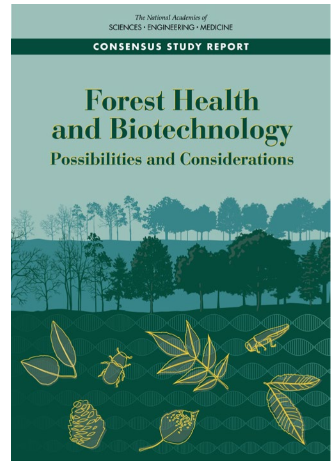
Consensus Study Report

January 2019

HIGHLIGHTS

Forest Health and Biotechnology: Possibilities and Considerations



Biotechnology has the potential to help mitigate threats to North American forests from insects and pathogens through the introduction of pest-resistant traits to forest trees. However, challenges remain: the genetic mechanisms that underlie trees' resistance to pests are poorly understood, the complexity of tree genomes makes incorporating genetic changes a slow and difficult task, and there is a lack of information on the effects of releasing new genotypes into the environment. This report recommends research and investment to improve the utility of biotechnology as a forest health tool.

Between the 18th century and the first half of the 20th century, two introduced pathogens caused blight and root rot in the iconic American chestnut, nearly wiping out the species. The loss of an estimated 4 billion trees caused adverse effects on other species and people who depend on chestnut tree products. Over the same period, white pine blister rust decimated white pines in the western United States. In this century, most eastern North American species of ash began succumbing to an insect pest introduced from Asia, the emerald ash borer. Losses in the form of timber value and removal of urban trees made the borer a costly forest pest. These are just a few of the North American tree species that have been functionally lost or are in jeopardy of being lost due to pest outbreaks.

Today, forests and their valued services and resources are threatened as never before. While outbreaks of native forest pests can help renew forest ecosystems and maintain biodiversity, new pressures are changing that dynamic. Expanded human mobility and global trade are providing pathways for the introduction of nonnative pests for which native tree species may lack resistance. At the same time, climate change is extending the geographic range of both native and nonnative pest species. Shorter cold seasons and fewer extreme cold spells allow insects to move into regions that previously had been unsuitable, help pathogens survive over the winter, and change the life cycles of the insects that disperse pathogens.

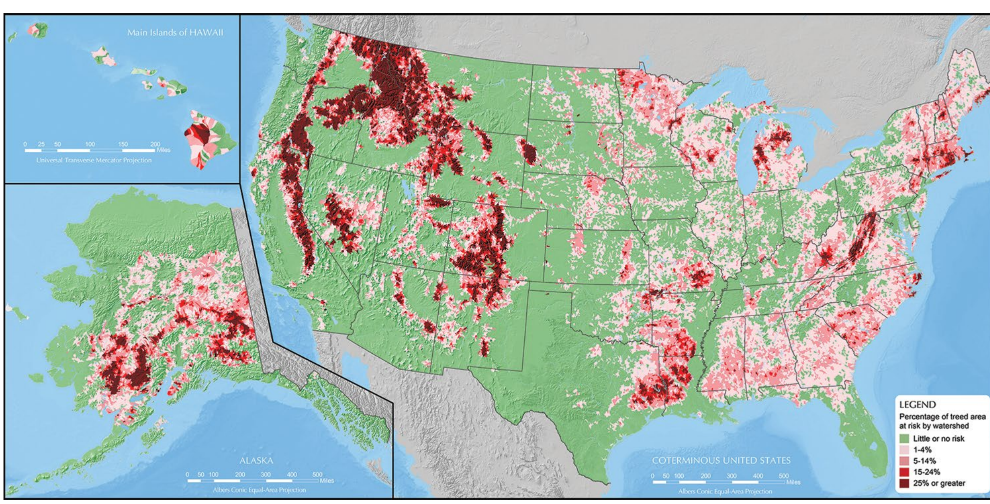


FIGURE 1

The most recent national insect and disease risk assessment, conducted in 2012 by the Forest Service of the U.S. Department of Agriculture estimated that almost 7 percent of all forested or treed land in the United States (81.3 million acres) are at risk of losing at least 25 percent of tree vegetation between 2013 and 2027 due to insects and diseases.

SOURCE: Krist et al. (2014).

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Given the growing threat to North American forests, the U.S. Department of Agriculture, the U.S. Environmental Protection Agency, and the U.S. Endowment for Forestry and Communities requested the National Academies of Sciences, Engineering, and Medicine form a committee to consider the potential for biotechnology to mitigate threats to the health of the nation's forests.

Galleries in ash tree caused by emerald ash borer larva.

Source: iStock Photo

USING BIOTECHNOLOGY TO MITIGATE THREATS TO FOREST HEALTH

A number of strategies are employed to fight forest pests, for example, preventing arrival of invasive species, site management practices, the use of biological control agents, and selective-breeding programs that promote trees with genetic characteristics that allow persistence despite the presence of damaging insects and pathogens. Biotechnological tools could also provide a means to introduce or modify genes in trees to increase resistance to pests. As of 2018, American chestnut and hybrid poplars were the only two tree species on which biotechnology had been used for forest health purposes in the United States, and these trees were still in field trials.

Many challenges to using biotechnology remain. The genetic changes to confer pest resistance are not easy to identify or implement. Currently, not enough is known about the mechanisms of pest resistance to efficiently identify the genes involved, although it is thought that some resistance traits involve hundreds or thousands of genes with complex interactions. Further, tree genomes are often huge in size and highly repetitive, which causes difficulties in DNA sequencing and genome assembly (pine genomes can exceed 20,000 Mega-basepair (Mbp), in contrast to the 135 Mbp genome of Arabidopsis, a plant commonly used in breeding experiments).

There is substantial genetic variation within many tree species in response to environmental differences. For example, trees in different portions of a species' geographic range may have adaptations to local conditions. In addition to evaluating the utility of the resistance trait added to a modified tree, researchers will also need to test the viability of biotech forest trees in the range of environments in which they will live. It will also be important to assess the effects of biotech forest trees on other species in the environment.

To address forest health, genetic resistance in trees needs to be durable over hundreds of years. Populations of trees with several different types of resistance would have the best chance of meeting this durability goal. Understanding the relationship of spatial distributions, genetic diversity, and local adaptation will be important to capture the maximum possible genetic variation within the species of interest.

Recommendations

- Sufficient investment of time and resources should be made to successfully identify or introduce resistance into tree species threatened by insects and pathogens.
- More research should be conducted on the fundamental mechanisms involved in trees' resistance to pests and adaptation to diverse environments under a changing climate.
- The deployment of any biotechnological solution with the goal of preserving forest health should be preceded by developing a reasonable understanding in the target species of (a) rangewide patterns of distribution of standing genetic variation, if known; (b) magnitude of local adaptation; and (c) identification of spatial regions that are vulnerable to genetic offset.
- Entities concerned about forest health should devote resources to identifying resistant trees within a population that have survived a pest outbreak. Research to understand the role of resistance in coevolved systems from the perspective of a global host–pest system, where the nonnative pathogen or insect originate, would help guide efforts in North America.
- Research should address whether resistance imparted to tree species through a genetic change will be sufficient to persist in trees that are expected to live for decades to centuries as progenitors of future generations.

IMPROVING IMPACT ASSESSMENT

Any decision framework for assessing the potential impacts of introducing a biotech tree on forest health will need to enable evaluation of trade-offs between positive, negative, and neutral impacts and incorporate sources of uncertainty associated with those evaluations. An impact assessment framework provides such a process for combining both an assessment of ecological risk to forest function and consideration of the full set of ecosystem services lost or maintained with or without the intervention. Ecosystem services are the goods and services that are of value to people, provided wholly or in part by ecosystems.

The longevity of trees and the large areas of land that would be involved in any planting of trees mean that predictive modeling will be needed to evaluate the potential impact of using a biotech approach. Tracking sources of uncertainty will help quantify the reliability of assessments, estimate the predictive capacity of the model, and identify data needs.

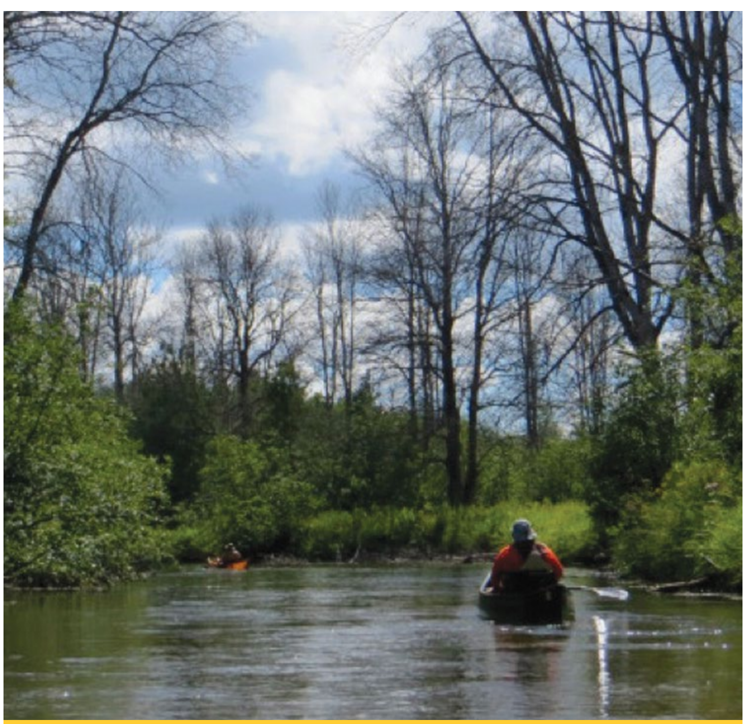
Incorporating climate change scenarios into modeling efforts could improve species restoration efforts by representing uncertainty about the suitability of habitats in the future. As field trials return more data and models improve, decisions based on those tools will be continually adjusted to ensure they maximize forest health benefits and minimize risks.

Recommendations

- Federal agencies should continue efforts to improve the incorporation of all components of ecosystem services into the integrated impact assessment.
- Modeling and other approaches should be developed to address questions about biotech tree gene flow, dispersal, establishment, performance, and impact that are precluded where flowering of field trial material is restricted.
- Models for tree biotech assessments should identify, quantify, and account for sources of uncertainty.
- An adaptive management approach to forest health should be used to ensure continued learning and address impacts to both the environment and society.
- Impact assessment should be a continuous and iterative process.

THE REGULATORY SYSTEM FOR BIOTECH TREES

The report's authoring committee was not tasked with suggesting changes to the U.S. regulatory system. However, the main regulatory agencies of biotech plants—particularly the U.S. Department of Agriculture and the Environmental Protection Agency—could explore whether an assessment of impacts on ecosystem services could be incorporated into their oversight responsibilities. Such assessments should be done for all approaches designed to address forest health, not just biotechnology.



Ash trees killed by emerald ash borer. Source: R. Papps

Recommendation

- Regulatory agencies should explore ways to incorporate into their regulatory oversight responsibilities the ability to assess the impact on ecosystems for biotech and non-biotech products developed for improving forest health.

RESEARCH AND INVESTMENT NEEDS BEYOND BIOTECHNOLOGY

Biotechnology is one of many approaches to addressing forest health and should not be pursued to the exclusion of other forest health management options. It may be necessary to integrate multiple management practices for positive impact. Further, insects and pathogens can evolve over time and can be reintroduced, and some management practices require decades for successful development and deployment. Therefore, all management approaches will require sustained resources and time.

Integrating biotechnology into selective-breeding programs could help capture existing genetic diversity, making biotechnology a more useful tool. However, many forest tree species under severe pest attack do not have adequate and sustained breeding programs. To guide the development and potential deployment of pest-resistant trees effectively, human capital will be needed in professions such as tree breeding, genetics, computational biology, forest pathology and entomology, invasion biology, and rural sociology.

Interventions to address forest health using biotechnology should be considered not only as a matter of technical feasibility but also as relevant to social values. Ongoing controversy over the use of biotechnology in agricultural crops demonstrates the significant concerns likely among segments of society about the potential use of biotechnology in trees. These views should be recognized as important parts of the public dialogue about the potential for the use of biotechnology to address forest health.

Biotechnical interventions for forest health are likely to impose varying risks, costs, and benefits on different groups of people over time, in particular on indigenous groups. Where the development and deployment of biotech trees is being considered, these social impacts should be investigated, research into the perspectives of individuals and communities likely to be affected should be carried out, and affected communities should be engaged transparently and respectfully. To take these concerns meaningfully into account, a conceptual framework is needed to complement impact assessment based on ecosystem services in order to account for forests' intrinsic value, that is, the value they have for their own sake.

Recommendations

- Investment in effective prevention and eradication approaches should be the first line of defense against nonnative species in efforts to maintain forest health.
- Management for forest health should make use of multiple practices in combination to combat threats to forest health.
- Public funders should support and expand breeding programs to encompass the genetic diversity needed to preserve tree species essential to ecosystem services.
- Investment in human capital should be made in professions, including tree breeding, forest ecology, and rural sociology, to guide the development and potential deployment of pest-resistant trees effectively.
- More studies of the societal responses to the use of biotechnology to address forest health threats in the United States are needed. Such studies might investigate (1) the responses of different social and cultural groups to the deployment of biotechnology in forests, (2) the stability and consistency of attitudes toward the different applications of biotechnology in a range of circumstances, (3) differences in attitudes toward biotechnology strategies (e.g., cisgenesis, transgenesis, genome editing), (4) the relationship between deeper value orientation and attitudes toward biotechnology, and (5) how people consider trade-offs between values such as wilderness and species protection.
- Studies of societal responses to the use of biotechnology to address forest health threats should be used to help in developing a complementary framework to ecosystem services that takes into account intrinsic values, related spiritual and ethical concerns, and social justice issues raised by the deployment of biotechnology in forests.
- Respectful, deliberative, transparent, and inclusive processes of engaging with people should be developed and deployed, both to increase understanding of forest health threats and to uncover complex public responses to any potential interventions, including those involving biotechnology.
- Developers, regulators, and funders should experiment with analytical-deliberative methods that engage stakeholders, communities, and the public.

COMMITTEE ON THE POTENTIAL FOR BIOTECHNOLOGY TO ADDRESS FOREST HEALTH

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For More Information . . . This Consensus Study Report Highlights was prepared by the National Academies of Sciences, Engineering, and Medicine based on the Consensus Study Report *Forest Health and Biotechnology: Possibilities and Considerations* (2019). The study was sponsored by the U.S. Endowment for Forestry and Communities; the U.S. Department of Agriculture's Agricultural Research Service, Animal and Plant Health Inspection Service, Forest Service, and National Institute of Food and Agriculture; and the U.S. Environmental Protection Agency. Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of any organization or agency that provided support for the project. Copies of the Consensus Study Report are available from the National Academies Press, (800) 624-6242; http://www.nap.edu or via the Board on Agriculture and Natural Resources web page at http://www.nationalacademies.org/banr.

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