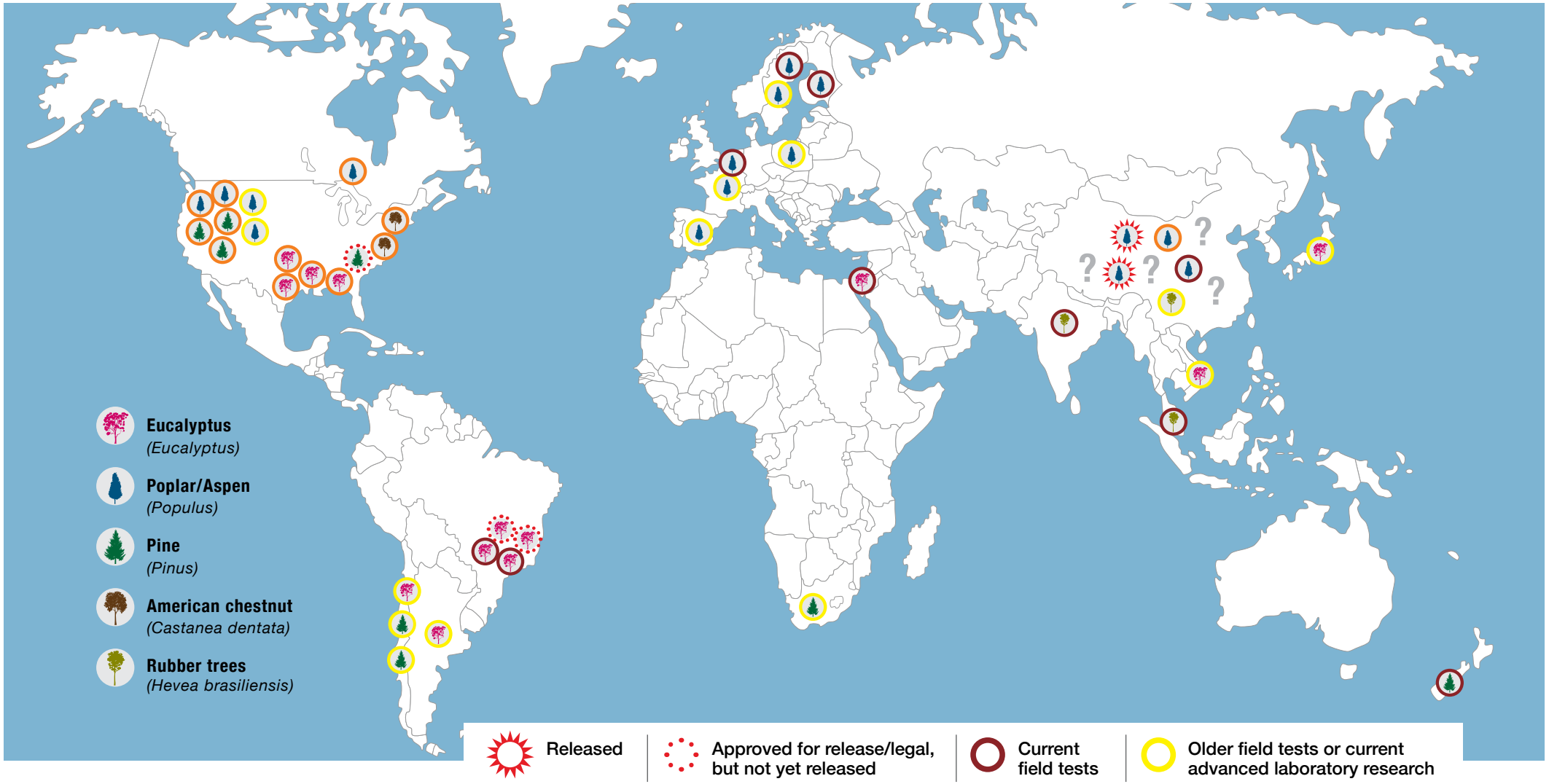
Veracel is a joint venture of Suzano and Stora Enso, based in Brazil, to produce eucalyptus-based cellulose. At the end of 2020, Veracel owned 213,000 hectares of land, of which 82,000 hectares were planted with eucalyptus for pulp production.[14]

Swetree is a Swedish forest biotechnology company founded in 1999. Stora Enso is one of SweTree's main shareholders. The company has partnerships with scientists at academic institutions, including the tree biotech research-focused Umeå Plant Science Center (UPSC) in Sweden and the Vlaams Instituut voor Biotechnologie (VIB) in Ghent, Belgium. SweTree is conducting two ongoing field trials of GE poplar (aspen) in Europe.

International Paper is one of the world's largest pulp, paper and packaging companies. It is headquartered in the US, and has operations in North America, Latin America, North Africa and Europe. The company bought several Brazilian companies to form International Paper do Brazil, which runs some field tests of GE eucalyptus. In 2006, International Paper sold part of its business, along with 50,000 hectares of land in Brazil, including pine and eucalyptus plantations, to Stora Enso.[15]

Oji Paper is a Japanese paper manufacturer and one of the top five paper companies in the world. Oji Paper runs plantations in Brazil, Australia, China, Cambodia, Vietnam and other countries.

Where? GE Trees Under Development



This map shows which tree species are in advanced development around the world and tracks other significant research.

The map is not an exhaustive survey of every country because there may be field tests or other advanced research that we did not identify. Some governments, such as the People's Republic of China, do not provide public information about GE field tests. Of the countries where information on GE tests is not accessible, China is most likely to have current field tests.

Where? Regional Summaries

This section highlights the most advanced research on GE trees around the world, and explains the information presented in the global map on page 12.

Our report finds that the development of genetically engineered forest trees is not evenly advanced across the world. The development of GE trees differs from region to region depending on multiple factors, including which tree species are in plantation production in each region.

Locations of field tests indicate the regions of the world that are most at immediate threat from potential GE tree introduction. However, once approved, GE plantation trees could quickly be adopted in any country where there are plantations of those species, or where such plantations are possible.

Field tests are one main indicator of advanced research, though very few field tests lead to product development. Field tests, and even government approvals for commercial release, do not automatically mean that a GE tree will come to market. For example, there are two GE trees that have been legal to use since 2015 – a GE loblolly pine in the US and a GE eucalyptus in Brazil – that have not been commercially released. In addition, it is common for research groups to announce the development of a GE trait based on laboratory research alone, even when the performance of the GE tree is not tested and there is no prospect of imminent release.

Aside from the unknown situation in China, GE tree field tests are now concentrated in the US and Brazil. If there are any new commercial releases of GE trees, these will likely take place in the US, Brazil or China, first. Many other countries are positioned to follow if this commercialisation begins.

In these summaries, there is some distinction between field test permits and actual field tests: permits can describe one or more field tests, for different lengths of time and for varying numbers of trees. Additionally, some permit documents are more detailed than others, and information requirements differ in different countries. In some cases, additional public sources of details about field trials are available.

Latin America

A GE herbicide-tolerant eucalyptus tree was recently approved for planting in Brazil and could soon be commercially released there.

The commercial pursuit of GE trees in Brazil is led by the pulp and paper company **Suzano**. In November 2021, Suzano, through its biotechnology subsidiary company **FuturaGene**, obtained approval in Brazil to plant its eucalyptus trees that are genetically engineered to be tolerant to the herbicide glyphosate.[16] This follows the earlier 2015 approval of FuturaGene's GE faster-growing eucalyptus tree[17] which has not been planted commercially, reportedly because other non-GE eucalyptus trees ultimately performed as well or better.[18] Both GE tree approvals were met with strong opposition from Brazilian civil society and international groups.[19] (See the profile on GE eucalyptus, pages 28-31.)

Brazil is the only country in Latin America where field tests of GE plantation trees are known to be taking place.[a]

All GE trees field tested in Brazil have been GE eucalyptus. Since 2007, four companies have field tested GE eucalyptus in Brazil: Almost half of these permits were issued to Suzano, and the rest were issued to the pulp and paper companies International Paper and SweTree, and the tree biotechnology company ArborGen.

Outside of Brazil, there are just a few early field tests reported, in Uruguay and Chile. There were some field tests of GE eucalyptus for herbicide tolerance and altered lignin in **Uruguay** in the 1990s.[20] In **Chile**, there were field tests of a GE glyphosate-tolerant eucalyptus in 1996 and a GE insect-resistance pine in 2000/2001.[21]

In Chile, there has been public sector funding from the Chilean Economic Development Agency (CORFO) and the Scientific and Technological Development Support Fund (FONDEF) for research projects on GE pine, eucalyptus and poplar, conducted by Fundación Chile, INIA (National Institute for Agricultural Research) and Chilean universities (University of the Frontier, Austral University, Catholic University and Andres Bello University).[22]

GE tree research has a high profile in Chile because of the Forest Genomics department of the Biotechnology Center at the University of Concepción. The lead researcher at the center, **Prof. Sofia Valenzuela**, has co-authored papers on GE eucalyptus for cold tolerance (2016)[23] and drought tolerance (2022).[24] She is one of the scientists publicly pushing the Forest Stewardship Council to allow GE trees in its certification program (see pages 38-39).[25] In 2022, Prof. Valenzuela was appointed as the Government of Chile's Secretary of Science (Seremi de las Ciencias). Responding to her political appointment, Lucía Sepúlveda Ruiz from the *Red de Acción en Plaguicidas y el Movimiento por el Agua y los Territorios* (Action Group on Pesticides and Movement for Water and Land) said, *"Her promotion to public office reads as an endorsement [of GE trees] and a warning about the power of the promoters of GM crops in opposition to those of us who stand for the protection of biodiversity and the transition to a model of agroecological agriculture."*[26]

The emergence of Chile as a centre of tree biotechnology in Latin America has been met with opposition: the 2017 International Union of Forest Research Organizations (IUFRO) Tree Biotechnology Conference held in Chile was forced to cancel its field trip to the University of Concepción's Biotechnology Center because of protests against genetically engineered trees.[27]

Argentina, the world's third largest producer of GE food crops, does not make field test information public. However, in 2016, the Biotechnology Forest and Agriculture Center in Chaco announced that it had developed a GE eucalyptus with government funding, for drought tolerance and faster growth,[28] and the government research council CONICET (Consejo Nacional de Investigaciones Científicas y Técnicas) later reported their investigation of GE poplar for early flowering.[29]

The Ministry of Environment and Water in **Bolivia** was reportedly ready to import GE eucalyptus for plantations in 2020, but the College of Biologists in La Paz raised environmental concerns and the importation did not take place.[30]

Peru, **Ecuador**, **Venezuela**, and **Panama** all ban the cultivation of GE plants.

There are no reports of field tests of GE trees in other countries of Latin America and the Caribbean.

a Brazil's field test permits do not provide information about when field tests will end. However, Suzano reports ongoing trials in its 2021 corporate filing to the US Securities and Exchange Commission. (Suzano S.A. 2021. Form 6K, Ex 99.1. Notice to the Market. November 12)

TABLE 1: All GE tree field test permits in Brazil

Data from the regulator, CNTBio.[31]

Company	Number of Field Trial Permits (eucalyptus)	Year of Permit Issue*	Traits**
Suzano	3	2003, 2004, 2005	• growth/yield • abiotic stress
FuturaGene (subsidiary of Suzano)	25	2013, 2014 (5), 2015 (7), 2016 (8), 2017 (3), 2018 (4)	• growth/yield • resistance to pest/ disease • resistance to herbicide • tolerance to abiotic stress
Fibria Celulose (merged with Suzano)	8	2013 (4), 2014 (2), 2017, 2018	• growth/yield • wood quality • herbicide tolerance
Stora Enso (their company Veracel is co-owned with Suzano)	5	2016 (2), 2017 (2), 2018	• growth/yield • wood quality • tolerance to frost
International Paper of Brazil	19	2004 (2), 2005 (2), 2006 (3), 2014, 2015 (7), 2016, 2017 (3)	• growth/yield • wood quality • tolerance to drought • biofuels
ArborGen	13	2006 (2), 2007 (2), 2008 (2), 2009, 2010, 2012, 2013, 2014, 2017 (2)	• wood quality • growth/yield
BioAgro (Federal University Viçosa)	1	1999	• glyphosate tolerance
Monsanto (now owned by Bayer)	1	1999	• glyphosate tolerance
Alellyx (subsidiary of Monsanto)	3	2005, 2007 (2)	• wood quality
TOTAL	**78**		

* CNTBio permits do not indicate the permit end date.

** Some companies do not describe their GE “wood quality” trait precisely in permits: It can include changes to lignin content (less or more) and/or changes to cellulose content, wood density, and fiber length.

Africa

There are no field trials of GE forest trees in Africa, and South Africa is the only African country where research into GE trees is taking place.[32]

Africa is the continent with "the most profitable afforestation potential worldwide," according to a 2019 report produced for the African Development Bank and World Wildlife Fund Kenya.[33] The study identified around 500,000 hectares of "viable plantation land" in ten countries, mainly **across Southern Africa**: Angola, Republic of Congo, Ghana, Mozambique, Malawi, South Sudan, Tanzania, Uganda, Zambia, and Zimbabwe.

The University of Pretoria in **South Africa** has a biotechnology research center called the Forestry and Agricultural Biotechnology Institute, which houses the Forest Molecular Genetics programme (FMG). It aims to develop fast-growing plantation trees "with a view to enhance biomass production and improve wood properties for timber, pulp, paper, and biomaterials production" along with pest and disease resistance,[34] in eucalyptus and pine in particular.[35]

FMG is funded by pulp and paper companies **Sappi** and **Mondi**; South African forestry and timber companies SAFCOL/Komatiland Forests and York Timbers; public institutions in South Africa; and the US Department of Energy Joint Genome Institute.[36] It was founded by **Prof. Zander Myburg** at the university, who is also the coordinator of the international Eucalyptus Genome Network (EUCAGEN) and the lead investigator of the US Department of Energy Eucalyptus Genome Project.

The United States Department of Energy is providing FMG with genetic components for research into genetically engineering eucalyptus for production of energy and "biomaterials."[37] FMG also has collaborations with **Prof. Steven Strauss** at Oregon State University (OSU) in the US, to support the development of technologies to genetically engineer eucalyptus.[38] In 2021, OSU announced[39] that their international collaboration with researchers at the University of Pretoria showed gene editing (CRISPR-Cas9) could be used to inhibit flower formation in eucalyptus.[40] The University of Pretoria's Forest Molecular Biology Program is the only other university member of GREAT TREES, a biotechnology university-public agency-industry research consortium run by OSU.

South Africa's forest industry is a multimillion-dollar industry, responsible for around 10% of the country's gross domestic product.

North America

The United States is home to the most research and field testing of GE trees globally, and university researchers in the US have asked for approval to plant a genetically engineered American chestnut tree in the wild.

The US accounts for around 40% of all the GE crop hectares in the world and also grows the only commercialized GM fruit trees: a GE virus-resistant papaya (also grown in China) and a GE non-browning apple.

There is already **a GE tree that is legal to plant in the US**. In 2015, the US Department of Agriculture (USDA) decided that a genetically engineered **loblolly pine** (*Pinus taeda*), developed by the company **ArborGen**, was outside their mandate for review and could therefore be released without any government risk assessment.[41] ArborGen said the pine was genetically engineered with increased wood density, for pulp and paper, timber, and "bioenergy."[42] The company can legally grow and sell the GE pine trees[43] but has said it is not using them and has "moved on to other things."[44] This decision may be explained by a later study that showed that while the GE tree had increased wood density, it also grew more slowly.[45]

An earlier request to release a GE cold-tolerant **eucalyptus** in the US, made in 2011 by ArborGen, ended without explanation in 2017, before the last stage in the process was completed.[46] Meanwhile, FuturaGene/Suzano of Brazil, which now has two GE eucalyptus trees approved in Brazil, has institutional and research partnerships in the US, as well as other countries.[47]

Two of the most active and globally prominent GE tree researchers are in the US: Professors **William A. Powell** at the State University of New York's College of Environmental Science and Forestry (SUNY-ESF), and **Steven Strauss** at Oregon State University (OSU).

- In 2020, led by Prof. Powell, SUNY-ESF asked the USDA to allow the release of a genetically engineered blight-resistant **American chestnut** tree into the wild, and said it will also ask approval from the Canadian government.[48] This decision is pending.

- By 2018, OSU said it had conducted over 100 field tests of GE trees for a variety of traits.[49] The most recent tests are on **GE poplar** for tolerance to the herbicide glufonsinate, and for early flowering. OSU is also running GE poplar field tests with the company **Living Carbon** (see Profile #3 on Living Carbon, pages 35-37). There have also been 32 field trial permits authorized for GE sweetgum (*Liquidambar styraciflua*), most recently run by **Oregon State University** to alter flowering.[50]

In Canada, there is one ongoing field test of GE **poplar** trees, managed by a research team at Queen's University in Ontario (2009-present), investigating various possible traits.[51] The Canadian government previously spent up to $20-million on GE tree research through the Canadian Forest Service,[52] which included field testing poplar trees genetically engineered with herbicide tolerance and other traits (2000-2014), as well as white spruce with insect-resistance (Bt) (2000-2006).[53]

New Zealand and Australia

There are ongoing field tests of GE radiata pine trees in New Zealand.

There are current, long-term field tests of GE radiata pine (*Pinus radiata*) in **New Zealand**, run by the government-owned forest research institute called **Scion**. The tests, approved in 2010, will run **for 25 years**[54] to examine altered plant growth/biomass acquisition, reproductive development, herbicide tolerance, biomass utilisation, wood density, and wood dimensional stability.[55]

There is a long history of GE tree field trials, and protest against them, in New Zealand. In 2000, Scion got approval to run a nine-year-long field test of GE herbicide-tolerant **radiata pine** (*Pinus radiata* D. Don) and **Norway spruce** (*Picea abies* (L.) Karst).[56] However, in 2006, four people were arrested at the research facility during a demonstration against GE trees[57] and in 2008 the trial was shut down after the Scion Field Test Containment Facility was broken into by

protestors who destroyed some saplings.[58] The field trial was replanted in 2011[59] but, in 2012, protestors again destroyed trees in the same project.[60]

In 2010, 260,000 GE cold-tolerant **eucalyptus** trees developed in New Zealand by Horizon 2 in partnership with Rubicon, now **ArborGen**, were sent for field testing to 28 sites across the Southern US.[61]

Government records show no field tests of GE plantation trees in **Australia**, which is the centre of origin for eucalyptus.

Asia

The first and only GE tree planted commercially anywhere in the world is a GE insect-resistant poplar that was widely planted in China.

CHINA

Genetically engineered insect-resistant (Bt) **poplar** trees were widely planted in **China** in 2002, and two varieties were ultimately released.[62] These GE trees were planted after a project to halt desertification using monoculture plantations of poplar trees was plagued by insect pests.[63] The release has not been closely monitored[64] and the sparse information available is difficult to confirm. By 2021, the GE poplar trees reportedly occupied 450 hectares in China,[65] though a researcher in China stated in 2004 that a million trees had been planted and the government had aimed to plant 44 million hectares by 2012.[66]

There is a huge amount of ongoing laboratory research on various questions and tree species in China,[67] including bamboo[68] and rubber,[69] with an unknown amount of field testing. While China requires field test permits, it does not list them publicly.[70] 84 GE tree field trial permits were reported to have been granted in China before 2010, for trees including poplar, locust tree (*Robinia pseudoacacia*) and Japanese pagoda (*Sophora japonica*).[71]

It is likely that GE **eucalyptus** field trials are taking place in China because it is a common tree in plantations in the country and there is evidence of laboratory research.[72] Additionally, in 2011, **FuturaGene**, the subsidiary of **Suzano** that developed the two Brazilian-approved GE eucalyptus trees, opened Chinese headquarters in Shanghai.[73] In 2014, Suzano said in relation to GE trees: "In the future, in China, we aim to plant poplar and eucalyptus in appropriate regions [in] various provinces."[74]

JAPAN

In **Japan**, a number of **GE eucalyptus** field tests have been run by the University of Tsukuba's Gene Research Center: The most recent was for cold tolerance, in a trial that ran from 2013 to 2017, and there were six permits granted for GE salt tolerant eucalyptus field tests that ran from 2005 to 2011.[75]

The Forest Tree Breeding Center in Japan also conducted a four-year field trial of GE cellulose-rich **poplar** (2007-2011).[76] In 2018, the Centre described its efforts to develop pollen-free **GE Japanese cedar/Sugi** (*Cryptomeria japonica*) because Sugi plantations cause widespread allergies in Japan.[77]

In 2003, Japan's Oji Paper Company reported that it had developed, with Gifu University, a GE eucalyptus tree to grow in acidic soils.[78] The researchers said they aimed to begin outdoor plantations within ten years, but there is no evidence that this happened. In 2000, Oji Paper Co. was also reportedly conducting field trials in **Vietnam**.[79]

INDIA AND MALAYSIA

In recent years, attention has been paid to genetically engineering **rubber trees** (*Hevea brasiliensis)* in Southeast Asia. Research was enabled by the 2016 sequencing of the rubber tree genome by Japan's main research institution, the RIKEN Center for Sustainable Resource Science in a collaboration with Universiti Sains Malaysia.

There are current field tests with **GE rubber** trees in India and Malaysia:

- In 2021, **India** approved its first GE tree field trial with a rubber tree, developed by the **Rubber Research Institute of India** to grow faster.[80] The director of the institute said, "It's a major achievement as we are the first to plant a GM crop on the soil, while others are still keeping them in labs."

- In 2015, in **Malaysia**, despite concerns from civil society groups,[81] a **20-year field test** of a GE rubber tree was approved.[82] The GE tree was developed by the **Malaysian Rubber Board** to produce compounds that can be used in medicines.[83]

Thailand, Indonesia, Vietnam, India, Cote d'Ivoire, mainland China, and Malaysia are the world's top seven rubber producers. Together, these countries account for 84% of the world's rubber production.[84] Approximately 90% of global rubber is produced by small producers.[85]

There is no current advanced development of GE oil palm trees (*Elaeis guineensis, Jacq*.). However, the Director General of the Malaysian Palm Oil Board is Dr. Ahmad Parveez Ghulam Kadir, who developed the first GE oil palm in 1997[86] and has been involved in research on to engineer oil palm to produce biodegradable plastics.[87] Researchers are also beginning to conceptualize using gene editing techniques such as CRISPR-Cas9 to create abiotic stress-tolerance in oil palm.[88]

We did not find evidence of GE tree research in **Indonesia**.

In 2003, the Government of **Thailand** issued a blanket ban on GMO field trials after public opposition.

ISRAEL

FuturaGene says it has conducted past field tests in **Israel** (2015)[89] and may have current trials.[90] The species are not identified but can be assumed to include eucalyptus because this is FuturaGene's research focus. The Government of Israel does not make field test information public.

Europe

TABLE 2: GE forest tree field test permits in Europe (2003 - present)

i.e. since the implementation of Directive 2001/18/EC (after 17 October 2002).[91]

Country	Number of Permits	Species	Traits*	Applicants	Current Field Tests
Sweden	13	Populus species (aspen)	altered wood quality	Umeå University (5) Swedish University of Agricultural Sciences (SLU) (3) SweTree (5)	2 field tests to end 2024 and 2026 (SweTree)
Finland	4	Populus species (aspen), birch	altered wood quality, growth, environmental risk	University of Joensnn (2) University of Helsinki (2)	1 field test ongoing, to end 2023 (University of Helsinki)
Belgium	3	poplar	altered wood quality, biomass production, resistance to biotic and abiotic stresses	University of Ghent (3)	1 field test ongoing, to end 2025 (University of Ghent)
Poland	2	Populus species (aspen & poplar)	altered wood quality	Warsaw University (2)	-
Spain	2	Populus species (aspen)	biomass production	Universidade Politécnica de Madrid (2)	-
France	3	Populus species (aspen)	altered wood quality	INRA - Institut National de la Recherche Agronomique (3)	-

* Some companies do not describe their GE “wood quality” trait precisely in permits: It can include changes to lignin content (less or more) and/or changes to cellulose content, wood density, and fiber length.

There are current field tests of GE trees in Sweden, Finland and Belgium.

Except for two field tests of GE **birch** (*Betula*) in Finland, all GE forest tree field experiments in Europe have used **Populus species**, in particular a hybrid **aspen** (*Populus tremula x Populus tremuloides*). All GE tree field tests in Europe have been conducted by universities except for field tests in Sweden run by the forest biotechnology company SweTree.

Almost half of all Europe's field test permits have been issued in Sweden, which is the world's fifth-largest exporter of pulp and paper products. There have been thirteen permits issued since 2010, including two ongoing field trials conducted by **SweTree**. SweTree has a "long-term strategic collaboration" with the tree biotechnology research center at Umeå Plant Science Centre in Sweden.[92]

The VIB (Flanders Institute for Biotechnology/Vlaams Instituut voor Biotechnologie) of Ghent University in **Belgium** houses the Center for Plant Systems Biology, where GE poplar trees are being field tested. There have been three field trials with GE poplars run by the university since 2008, with **one ongoing trial set to run until 2025**. This project aims to lower the amount of lignin in poplar trees "for the production of bioenergy and a variety of other biobased products."[93] In 2020, the research group announced its paper[94] on using the gene editing technique of CRISPR-Cas9 to stably **"finetune the amount of lignin"** and described this as "CRISPRing trees for a climate-friendly economy."[95]

Prof. Wout Boerjan of Ghent University is a prominent promoter of GE trees and co-authored a 2019 letter with Prof. Ove Nilsson of the Department of Forest Genetics and Plant Physiology at the Umeå Plant Science Centre in Sweden and Prof. Steven Strauss (US), calling on forest certification schemes to accept GE trees.[96] (See Forest Stewardship Council, pages 38-39.) He also co-authored a paper with Prof. Strauss discussing their complaint that the United Nations Convention on Biological Diversity (CBD) "has become a platform for imposing broad restrictions on research and development of all types of transgenic trees,"[97] after the CBD reaffirmed the need for governments to take a precautionary approach when addressing the issue of genetically engineered trees.

THE RISKS

The Environmental Risks of Genetically Engineered Trees

"Genetically engineered trees are a threat to a sustainable future. Genetic engineering provides a distraction from real solutions and its deployment would pose a concrete danger to forest ecosystems."

— Fundación Ambiente y Recursos Naturales (FARN); Huni Kui Peoples' Federation of Acre, Brazil; Indigenous Environmental Network; Ecoropa; Global Forest Coalition; Global Justice Ecology Project; Biofuelwatch; Canadian Biotechnology Action Network, 2021[98]

Genetically engineered trees present vast uncertainties and pose a wide range of new, unique risks to forests and other ecosystems.

Forest ecosystems are highly complex and poorly understood. Assessing how the release of GE trees will affect other trees, understory plants, insects, soils, fungi, wildlife and human communities over time, would require a far better understanding of forest ecology than we currently have. Recent advances have revealed highly intricate interdependencies, feedback loops and communication networks between and among forest species.[99] **This incredible complexity increases the unknowns and uncertainties of introducing GE trees.**

"Even seemingly small changes in characteristics of a key forest tree can have cascading impacts."

— Dr. Martha Crouch, Centre for Food Safety, 2015[100]

GE contamination is inevitable

GE contamination – the unwanted escape and spread of genetically modified organisms (GMOs) or genetic material from GMOs to non-GM organisms – is a clear, serious risk with GE trees. The global experience with GE crop plants and animals shows that escape can and will happen, from both experiments and commercial release.[101] Human error, biology, pollinator and wind movement, extreme weather events, and other factors all make GE contamination likely and, in many cases, inevitable.

GE trees pose a particularly high risk of escape. The contamination risks are elevated because trees are large, long-living organisms that produce abundant pollen and seed designed to travel long distances,[102] with help from wind and animals.[103] For example, one pine tree produces around 100 million pollen grains per day, and pine pollen that had travelled up into the atmosphere to 610 meters and more than 41 kilometres across water to an island were still found to be viable.[104] Trees produce pollen and seeds year after year, for decades or hundreds of years.

Additionally, some trees, such as poplar, are able to reproduce asexually through vegetative propagation. In some species, isolated twigs can root or roots can form sprouts and grow into mature trees. This is why, in Canadian regulation for example, the root system must be fully removed and the ground must be monitored for developing suckers for three consecutive years after field tests of GE poplar trees.[105] These roots are numerous and tiny, increasing the likelihood of human failure in this management of plant material. This is just one of many known pathways of possible escape. **Despite the risk of contamination from outdoor experimentation, field tests of GE trees continue around the world.**

Once GE contamination in forests begins, it cannot be stopped.

Trees are also less domesticated than crop plants, which means that many have wild or feral relatives with which they can cross-breed. GE trees can therefore spread and persist in the environment more easily than most GE crop plants.

GE contamination is living pollution that can self-replicate. Once released into our environment, genetically modified organisms can be difficult or impossible to control or recall. **Once GE contamination in forests begins, it cannot be stopped.** If GE trees contaminate native forests, these forests will themselves become contaminants, creating a never-ending cycle.

Proposals to make GE trees sterile are common because the threat of contamination is widely recognized,[106] but these technologies would not be reliable and pose their own serious environmental risks.[107] Research to prevent the movement of genetic material from GE trees, such as inhibiting development of flowers, pollen, or seeds, is ongoing, and some of these methods are being field tested.[108] However, it is extremely difficult to totally suppress tree reproduction, and even a small amount of gene flow can result in the eventual spread of GE traits into the wild.

> "We should not have confidence in our ability to keep GM plants on a tight leash. Rather, total containment can never be assured or assumed, and our evaluation of risk should be predicated on the idea that transgenes always have some chance of escaping."
>
> — Michelle Marvier and Rene Van Acker, 2005[109]

The unique and inherent risks of genetic engineering

The processes involved in genetic engineering, including in genome editing (also called gene editing), often result in unintended changes to DNA and traits.[110] Altering or introducing genes can result in changes, not only to the target gene(s) but also elsewhere, in unexpected, often surprising, and unpredictable ways that can have profound impacts on the organism. Unwanted genetic errors can occur even when the intended changes themselves are small.[111]

Genes do not function as isolated units but interact with each other and their environment in complex ways that are not well understood or predictable. The concept that one gene determines one trait is overly simplistic and outdated.[112] Rather, many genes may interact to determine a particular trait, and one gene can be involved with multiple traits. Changes made to any of the genes involved can therefore have far-reaching impacts, even on seemingly unrelated traits.

Unintended traits are common in commercialized GE crops.[113] In the case of trees, unintended effects from genetic engineering could, for example, unexpectedly alter the nutrients in seeds upon which so many animals depend,[114] or the ability of the tree to collaborate with the mycorrhizal community and thus compromise the tree's resilience or defences.[115] **Unexpected traits can also be the product of gene-environment interactions** and only become apparent, for example, during times of environmental stress such as drought.

New GE traits can perform as intended for their desired commercial purpose, while simultaneously behaving in unanticipated ways. For example, the level of GE Bt toxin present in commercialized GE insect-tolerant corn was found to vary in different plant tissues as well as in different stages of development and across generations.[116]

Intended GE traits could also fail to function over time, leading to possible unexpected impacts in the long term. The proposal to introduce a GE American chestnut tree into the forests of Eastern North America is predicated on the presumed success of a new GE trait to protect the trees from the *Cryphonectria parasitica* blight. However, the studies submitted to the US government as part of a request to plant these GE trees offer limited information about the future performance of the blight tolerance trait. The tests have all been on young trees grown in the laboratory and short-term field tests, even though it is known that younger trees are naturally more resistant to the blight. American chestnut trees can live for over 200 years, and the performance of this, or any other GE trait, can be affected by environmental conditions experienced over the lifespan of a tree, such as drought, flood, heat, pests, as well as by basic changes associated with aging. Furthermore, such efforts to genetically engineer pathogen resistance are likely to be unsuccessful over time simply because pathogens quickly evolve to overcome plant defenses.[117]

Altering traits may result in trade-offs against other functions, some more predictable than others. For example, ArborGen found that genetically engineering eucalyptus for increased wood density resulted in slower growth.[118] Trade-offs could result in **weaker trees**. For example, reducing the lignin content is a commonly attempted GE trait that is desired for biofuel production, but could compromise the structural integrity of trees and their defences against pests and other (abiotic) stresses, such as storms or floods.[119] Trees genetically engineered to grow faster may exhibit similar vulnerabilities. **The spread of such traits from plantations into neighbouring forests and ecosystems could lead to serious impacts on forest health.**

Altering forest ecosystems

Genetically engineering trees to alter wood characteristics can increase or decrease the rate of wood decomposition, which can have implications for **nutrient cycles and biodiversity in a forest**. The speed of wood decomposition is important for the lifecycles of insects, the composition and abundance of fungi and soil microorganisms, and the entire food web.

The first and, so far, only GE tree released commercially is an insect-resistant (Bt) poplar in China. Bt toxins engineered into plants can impact target pests as intended, but can also be toxic to non-target, beneficial insects,[120] with possible impacts throughout forest food chains and other forest systems. Approximately a decade after Bt corn was commercialized, research found negative impacts of Bt corn residue on aquatic organisms in streams near farms,[121] and while laboratory tests show varying toxicity,[122] the real-world impacts of Bt plants on bees and other pollinators, and on herbivores and their predators, remain undetermined.

Trees are being genetically engineered to exhibit characteristics that could result in them becoming invasive and outcompeting other trees. For example, trees engineered for

faster growth or with bigger leaves could outcompete other tree seedlings, leaving them struggling for light and space in forests.

In addition, a great deal of effort is being expended to genetically engineer cold tolerance in eucalyptus trees. This trait, if it functions as intended, could enable the trees to thrive in areas where they could not before, further expanding their range, and posing new risks.

"Genetic changes introduced into trees to address forest health threats have the potential to take on characteristics of invasive species that tip the balance of ecosystems."

— National Academies of Sciences, Engineering, and Medicine, US, 2019[123]

Changing the traits of trees grown in plantations could have ecological impacts beyond the plantation, even without any escape of GE trees. For example, experience with GE crop plants suggests that plantations of GE insect-resistant trees could trigger **the rise of other (secondary) pests**,[124] which could affect nearby forests or plantations.

The environmental impacts of expanding plantations

Most experiments to genetically engineer trees are focused on plantation trees, to increase the productivity and profitability of monoculture plantations used to produce timber, paper, and other materials. If GE trees are successfully commercialised for such uses, they could be extensively planted across the world, **further driving investment in destructive monoculture plantations to produce industrial materials**. Genetically engineering trees to be more efficiently converted into liquid fuel is widely proposed, for example, but could increase – rather than decrease – the economic pressure to convert more land into tree plantations.

Tree plantations are not forests: they do not support the same biodiversity as forest ecosystems. They often deplete water resources; degrade and erode soil, and make extensive use of chemical pesticides. The ecological impacts of plantations are felt by local communities, who are often left without livelihoods, food, or water, with little recourse.[125] In 2018, more than one thousand women from the Rural Landless Workers Movement (MST) in Brazil took over a mill owned by the pulp and paper company Suzano. The women's key grievances included the depletion of critical freshwater resources and the contamination of water by aerial spraying of pesticides on eucalyptus plantations (see Profile #1 pages 28-31).[126]

"Ending the prevailing forest model is a matter of life or death. We must put an end to the harmful effects of monoculture forestry: the ongoing water crisis, degradation of arable land, urban and rural poverty, loss of native forest, wetlands, ecosystems and the proliferation of forest fires."

— Public declaration issued by social movements of the Chilean and Mapuche Peoples, 2017[127]

False climate and biodiversity solutions

"Attempts to promote forest health by circumventing evolution and genetically engineering trees…is bound to fail, with potentially irreversible impacts on the very ecosystems they ostensibly are intended to help."

— Rachel Smolker, Anne Petermann and Rachel Kijewski, 2018[128]

Many proponents of GE trees argue that we need to change trees to protect struggling forests and help stop climate change. For example, the website of the "Petition in Support of Forest Biotechnology Research" hosted by Oregon State University argues that, "Many forests are under existential threats due to spreading pests and climate change and are in need of biotech or other novel genetic solutions to help them survive and thrive."[129] However, **far from protecting forest ecosystems, GE trees would present a new threat**.

PROFILE #1

751KO32: Approval granted in Brazil for commercial planting of genetically engineered herbicide-tolerant eucalyptus

STATUS: Approved but not planted

Aside from the GE poplar planted in China twenty years ago, GE herbicide-tolerant eucalyptus in Brazil may soon be the first GE plantation tree to be released commercially. This is the second of two GE eucalyptus trees approved in Brazil but not yet planted.

On November 16, 2021, Brazil's National Technical Commission on Biosecurity (CTNBio) approved the planting and commercial use of a GE herbicide-tolerant eucalyptus tree. This GE eucalyptus (identified with the number 751KO32) was developed by the company FuturaGene, a subsidiary of the Brazilian pulp and paper company Suzano, and it follows a 2015 approval in Brazil of Suzano's GE fast-growing eucalyptus tree, which is also not yet commercially released.[b]

Brazil's 2021 approval for this GE herbicide-tolerant eucalyptus was granted in just five months. This approval was denounced by 33 organizations in Brazil, along with many groups across South America and around the world.[130]

The new GE eucalyptus is designed to be used with the herbicide glyphosate

The newly approved GE eucalyptus tree is glyphosate-tolerant which means that the tree has been genetically engineered to survive being sprayed with glyphosate-based herbicides, even when the tree is young and more vulnerable, while all the weeds and other plants around it will die.

Suzano claims that this GE eucalyptus, "will allow more efficient weed control with lowered chemical load and improved worker conditions."[131] However, this promise was also made by the biotechnology industry for the use of GE herbicide-tolerant crops and it proved false. **Herbicide use increased significantly with the use of GE herbicide-tolerant crops in North America**[132] **and South America.**[133] Pesticide use in soybean production in Brazil increased three-fold between 2000 and 2012 after the introduction of GE (Roundup Ready) soy.[134] Official statistics show rates of glyphosate use increased significantly in both Brazil and Argentina[135] where glyphosate-tolerant soy is 85% and 100% of all soy grown respectively.[136]

Glyphosate is used to clear the land of other plants in order to prepare tree plantation sites and it is also applied to new plantations in the first few years of growth. As observed with GE crops, the convenience of trees that can survive glyphosate will likely result in the use of more glyphosate, more often. In the case of eucalyptus plantations, it may also encourage ariel spraying of new plantations where direct spraying of plants on the ground is the current norm.

b Suzano is seeking approval for additional versions of its GE glyphosate-tolerant eucalyptus trees. In August 2022, CNTBio approved #955S019.

Approximately 88% of all the GE agricultural crops currently grown across the world are genetically engineered to be herbicide-tolerant,[137] and most of these are glyphosate-tolerant.[138]

Glyphosate is now the most widely used herbicide ingredient in the world. Brazil's health agency, Anvisa, concluded that there are **health risks for people exposed to glyphosate** when it is applied to crops and stipulated a safe distance be kept from populated areas when using it.[139] This is important because many small communities are surrounded by eucalyptus plantations, just as others are surrounded by GE glyphosate-tolerant soy monocultures. Pesticide use in Brazil with GE soy causes injury to thousands of people each year.[140]

The **"green deserts"** of industrial eucalyptus plantations[141] will become even more devoid of life with the use of glyphosate-tolerant trees, and could mirror the human health and environmental impacts of glyphosate use with GE glyphosate-tolerant soy in South America.[142]

An earlier GE eucalyptus tree from Suzano was approved in Brazil but not commercialised.

In 2015, CTNBio approved a GE eucalyptus tree (identified with the number H421) that was genetically engineered to be faster growing, for higher yield.[143] **The initial CTNBio meeting to consider the approval was shut down when three hundred peasants of La Via Campesina interrupted the meeting.**[144] That same day, a thousand women from the Landless Workers' Movement (MST) took over FuturaGene's nursery in São Paulo and destroyed tree seedlings.[145]

In June 2014, 103 groups in Latin America, including 57 from Brazil, **called for a global moratorium on the commercial release of genetically engineered trees**, "due to their unknown but potentially severe social and ecological impacts and incalculable economic risks, which would overwhelmingly accrue to the public."[146] The groups stated, "The only benefit we see from this new high-risk technology with unknown future impact (and possible associated incalculable cost) is that of increased profits to Suzano's shareholders." Their call was ultimately supported by 146 environmental and social justice groups from around the world.[147]

Suzano said that their GE tree increased productivity by 20%[148] and the head of FuturaGene said, "Our trees grow faster and thicker. We are ahead of everyone. We have shown we can increase the yields and growth rates of trees more than anything grown by traditional breeding."[149] However, Suzano did not release this approved GE eucalyptus tree,[150] reportedly because **other eucalyptus trees developed through conventional breeding were ultimately more efficient**.[151]

About 1,000 women of the Landless Workers Movement (MST) occupied Suzano's in Itapetininga, Sao Paulo, Brazil. 2015. Photo courtesy of MST.

Eucalyptus plantations could continue to expand

The introduction of trees that are genetically engineered to increase their productivity may not limit the expansion of plantations as promoted, but could increase it. Companies running tree plantations have long promised that gains in productivity would lead to less land use and are now proposing that genetic engineering could be used to facilitate this so-called "sustainable intensification."[152] However, there is no evidence that increased productivity has resulted in less land being taken up by plantations. The UN Food and Agriculture Organization found that the amount of land covered by tree plantations increased by 60% between 1990 and 2010, even though the amount of wood harvested per hectare of land increased by 50%.[153] In Brazil, the productivity of eucalyptus plantations increased by 2.8%[154] while there was a 34.3% increase in the area planted, from 5.56 million hectares in 2014 to 7.47 million hectares in 2020.[155]

Suzano is the largest pulp producer in the world, and one of the world's largest manufacturers and exporters of eucalyptus pulp. From 2015 to 2020, Suzano's area of eucalyptus almost tripled to 1,364,000 hectares.[156] In 2021, Suzano announced construction of a new factory in Brazil that is set to be the largest single line pulp plant in the world.[157]

Eucalyptus is about 78% of tree plantations in Brazil[158] and products from tree plantations represent almost 5% of Brazil's total exports.[159]

Social conflict will increase

"The Suzano eucalyptus is the enemy of peasant populations, indigenous people, quilombola communities, babaçu nut breakers and other traditional peoples and groups."

— Open Letter Denouncing Suzano's Genetically Engineered Eucalyptus, 2022[160]

Suzano's GE glyphosate-tolerant eucalyptus was approved without consulting Brazilian civil society or the communities in areas where the plantations will be located. Suzano carried out field tests in three Brazilian states without informing the local communities.[161]

If GE eucalyptus is planted, the future of international markets for Brazilian honey would be in jeopardy. The contamination of honey with traces of GE pollen is inevitable because an estimated 35% of Brazil's honey production comes from eucalyptus.[162] There are 350,000 producers of honey in Brazil.[163]

Communities in Brazil have long resisted eucalyptus plantations.[164] In 2008, on International Women's Day, 900 women from the peasant movement La Via Campesina, with 250 children, occupied 2100 hectares of monoculture eucalyptus plantations in Rio Grande do Sul that belonged to the Swedish company **Stora Enso**.[165] In 2018, more than one thousand women from the Rural Landless Workers Movement (MST) took over a pulp mill in Bahia owned by **Suzano**, to protest the company's eucalyptus plantations and their future plans for genetically engineered trees.[166]

Groups opposing Brazil's 2015 GE eucalyptus approval said, *"Many and serious conflicts over access to land already exist, and living conditions of communities surrounded by Suzano's operations have deteriorated to the point that communities are now struggling to guarantee their food sovereignty and are increasingly at risk of losing their territories."*[167] World Rainforest Movement writes: "In Brazil there are two conflicting models: that of the large monoculture plantations (ranging from eucalyptus, soybeans and rice to sugarcane), on lands held by a few large companies; and that of the peasant, Indigenous and landless communities that build collective and diverse productive spaces and demand the historically promised agrarian reform."[168] Members of some rural communities in Mozambique, Tanzania, and Brazil met in 2021 and released a statement that said, *"…the eucalyptus and rubber trees have taken over and destroyed the fertile farm lands, and families today no longer have any means to feed themselves, and some no longer have anywhere to live."*[169]

In 2013, Veracel, a joint venture with **Stora Enso** and **Suzano**, took the Indigenous Pataxós to court to try to evict them from an area they reclaimed near the company's plantations in the state of Bahia.[170] Pataxós have been seeking to stay on twenty hectares, surrounded by Veracel's eucalyptus plantations[171] and their land claim is tied up in the courts.[172] They allege that Suzano is partly responsible for the ongoing destruction of their territory. In June 2022, Pataxós took over two farms including one growing eucalyptus trees for Suzano.[173] In a video manifesto, Pataxós leaders declared, *"We are expelling the multinationals, the millionaires and billionaires from here. There won't be a single eucalyptus tree left on our sacred land, because that's bad. We want our water, quality land, and our biome recovered. We do not accept this shameful destruction."*[174]

FuturaGene's Plans

Suzano's subsidiary FuturaGene has plans to develop GE eucalyptus for use in Brazil, the US, and China.[175] In 2018, the company announced that it is using (RNAi) technology from the Australian government research company CSIRO, to genetically engineer eucalyptus to be resistant to pests and diseases, and to modify wood properties.[176] In December 2021, FuturaGene announced that it would start using gene editing (CRISPR-Cas9) to genetically engineer eucalyptus to be "more productive, resistant to diseases and pests and have improved fiber properties."[177] FuturaGene also says, "the company aims for the new varieties to be more resilient to climate change and to serve as an alternative to products derived from fossil fuels."[178]

PROFILE #2

"Darling 58": Proposed release of genetically engineered American chestnut trees in the US and Canada

STATUS: Pending approval in the US

University researchers have asked the US Department of Agriculture to approve the release of genetically engineered American chestnut trees into the wild.

The American chestnut (*Castanea dentata*) is classified as an endangered species in Canada and often referred to as "functionally extinct" in the US, despite millions of trees still growing in Eastern US forests.[179] It was a dominant tree in the eastern forests of North America until a fungal blight, along with logging, decimated populations in the first half of the 1900s.

Now, researchers at the State University of New York College of Environmental Science and Forestry (SUNY-ESF) have genetically engineered an American chestnut tree to be blight-tolerant, and are asking the US government to approve its unrestricted planting in the wild.[180] They call this GE tree "Darling 58," and propose that it can be used to re-establish the American chestnut in the US and Canada.

If their request is approved, the GE American chestnut would be the first-ever genetically engineered forest tree planted outside field tests in North America. **It would also be the first-ever genetically engineered plant released with the purpose of spreading freely through wild ecosystems.**

The genetically engineered American chestnut (GE AC)

The genetically engineered American chestnut tree (GE AC) has been modified to tolerate the blight *Cryphonectria parasitica*. Research on the GE tree began as a collaboration between SUNY-ESF and the New York Chapter of The American Chestnut Foundation in 1990.

The GE AC is a transgenic tree, meaning that it was genetically engineered by inserting genetic material from other species into the tree's DNA (in this case, genetic material from wheat, a plant related to mustard, two different bacteria, and a plant virus).

Releasing the GE AC is a large-scale experiment

If the GE AC is released, it will be planted specifically to spread freely through forests. Once it is released in the wild, there will be little or no potential to track or reverse its spread.

The researchers propose to plant GE AC trees in wild forests so that the blight-tolerant GE trees would spread GE pollen and seeds, and cross-pollinate with remaining wild American chestnuts, spreading blight-tolerance to subsequent generations. They say that planting this genetically engineered tree will "restore" the species. Opponents argue, however, that the GE version of the American chestnut will not restore, but will replace the wild American chestnut.

It is not possible to assess the risks of releasing this GE tree because we do not know what would happen in highly complex forest ecosystems that are subject to climate change, over multiple generations of American chestnut trees, which can live for over 200 years. The impacts of its release on ecosystems are unknown, and cannot be known, until they are observed in the wild over decades and centuries.

The release of a GE American chestnut into forests would be a large-scale, irreversible experiment.

Additionally, locating and monitoring all the GE AC trees and their progeny in our forests will be nearly impossible, especially over a long period of time. In fact, there can be no comprehensive monitoring because the public will be able to freely plant and share the trees.

GE AC pollen and nuts could also spread across borders and jurisdictions. The impacts of this spread could include violations of Indigenous sovereignty across the range of the American chestnut.

Many animal species would interact with GE American chestnut trees if it is released. Direct impacts on animals could result from their consumption of pollen, nuts, leaves and other parts of the tree. Indirect impacts could also result from the disruption of habitat if the Darling 58 replaces other trees that have since become established in forests.

The observations and data submitted to the US Department of Agriculture for approval of the GE American chestnut are insufficient to assess the environmental risks. For example, the Darling 58 trees were only in field trials for three growing seasons.[181] Also, some studies relating to environmental impacts of the GE AC, such as those to examine if the leaves are toxic to tadpoles and aquatic insects, did not use the Darling 58, but earlier versions of the GE tree that have a lower expression of the blight-tolerant trait. Similarly, feeding studies to examine potential impacts on bees did not use Darling 58 pollen.[182]

Oversimplifying the complex

The blight tolerance trait that has been genetically engineered into the American chestnut tree may not even work.[183] The trait may not be stable over the long lifespan of the trees, and faced with variable conditions in the wild.

Furthermore, the survival of American chestnuts is additionally challenged by at least one other lethal pathogen, as well as a variety of other stresses including climate change.[184] Whether the Darling 58 will grow tall enough and live long enough to establish in forests, as the American chestnut once did, is unknown.

> “Public communications about the project to genetically engineer American chestnut have theatrically oversimplified the science and certainty involved.”
>
> — The Campaign to STOP GE Trees, Biofuelwatch and Global Justice Ecology Project[185]

Restoring the American chestnut tree

Dedicated volunteers and researchers in Canada and the US have been locating and studying American chestnut trees that have survived in the wild. Many prominent volunteer groups in both countries are also using conventional breeding to try to develop American chestnut that survive the blight, including by crossing the American chestnut with naturally resistant Chinese chestnuts. All these efforts will be undermined by the release of a genetically engineered American chestnut tree that will spread and cross-breed.[186]

> "A lot of important and valuable back cross breeding work [a kind of traditional breeding] is being done and we feel that this progress is threatened if these 94% American [chestnut] hybrids are contaminated by GE chestnuts that are allowed to spread their pollen with no controls or regulations as is proposed."
>
> — Lois A. Breault-Melican & Denis M. Melican, former board members of the Massachusetts/Rhode Island Chapter of The American Chestnut Foundation, in their letter of resignation from the Foundation[187]

The "test tree"

The GE American chestnut has been described by some supporters as a "test tree" or "poster child" that can be used to build public support for genetically engineered trees.[188] Proponents expect that a GE tree promoted for species restoration will be more acceptable to the public than trees genetically engineered for industrial purposes, and could therefore make way for these other uses.

The development of the GE American chestnut is already tied to industrial profit motives. Monsanto and ArborGen provided early financial and technical support, and Duke Energy, the largest electric power holding company in the US, funded the tree's development with an eye to future plantations to feed its wood pellet mills[189] and to provide high-quality lumber.[190] Duke Energy has said that GE American chestnut trees would also be "highly effective carbon-sequestering machines" and mentioned plans to get carbon credits for planting these GE trees on its environmentally degraded surface-mine sites in the Appalachia region of the Eastern US.[191]

PROFILE #3

Living Carbon: Hyping the "enhancement" of trees to sell a false climate techno-fix

STATUS: In early field tests, selling carbon credits

US company Living Carbon that says it has developed genetically engineered fast-growing poplar trees to capture more carbon. Field tests started in 2021 but the company is already selling carbon credits.

Living Carbon is a small venture capital company based in California, founded in 2019 based on the idea of genetically engineering trees to capture and store more carbon. The research is in its infancy, yet the company is already promoting and selling their idea. The concept is misguided and dangerous.

What

Living Carbon promotes genetically engineered "photosynthesis enhancement" in poplar trees to increase growth and thereby capture more carbon: "By increasing the efficiency of photosynthesis, we can help trees grow faster and act as partners in capturing more carbon from the atmosphere."[192] After growing for around 25 years, the GE poplar trees would be cut down and sold for timber.[193]

The company promotes "biotech-enhanced reforestation"[194] and has **a vision for "planting forests of Living Carbon trees**."[195] Co-founder Maddie Hall says, "Our goal is to draw down two per cent of global emissions by 2050 using approximately 13 million acres of land."[196] This is an ambitious sales pitch that assumes the success of their technology, regulatory approval for planting their GE trees, and access to 13 million acres of land (5.2 million hectares).

However, the only scientific paper available that discusses the research behind this GE tree is a 2022 company "white paper"[197] that is not peer-reviewed. Living Carbon reports finding a 53% increase in the biomass of some of the experimental GE poplar trees but this result is from just five months of tests under controlled indoor growing conditions.[198] The research does not show if the trees can continue to grow at this increased rate throughout their lifetime, or what else may happen to the trees because of the genetic changes. The measurements taken are not enough to support the paper's claim that, "Our results provide a proof-of-concept for engineering trees to help combat climate change."

The company promotes a wide range of other intentions and ideas that do not appear to have any substantial research behind them. The company says it has developed a metal accumulation trait that allows trees can to take up higher levels of metals in their roots[199] so they can be grown on "marginally productive land"[200] and it says it has started a "discovery project" to engineer a decrease in the rate of wood decomposition to prolong carbon storage,[201] and to inhibit rot for "permanent carbon storage."[202] Overall, the company states that its goal is to genetically engineer many common species such as Douglas fir and pine, as well as switchgrass and flax, with traits such as nitrogen fixation, salt tolerance, drought tolerance, and fire resistance.[203]

"The biological system is a powerful one when it comes to carbon drawdown and storage, but at the same time, is complex. Needless to say, it is a challenging goal to engineer trees to make a meaningful impact on climate change."

— Living Carbon, white paper, 2022[204]

When

"We don't have the luxury to wait for 30 years and make sure nothing can possibly go wrong."

— Professor Steven Strauss, Oregon State University, speaking about Living Carbon's trees, 2022[205]

Living Carbon has a research and development partnership with Oregon State University[206] where it **began field tests in 2021**.[207] The hybrid poplar tree that Living Carbon is experimenting with was "a gift" from Prof. Steven Strauss at the University[208] who also sits on the company's science advisory board.[209]

The company says that it will be evaluating the tree's photosynthetic performance and biomass accumulation with staff and students in 2022.[210] However, at the same time, the company says that in 2022 it will start to propagate its seedlings "at scale" in pilot planting projects on 3,200 acres in the US.[211]

In answer to the question, "Is this just theoretical or do you have trees in the ground?" the company refers to its university field tests and to over 3,000 acres of "carbon projects."[212] Much of their promotion leaves the impression that the GE trees are ready for planting or are already growing, however, **it is still illegal to plant these GE poplar trees**.

If the technology works as envisioned, the commercial release of their GE photosynthesis-enhanced trees may be 10 to 15 years away.[213]

How

"Without revenue from carbon credits or the purchase of seedlings, [Living Carbon's] photosynthesis-enhanced seedlings would not be supplied to the market"

– G-dash promotion of Living Carbon's carbon offset purchase, 2022[214]

Living Carbon does not have a GE tree to sell but it is already selling their idea.

Living Carbon is selling carbon offsets on its own website[215] and on least four other sites, including the Japanese website persefoni.com for US$40 per ton of CO2.[216]

These promotions could lead to a misunderstanding that the GE trees are already being planted commercially, and that they are proven to work as intended. For example, the description when purchasing offsets from the company's website says, *"Living Carbon has developed the world's first photosynthesis-enhanced trees to capture more carbon and generate more revenue per*

acre for US-based family forests. By subscribing, you directly contribute to planting on a 800-acre land in Georgia, as part of our first large-scale bioengineered reforestation project." [217] Elsewhere, the company clarifies that the Georgia planting of GE poplar is "an active research site."[218]

Living Carbon was selling carbon credits for "Living Carbon Hybrid Poplar Biotech-Enhanced Reforestation" but, by late July 2022, began switching their promotion to pine instead, renaming their offset project "Living Carbon Loblolly Pine Biotech-Enhanced Reforestation."

The company says its carbon project was "developed according to the Verra Verified Carbon Standard (VCS) ARR methodology."[219] However, it does not have a certified VCS project.[220]

Living Carbon's GE tree is not proven to work and yet the company has raised $15-million USD from investors hoping to profit from it.[221] **With or without a GE tree, Living Carbon is already making money.**

A false techno-fix

Despite the risks, such visions for technological fixes to the climate crisis are viewed by some as compelling; if the technologies actually work as claimed, they could avoid the complicated politics and social change involved in implementing some of the existing effective real solutions that might interfere with profit-making. But false techno-fixes are a distraction and delay. In this case, healthy diverse forests are already recognized as a proven solution. GE trees would put them in jeopardy. Living Carbon's proposal to fix trees is a profoundly misguided approach based on the idea that trees are not good enough and that humans can improve them.

The Forest Stewardship Council is Opening the Door to GE Trees

The Forest Stewardship Council's prohibition on the use of genetically engineered trees in its certification program has been an obstacle to commercial use of GE trees globally, but FSC is now planning to oversee GE tree field tests and is moving towards reviewing their ban.

"FSC is at the moment is a market barrier…But we are seeing a change in the certification bodies. FSC now allows forestry companies to look at research into GM trees. We are encouraging dialogue with FSC."

— Stanley Hirsch, Chief Executive Officer, FuturaGene (Suzano), 2012[222]

Ironically, it could be the Forest Stewardship Council (FSC) – the organization that claims to "promote the responsible management of the world's forests"[223] – that may open the door to the commercialisation of GE trees. Genetically engineered trees are currently prohibited in FSC certification, yet FSC is preparing to directly oversee field tests and taking concrete steps to allow GE trees.

Certification for forest protection

The Forest Stewardship Council is a leading certifier of forestry products in the world, along with the Programme for the Endorsement of Forest Certification (PEFC). These and other programs, sometimes called "Sustainable Forest Management Systems," provide certification of forestry products according to their own environmental and social standards. 39% of tree plantations in Brazil are certified by FSC and/or CerFlor/PEFC.[224]

Both the FSC and PEFC have prohibitions on the use of genetically engineered trees in their certification schemes, and both are under pressure from the major pulp and paper company Suzano[225] and university biotechnology tree researchers[226] to allow GE trees in their certification programs.

In order to be sold with the FSC logo, products must be produced from FSC-certified lands by companies that are FSC-certified, however, company activities carried out on non-certified lands are also subject to FSC standards. Currently, FSC prohibits certified companies from commercially growing GE trees on both certified and non-certified lands. **FSC names growing GE trees[c] as an "unacceptable activity."** Since 2011, FSC has, however, allowed companies to conduct GE tree field tests for research purposes on non-certified areas.

c The FSC "Policy for Association" names genetically modified organisms (GMOs) as prohibited but the FSC Board proposed a change to this language in 2021, to narrow the ban to genetically modified trees in particular.

FSC currently stands in the way of GE trees

FSC's decisions could determine the future of GE trees.

FSC's prohibition on GE trees currently stands in the way of FSC member company Suzano commercialising its recently approved GE eucalyptus in Brazil. Suzano can only commercially plant its GE eucalyptus if FSC overturns its policy, or if Suzano leaves the FSC.

Suzano is a member of FSC and PEFC, along with the companies **Stora Enso** (Sweden) and **International Paper** (US), all of whom are field testing GE trees. In 2012, the Chief Executive Officer of FuturaGene (Suzano's tree biotechnology company), Stanley Hirsch, called FSC certification "**a market barrier" to GE trees**.[227]

FSC's policies have a direct impact on the global development of GE trees. For example, FSC's 2011 decision to allow field tests of GE trees for research purposes in non-certified areas resulted in Suzano, and other member companies, expanding testing of GE trees.[228]

FSC is taking the first steps to accepting GE trees

"FSC will explore if it could play any role in responsible governance of genetic engineering."

— Forest Stewardship Council, 2021[229]

In 2021, FSC began a "genetic engineering learning process" to help FSC discuss "whether or not we should allow companies to be associated with FSC while using GE outside of any FSC certified operations."[230] Significantly, if the process moves ahead as proposed, **FSC would directly oversee selected outdoor field tests of GE trees** on non-certified areas.

> *"FSC intends to use this knowledge to determine whether it could develop a governance model ensuring rigorous safeguarding, risk management and shared value creation for genetic engineering in forestry in non-FSC certified area.* ***The learnings would also be used to update existing policies*** *and enable informed decision making for FSC and its members … in the future [emphasis added]."*[231]

In the first phase of its learning process, FSC established a panel of experts (June/July 2022) to develop "safeguards" that future FSC-governed field tests of GE trees would need to comply with.[232] The panel includes the GE tree researcher and promoter Prof. Steven Strauss of Oregon State University in the US who has campaigned for twenty years for FSC to remove its ban on GE trees.[233]

> "GE tree research should be allowed immediately on certified land, and GE trees proven by research to provide value should eventually be allowed in certified forests."
>
> — Steven Strauss et al, 2019[234]

This quote is from a statement written by GE tree researchers including many identified in this report as leading development efforts: Professors **Steven Strauss** at Oregon University who is working with Living Carbon; **William A. Powell** who is leading the pursuit for approval of the GE American chestnut in the US; **Wout Boerjan** who is running GE tree field tests in Belgium; **Sofia Valenzuela** from the University of Concepción in Chile; and **Zander Myburg** at the University of Pretoria in South Africa.

FSC rationalizes its new project by saying, **"Genetic engineering in forestry is likely to continue to happen with or without FSC"** and so FSC should discuss how it "can contribute to minimize the potential negative impacts and optimize the potential benefits of the technology in this sector."[235] However, as seen with FSC's decision to allow field testing for GE trees on the non-certified lands, what FSC deems allowable for certified companies has a huge impact on the advancement of GE technology. **It is clearly incorrect for FSC to see GE trees as inevitable and to ignore its own role in determining this future.**

It is incorrect for FSC to see GE trees as inevitable and to ignore its own role in determining this future.

Governments are Removing Regulation

"The only reliable method for preventing the escape of genetic material such as transgenes from genetically engineered trees is to not release such trees into the open environment."

— EcoNexus, Canadian Biotechnology Action Network, STOP GE Trees Campaign, ECOROPA, Global Justice Ecology Project, Global Forest Coalition, and World Rainforest Movement, 2008[236]

Already, governments are not equipped to assess the risks of releasing GE trees. For example, the National Academies of Sciences, Engineering and Medicine concluded that in the US, *"Forest health is not accounted for in the regulations for the use of biotechnology or for other approaches to mitigating forest tree insect pests or pathogens…There are no specific regulations or policies that those agencies apply to biotech trees."*[237]

Just as the development of GE trees is advancing, government regulation is retreating. Many national governments are reducing or removing their oversight of the field testing and commercial release of new genetically modified organisms (GMOs), including some GE trees.

There may be no future government regulation for some GE trees

The biotechnology industry has always argued for minimal or no government regulation of their products, but the emergence of the new genetic engineering techniques of genome editing, such as CRISPR-Cas, has been used as an opportunity to encourage significant changes to regulation.[238]

Many governments are revising their regulations of genetically modified organisms to exempt many new GMOs developed using genome editing. This means that some future GE plants may not be subject to independent government risk assessments, and some may be released into the environment without any notification to governments. In some countries, such as the UK and Canada, these new proposed changes are set to apply to GE trees.[239] In the US, there are already a number of exemptions that apply to GE trees based on details of *how* they were genetically engineered.[240]

While transgenic genome-edited plants are generally still regulated around the world, some countries, including the US, Australia, Japan and Argentina, have decided that many genome-edited organisms can be released onto the market with minimal or no government oversight if those GMOs have no foreign DNA remaining in them.[241]

Genome editing techniques may speed up the development of GE trees, and if many genome edited products are not regulated, we can expect companies to focus on using these techniques above others. Removing government risk assessments and other oversights will multiply and magnify the environmental risks of releasing GE trees, and it will shorten the time between their development and release.

GE trees demand use of the precautionary principle

Carefully assessing the potential impacts of using genetically engineered plants is particu-larly critical because these are living organisms that, once released into the environment, may be difficult or impossible to control or recall.[242] The risks are further compounded with GE trees (see Environmental Risks, pages 23-27). The question of whether to develop and release GE trees requires use of the precautionary principle, which prioritizes the protection of human health and the environment when faced with scientific uncertainty and gaps in our knowledge.

The high level of uncertainty and missing knowledge around GE trees was why, in 2008, the United Nations Convention on Biological Diversity (CBD) reaffirmed "the need to take a precautionary approach when addressing the issue of genetically modified trees."[243] The CBD urges governments to "authorize the release of genetically modified trees only after completion of studies in containment, including in greenhouse and confined field trials, in accordance with national legislation where existent, addressing long–term effects as well as thorough, comprehensive, science-based and transparent risk assessments to avoid possible negative environmental impacts on forest biological diversity."

The CBD also urges governments to "consider the potential socio-economic impacts of genetically modified trees as well as their potential impact on the livelihoods of indigenous and local communities." These considerations are missing from regulation in most countries.

The frequency and diversity of escape and contamination incidents with GMOs shows that contamination risks cannot be managed by current government regulation or by industry programs.[244] **The only way to prevent contamination from certain GMOs is to stop their release.**

The biotechnology industry appears to agree that contamination will occur because it advocates for governments to adopt "Low Level Presence" policies that would **accept GE contamination**. Fourteen countries have signed the "International Statement on Low Level Presence," including the US, Canada, Brazil, Chile, Indonesia, South Africa, and Australia.[245]

Ultimately, **some GMOs may simply be too risky to develop and release**. Some GMOs, such as many GE trees, would be too prone to escape, and others would have consequences that are too serious if escape occurs.

Conclusion

Research into GE trees has been accompanied by protest around the world. Diverse civil society, farmer, and Indigenous peoples' groups have protested and disrupted government meetings and tree biotechnology industry conferences, and continue to co-publish letters denouncing GE tree developments. Field tests and greenhouse experiments have been sabotaged in the UK, Belgium, Zealand, Canada, the US, and Brazil. When Brazil approved the first GE eucalyptus tree in 2015, protests took place at Brazilian consulates and embassies around the world.

This global opposition continues because the release of genetically engineered trees would be a profound threat to forests and forest ecosystems, as well as to many local communities and Indigenous peoples. The gaps in our understanding of genetic engineering, tree biology, and forest ecology conspire to build a profile of tremendous uncertainty. At the same time, the enormous ability of trees to spread pollen and seeds increases the reach of potential environmental and social impacts across national borders and in violation of Indigenous sovereignty. Genetically engineered trees would also perpetuate environmentally and socially destructive industrial plantation production that contributes to the climate crisis. Instead of moving towards a climate solution, genetically engineered trees would add unnecessary risks to forests, with possible irreversible impacts.

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