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Slides adapted from AAAS Meeting, Washington DC 2/16/19

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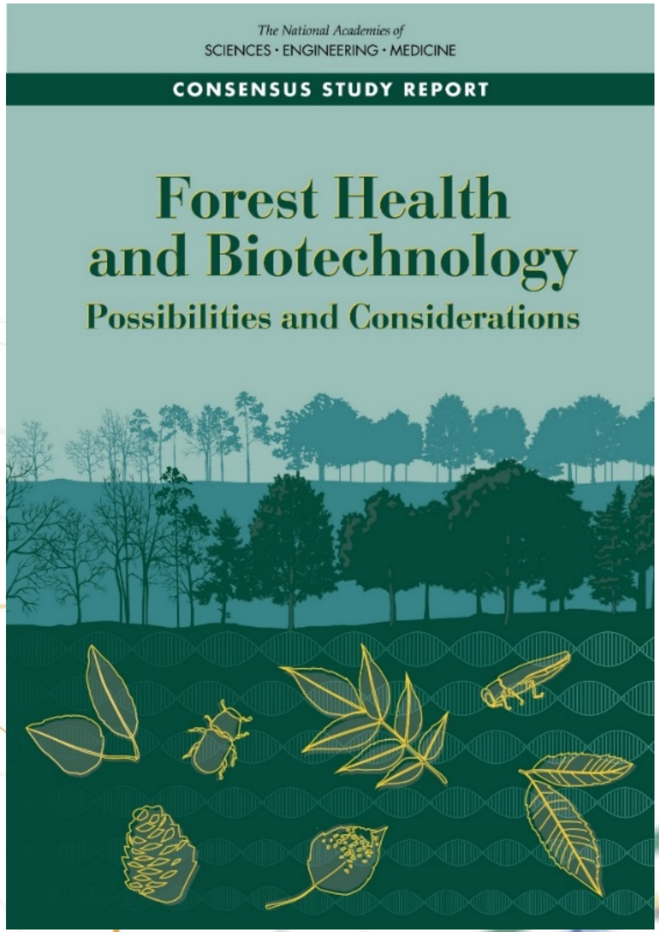

The Potential for Biotechnology to Address Forest Health

(NASEM Report)

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PA/NJ TACF Spring Growers Webinar
March 21, 2020

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#ForestBiotechStudy

Committee on the Potential for Biotechnology to Address Forest Health

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Jeanne Romero-Severson, University of Notre Dame

Ronald R. Sederoff (NAS), North Carolina State University (emeritus)

Diana L. Six, University of Montana

Richard A. Sniezko, U.S. Forest Service

Forest population genetics
Tree gene flow and reproductive biology
Genomics and quantitative genetics
Forest ecology and entomology
Selective breeding and genetic engineering of forest trees
Sociology and ethics
Economics
U.S. environmental and regulatory law

Impetus for the Study

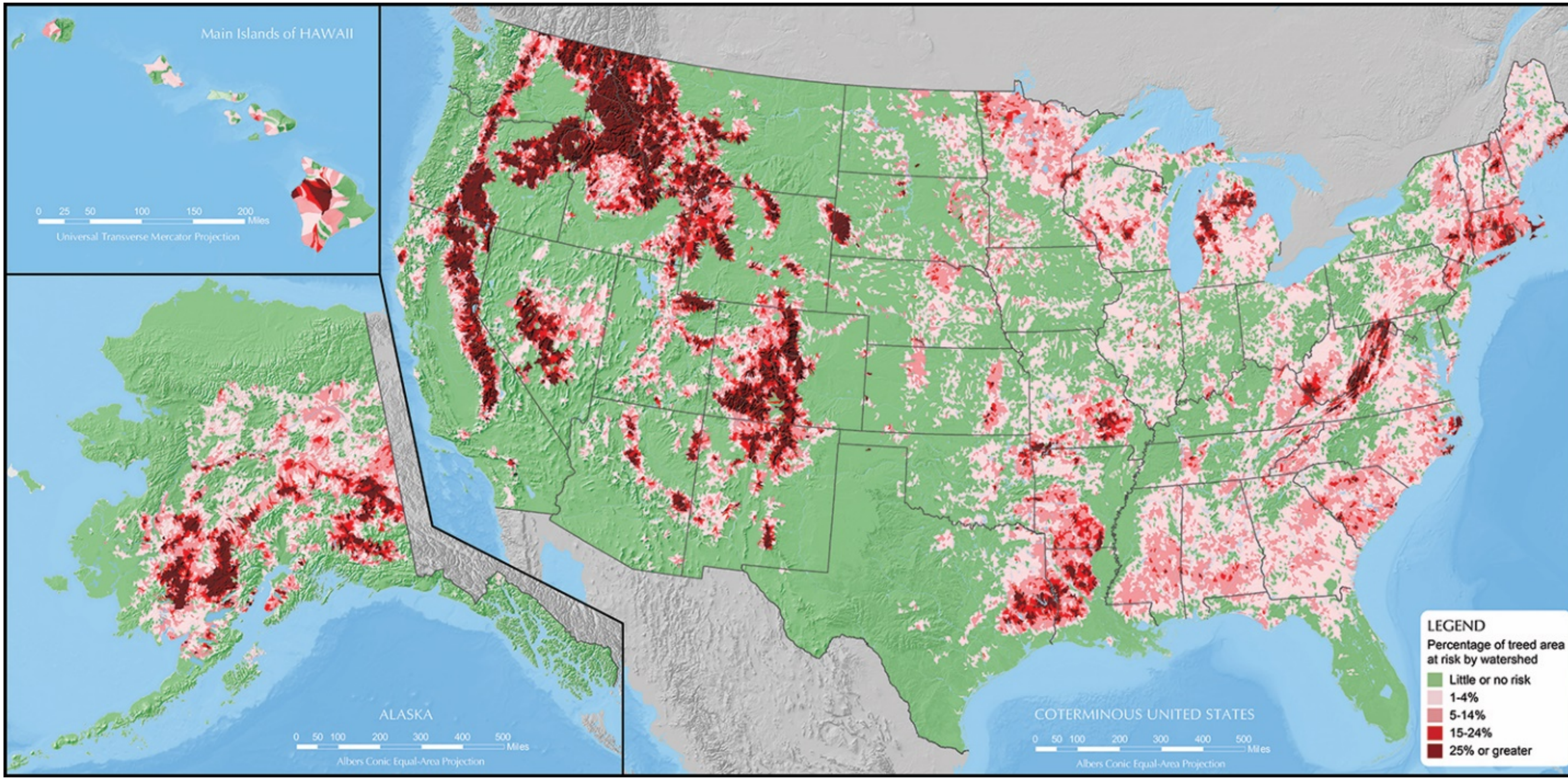
- A healthy forest sustains ecosystems over time and space and provides value to humans
- Forest health is threatened by invasive pests, exacerbated by climate change
- Existing regulatory system has not yet reviewed biotech plants to be released into unmanaged forest ecosystems
- Public sector plays an important role in protecting forest health

Definition of Forest Health

A condition that sustains the structure, composition, processes, function, productivity, and resilience of forest ecosystems over time and space.

An assessment of this condition is based on the current state of knowledge and can be influenced by human needs, cultural values, and land management objectives.

Increasing Threats to Forest Health: Insect Pests and Pathogens

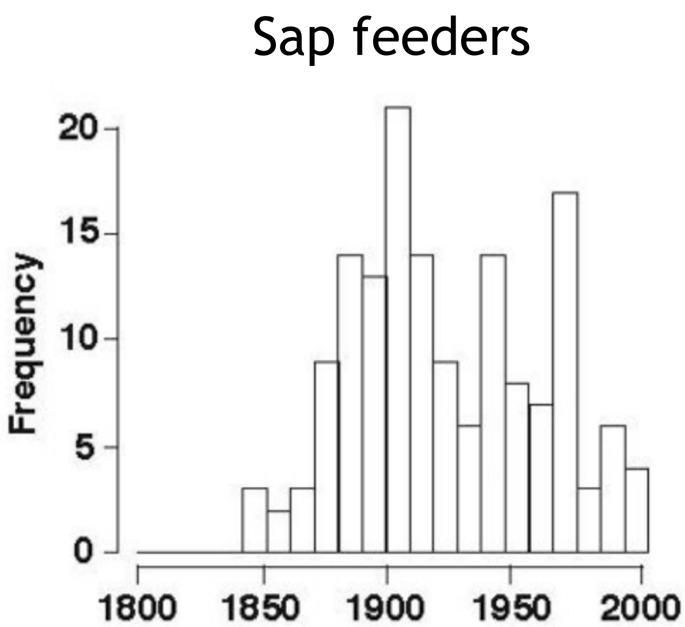


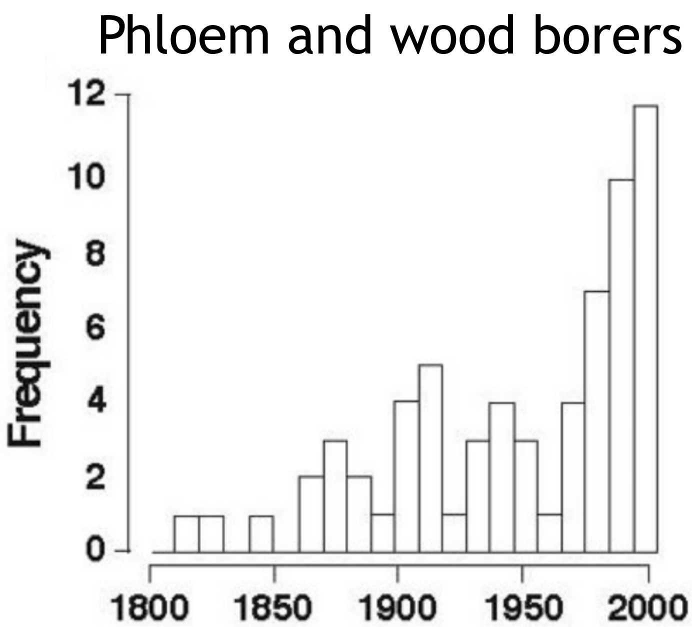
Dark red areas represent estimates of at least 25% loss of tree vegetation between 2013 and 2027 due to insects and diseases.

SOURCE: Krist et al., 2014.

Harmful Introductions: Nonnative Insect Pests and Pathogens

- 455 known insect species introductions since 1600s
- 62 high-impact insect species
- 16 high-impact pathogen species





SOURCE: Aukema et al., 2010.

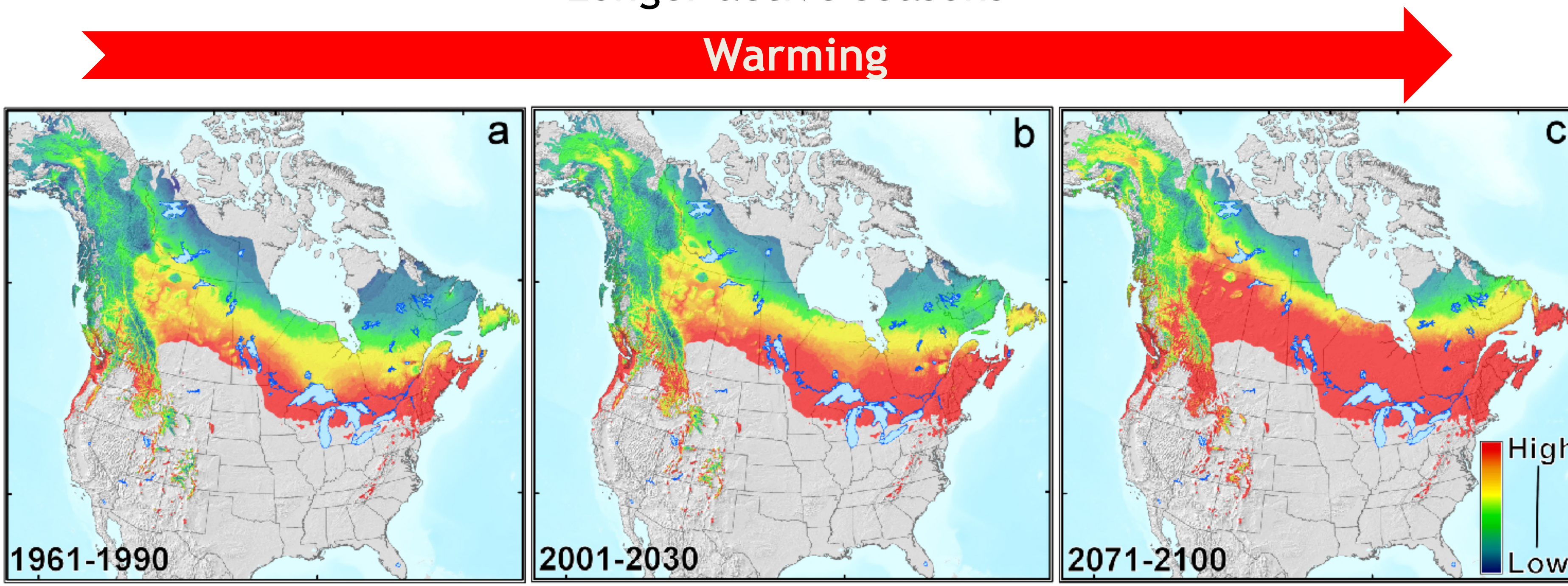
Lack of Resistance: Novel Insect Pests and Pathogens

Ash trees killed by emerald ash borer

SOURCE: R. Papps

Climate Change: Synergistic Effects

- Warmer winters
- Fewer cold spells
- Longer active seasons



Estimated development of spruce beetle in a single year in North American spruce forests. SOURCE: Bentz et al. 2010

More than One Threat: Diseases, Insect Pests, Climate

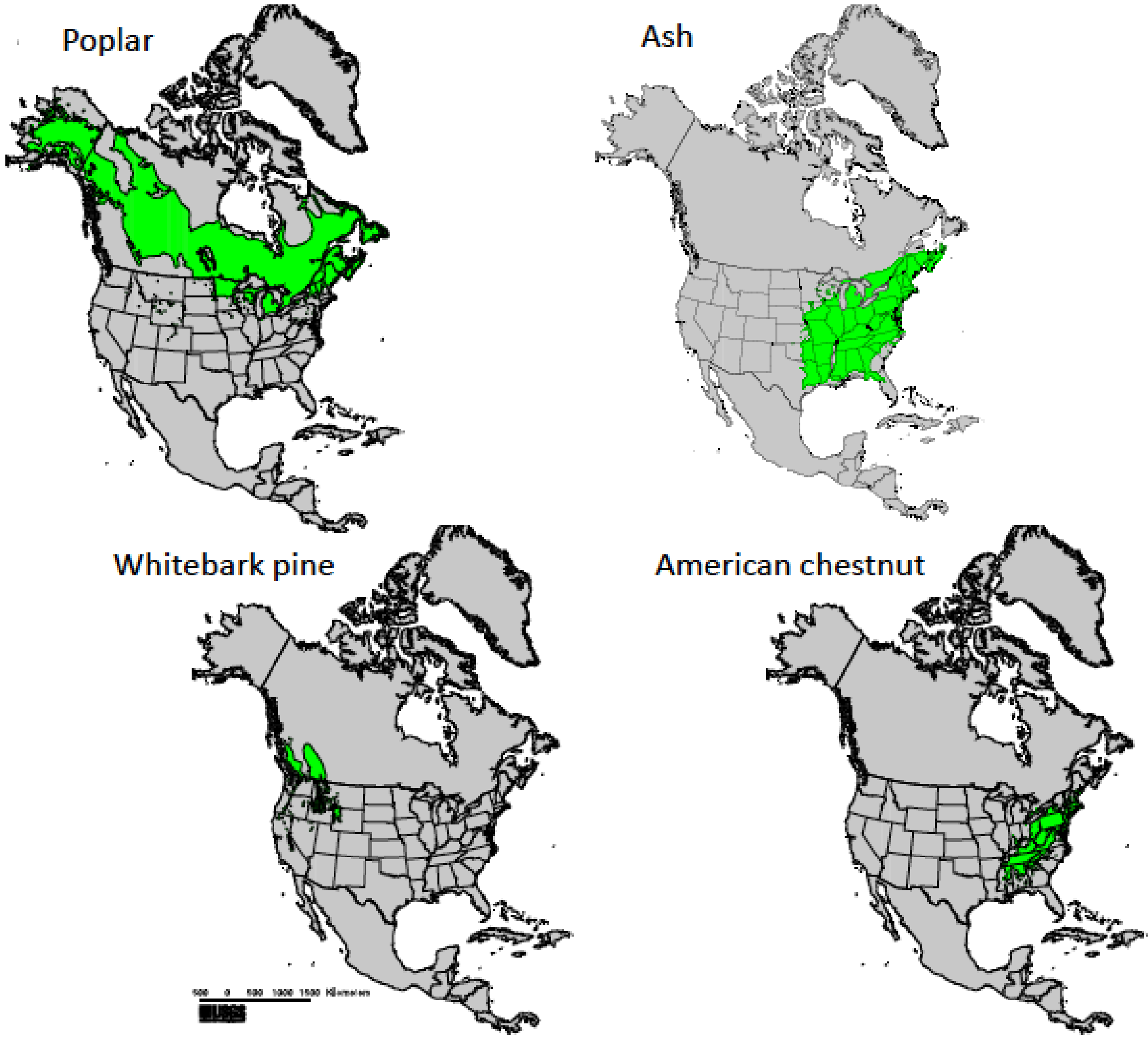
Chestnut: Chestnut Blight, Root Rot

SOURCE: U.S. Forest Service

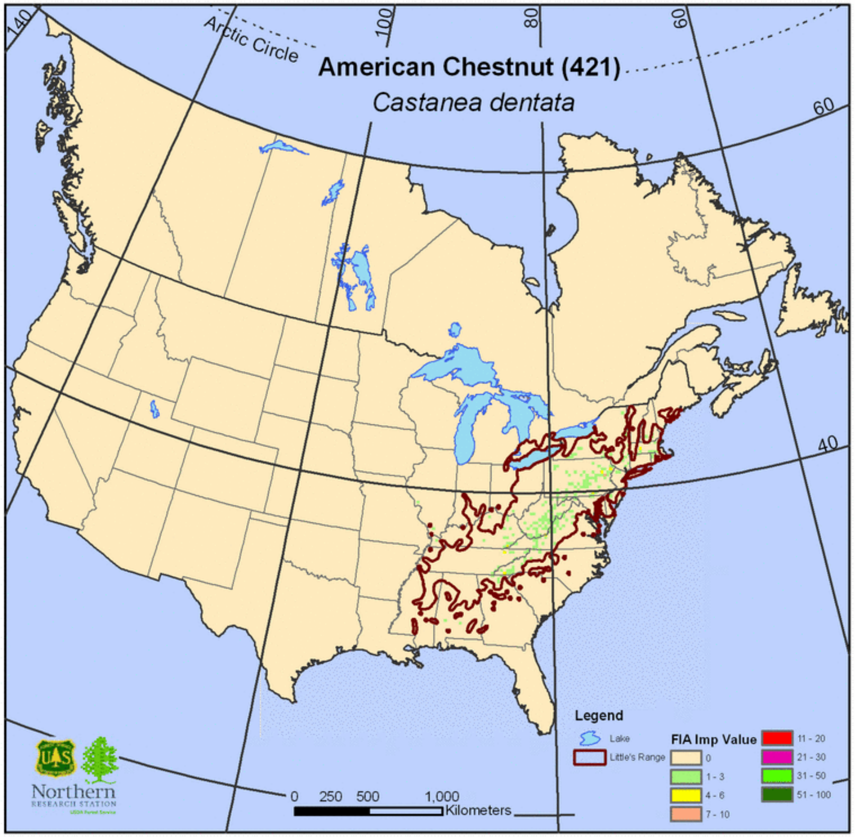
Whitebark Pine: White Pine Blister Rust, Mountain Pine Beetle

SOURCE: R. Sniezko

Case Studies



American Chestnut – *Castanea dentata*



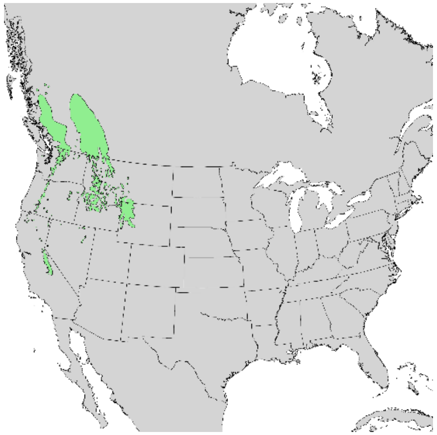
SOURCE: https://www.fs.fed.us/nrs/atlas/tree/curr_ivlittlef_421.gif

Chestnut: Chestnut Blight, Root Rot

SOURCE: U.S. Forest Service

Whitebark Pine - *Pinus albicaulis*

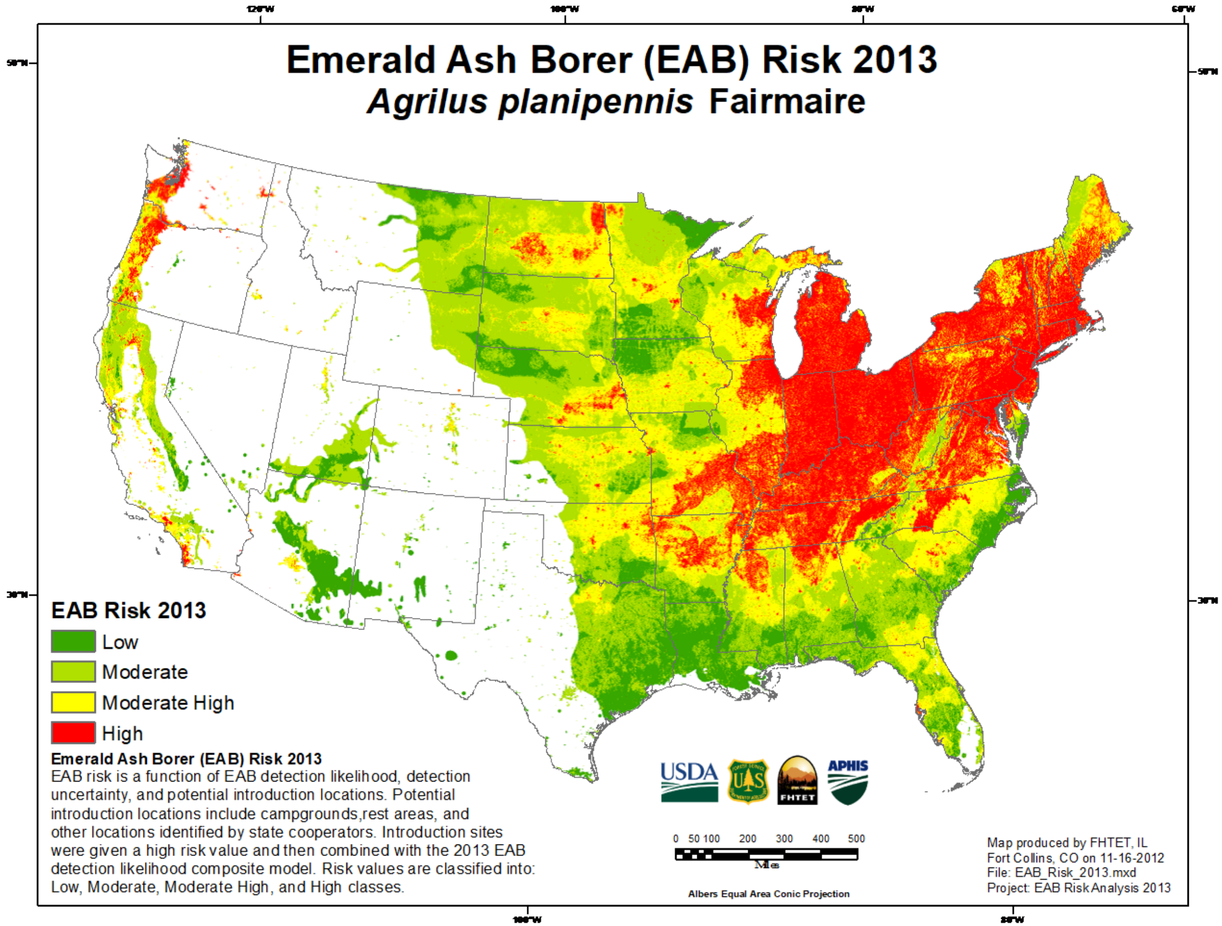
Whitebark Pine: White Pine Blister rust
SOURCE: R. Sniezko



SOURCE: Elbert L. Little, Jr., of the U.S. Department of Agriculture, Forest Service

Ash – *Fraxinus* spp

Ash: Emerald Ash Borer
https://www.istockphoto.com/photo/dead-tree-trunk-showing-tracks-of-emerald-ash-borer-larvae-gm936680918-256245154



Poplars – *Populus* spp

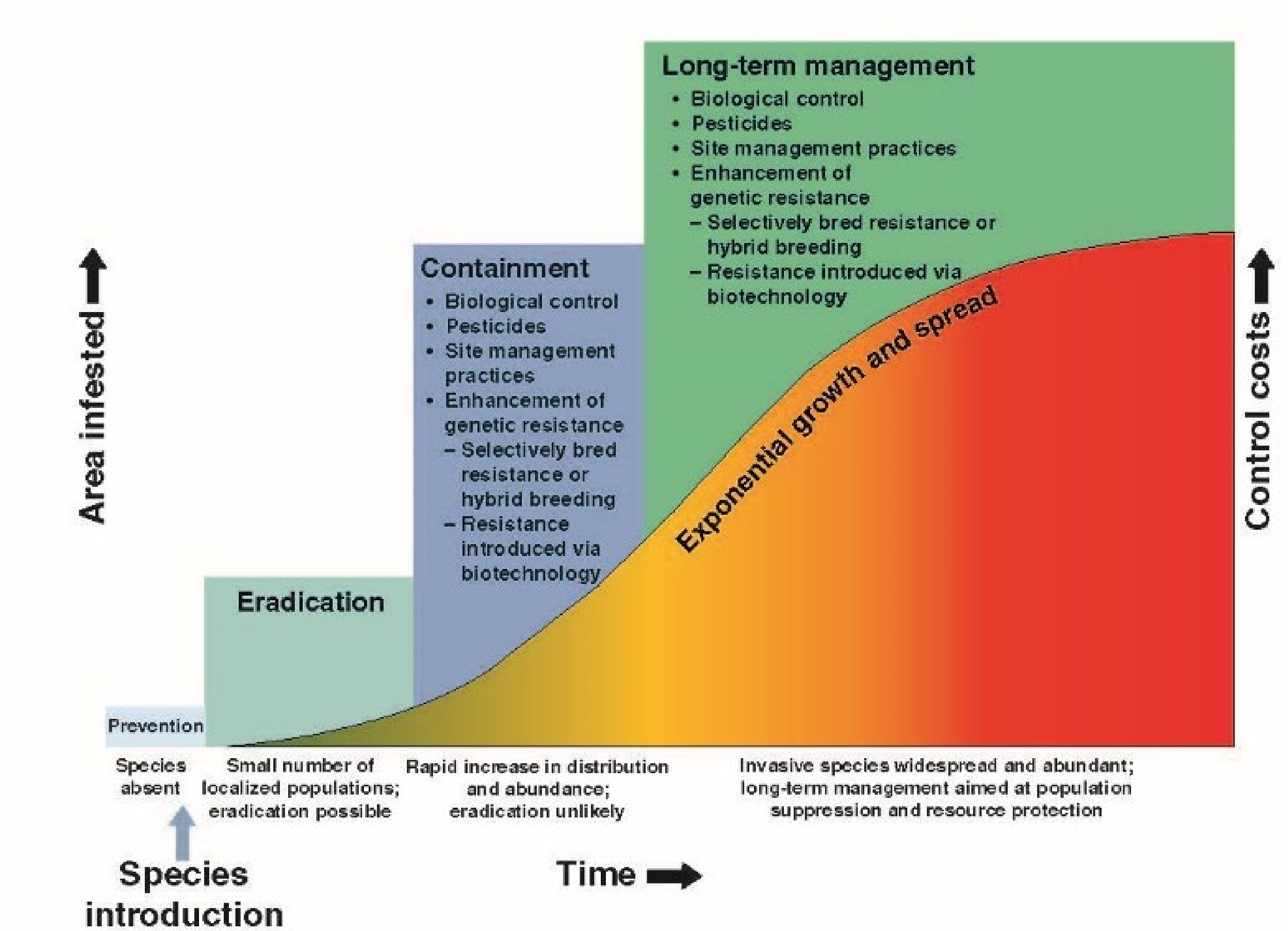
Balsam poplar

SOURCE: Elbert L. Little, Jr., of the U.S. Department of Agriculture, Forest Service

Poplars: Canker Disease.

Photo credit: S. Simon

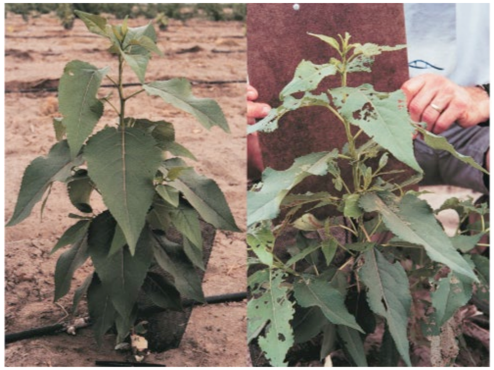
Measures to Curtail the Attacks from Insect Pests and Pathogens



SOURCE: Adapted from GAO, 2015.

Using Biotechnology to Mitigate Threats to Forest Health

- **Biotechnology provides a means to introduce or modify genes in trees to increase resistance to pests**
  - **Several tree species have been altered with biotechnology for forest health purposes**
  - **None have been deregulated and released into the wild**
- **Challenges to using biotechnology include:**
  - **Lack of knowledge about the mechanisms of pest resistance in trees**
  - **Large genome size and long life span**
  - **Lack of information on the effects of releasing new genotypes into the environment**
  - **Need for resistant trees to be suitably adapted to specific environments**



Bt Populus Control

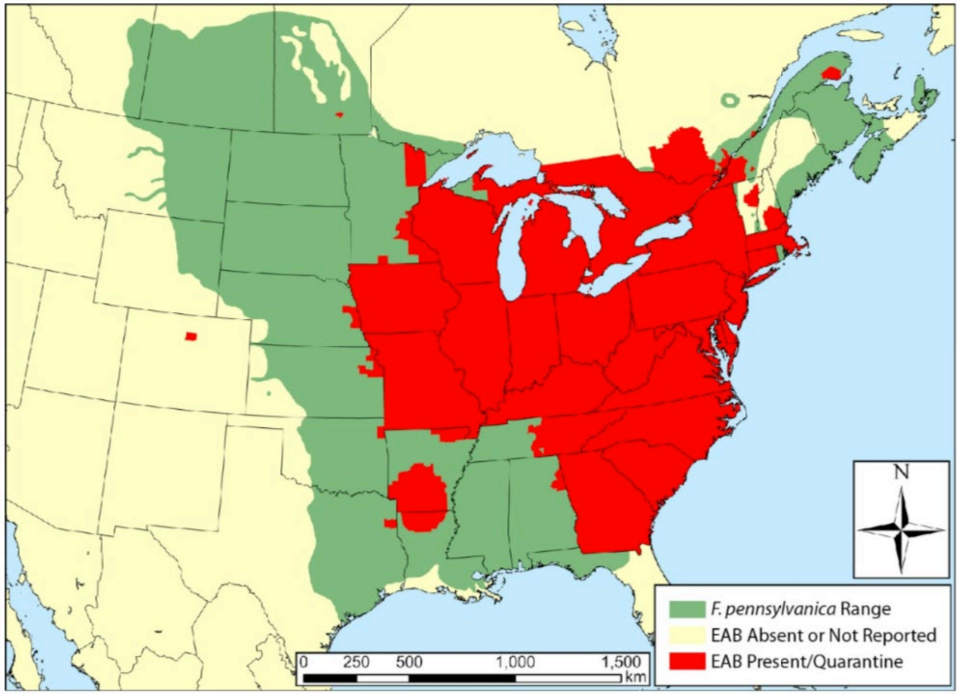
SOURCE: Steve Strauss, Oregon State U.

Transgenic American chestnut (center) and blight-killed control (left), with Chinese chestnut (right)

SOURCE: Bill Powell, SUNY-ESF

Using Biotechnology to Mitigate Threats to Forest Health Recommendations

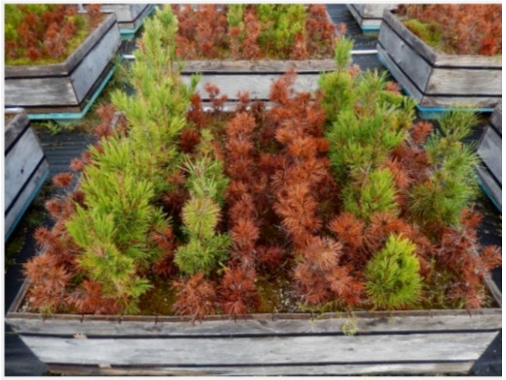
- **Investment in identifying or introducing resistance into tree species threatened by insects and pathogens**
- **Research on fundamental mechanisms of resistance to pests and adaptation to diverse environments under a changing climate**
- **Deployment of biotech solutions requires an understanding of adaptive variation in the target species**
  - **Rangewide patterns of distribution of standing genetic variation**
  - **Magnitude of local adaptation**
  - **Spatial regions that are vulnerable to genetic offset**



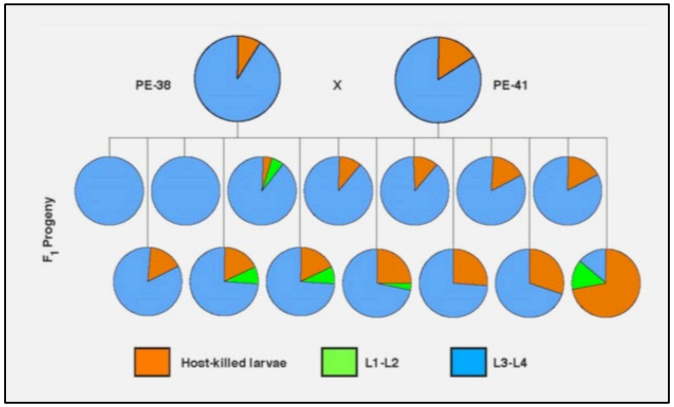
Range of green ash and extent of emerald ash borer invasion as of May 17, 2018
SOURCE: Devin Shirley, Notre Dame University

Using Biotechnology to Mitigate Threats to Forest Health Recommendations

- Identify resistant trees within a population that have survived a pest outbreak.
- Study the role of resistance in coevolved systems from the perspective of a global host-pest system, where the nonnative pathogen or insect originate
- Address whether resistance will persist in trees that are expected to live for decades to centuries as progenitors of future generations.



Testing whitebark pine families for resistance to blister rust
SOURCE: R. Sniezko, US Forest Service



Larval-killing response in progeny of lingering ash
SOURCE: J. Koch, US Forest Service

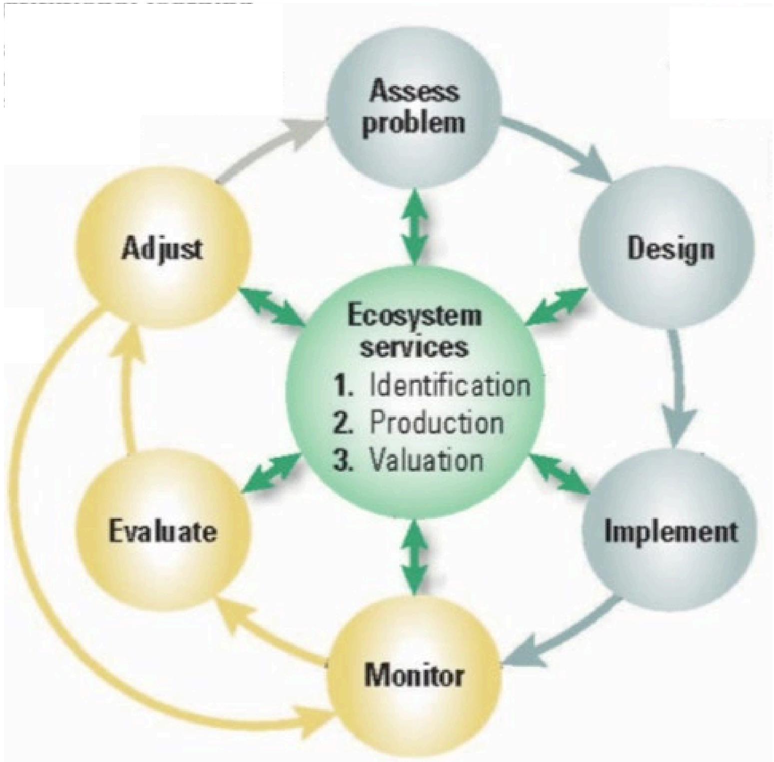
Improving Impact Assessment

- **Decision framework should evaluate trade-offs among positive, negative, and neutral impacts**
- **Consider ecological risk to forest functions as well as ecosystem services lost or maintained with or without forest health**
- **Field trials are essential to provide estimates of**
  - **Gene flow**
  - **Durability and effectiveness of resistance**
  - **Seed generation and dispersal**
  - **Genetic fitness**
  - **Ecosystem impacts**

Field trial of transgenic *Populus*
SOURCE: Macaya-Sanz et al., 2017, *Biotech for Biofuels* 10:253

Improving Impact Assessment Recommendations

- Federal agencies should continue to improve **incorporation of ecosystem services** into 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 iterative **adaptive management approach** to forest health should be used to ensure continued learning and address impacts to both the environment and society.
- Investment in **human capital** is needed in tree breeding, forest ecology, and rural sociology.



Integrating ecosystem services with risk assessment in an adaptive management framework

SOURCE: Epanchin-Niell et al., 2018. USGS Circular 1439

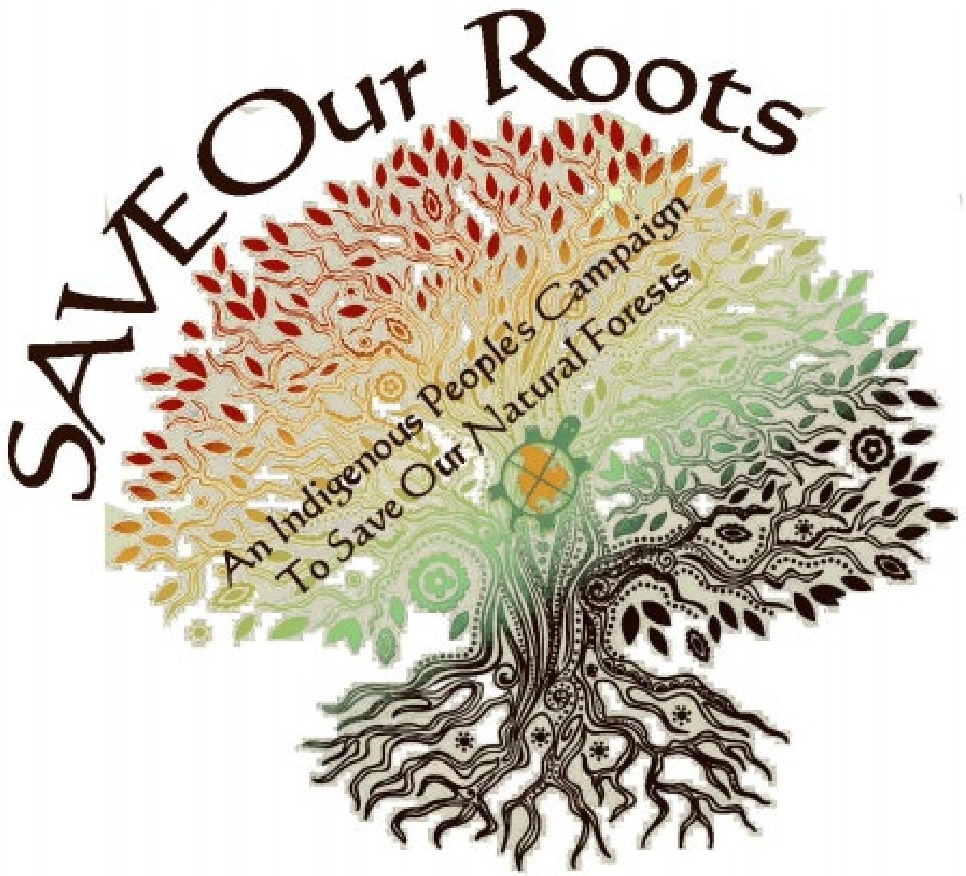
Biotech trees are designed to spread and persist in unmanaged environments

Photo by Tom Harpel http://www.flickr.com/photos/tomharpel/1769680/

SOURCE: https://www.arcticapples.com/contest-name-the-arctic-apples-orchard/

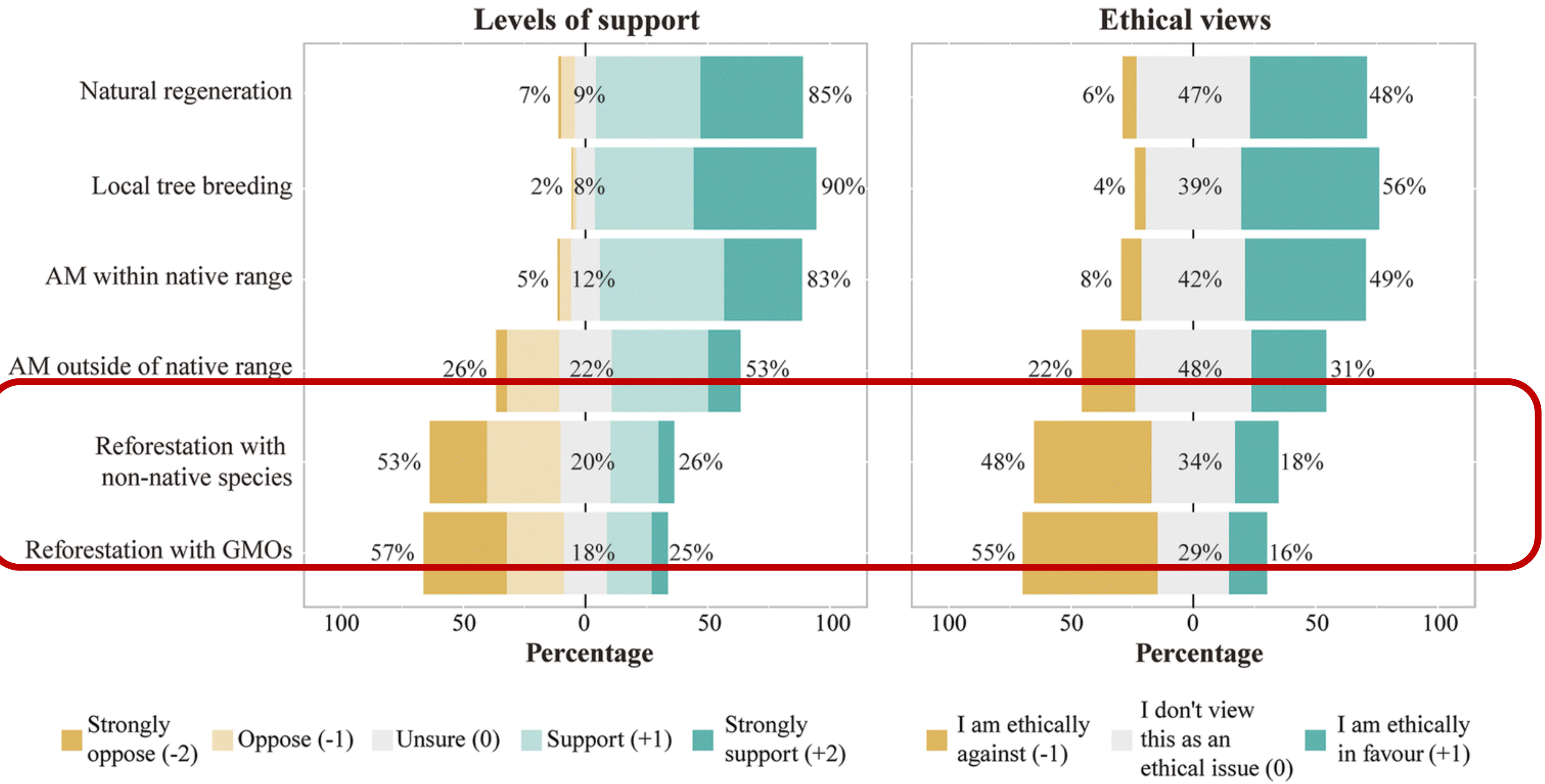
Values extend beyond ecosystem services framework

- Intrinsic value
  - Spiritual
  - Kinship
- "Wild-ness"
- Social justice
  - Distributive
  - Procedural
  - Intergenerational



SOURCE: Indigenous Environmental Network, saveourroots.org

Public attitudes about forest biotechnology are mixed

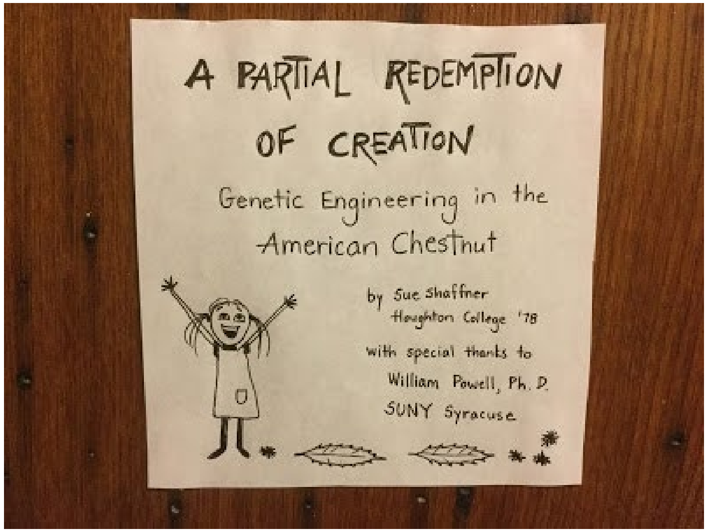


SOURCE: G. Petersen St-Laurent, et al. 2018. “What risks matter? Public views about assisted migration and other climate-adaptive reforestation strategies.” *Climatic Change* 151 (3-4): 573-87. Fig 2.

More knowledge about societal responses to biotech trees for forest health

- Responses of different social and cultural groups
- Stability and consistency of attitudes toward different applications and circumstances
- Differences in attitudes toward biotechnology strategies (cisgenesis, transgenesis, CRISPR)
- Role of deeper value orientations
- Trade-offs between values such as wilderness and species protection

SOURCE: https://stopgetrees.org/category/ge-trees-statements/page/2/

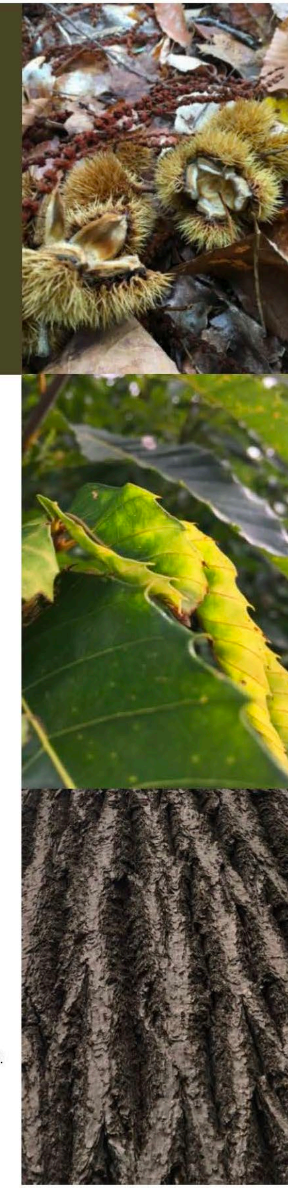


SOURCE: https://theshaffners.blogspot.com/2017/11/chestnut-redemption.html

Need for engagement

- Respectful, deliberative, transparent, and inclusive
- Increase understanding of forest health threats
- Uncover complex public responses to any potential interventions, including biotech
- Analytical deliberative methods that engage stakeholders, communities, and the public

Biotechnology, the American Chestnut Tree, and Public Engagement
Workshop Report



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Louie Rivers, Ph.D.

Research Team
Jessica Cavin Barnes, Ph.D.
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Dalton George, M.S.
Adam Kokotovich, Ph.D.
Jayce Sudweeks, M.S.

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Chapter 6: Regulation for Biotech Trees and Other Methods to Address Forest Health

- Task was to determine how well the regulatory system for biotech trees take forest health into account in its decisionmaking
- Compare that process with how well forest health is addressed for non-biotech interventions to address forest pests and pathogens
- Committee was not tasked with analyzing the current biotech regulatory system and making suggestions other than around the issue of forest health (see other recent National Academies reports on Future Products of Biotechnology and GE Crops)

Regulation for Biotech Trees and Other Methods to Address Forest Health

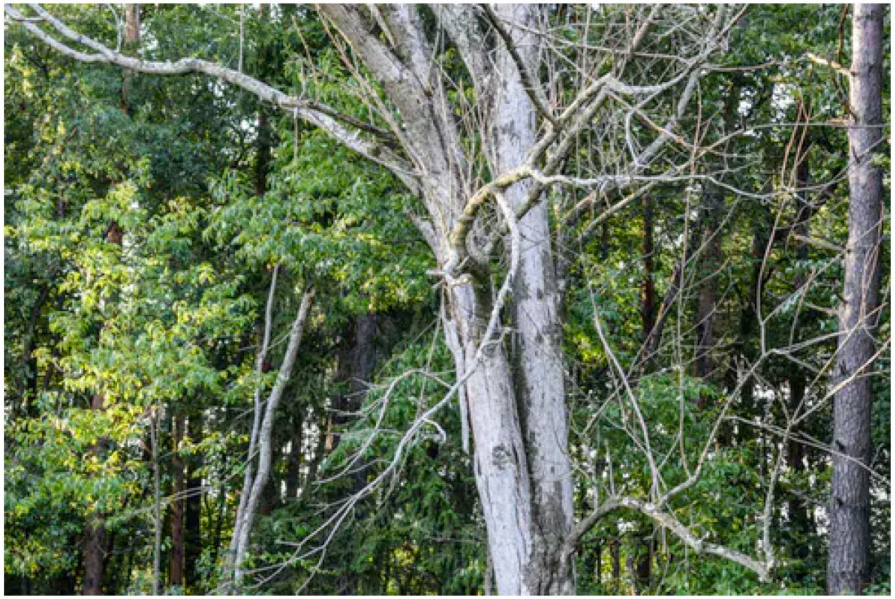
- The current regulatory system for biotech plants applies for biotech forest trees and does not impose any additional requirements.
  - Just as some biotech plants are not regulated by one or more agencies, biotech trees for forest health could be commercialized without federal oversight
- That regulatory system encapsulates very few elements of the committee's comprehensive definition of forest health
  - Regulatory system primarily deals with more traditional agricultural (e.g. plant pest) and environmental (e.g. soil quality) impacts
- If a detailed EA or EIS is required to be completed by an agency with oversight over a biotech tree, then some components of forest health will be analyzed
  - EA and/or EIS is only completed for a subset of biotech

Regulation (continued)

- Forest health is also not considered in the oversight for non-biotech products designed to address forest health
  - Biological control agents
  - Pesticides
  - Assisted migration
    - Some agencies have policies on this topic for public lands
    - Private landowners can generally plant any tree on their land

THE CONVERSATION

Academic rigor, journalistic flair



Ash tree killed by the invasive emerald ash borer. K Steve Cope

https://theconversation.com/can-genetic-engineering-save-disappearing-forests-109793

Can genetic engineering save disappearing forests?

January 18, 2019 6.41am EST

Compared to gene-edited babies in China and ambitious projects to rescue woolly mammoths from extinction, biotech trees might sound pretty tame.

But releasing genetically engineered trees into forests to counter threats to forest health represents a new frontier in biotechnology. Even as the techniques of molecular biology have advanced, humans have not yet released a genetically engineered plant that is intended to spread and persist in an unmanaged environment. Biotech trees – genetically engineered or gene-edited – offer just that possibility.

Author

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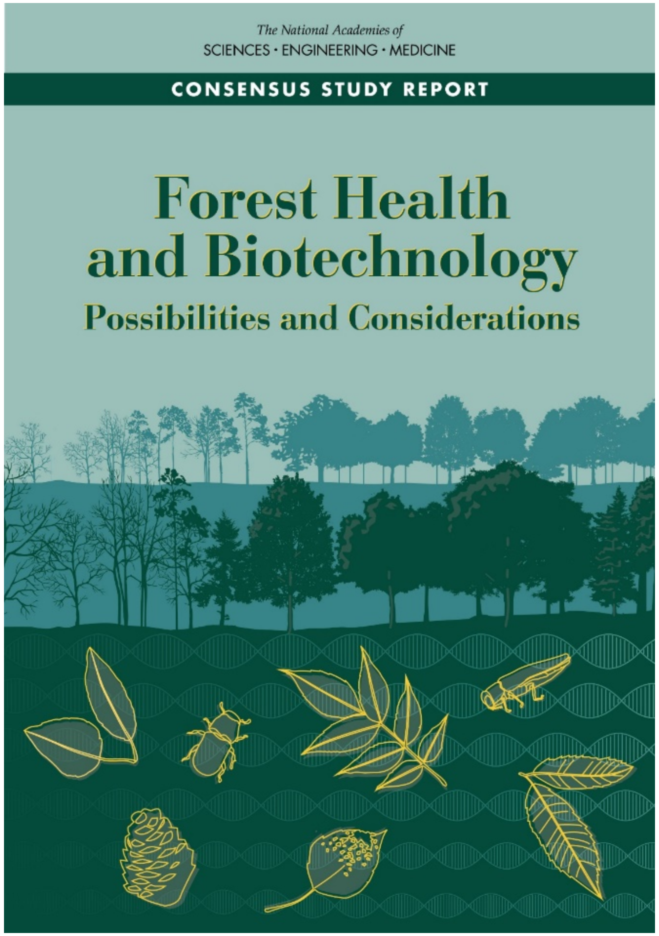

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Responsible Innovation with Genetically Modified American Chestnut Trees

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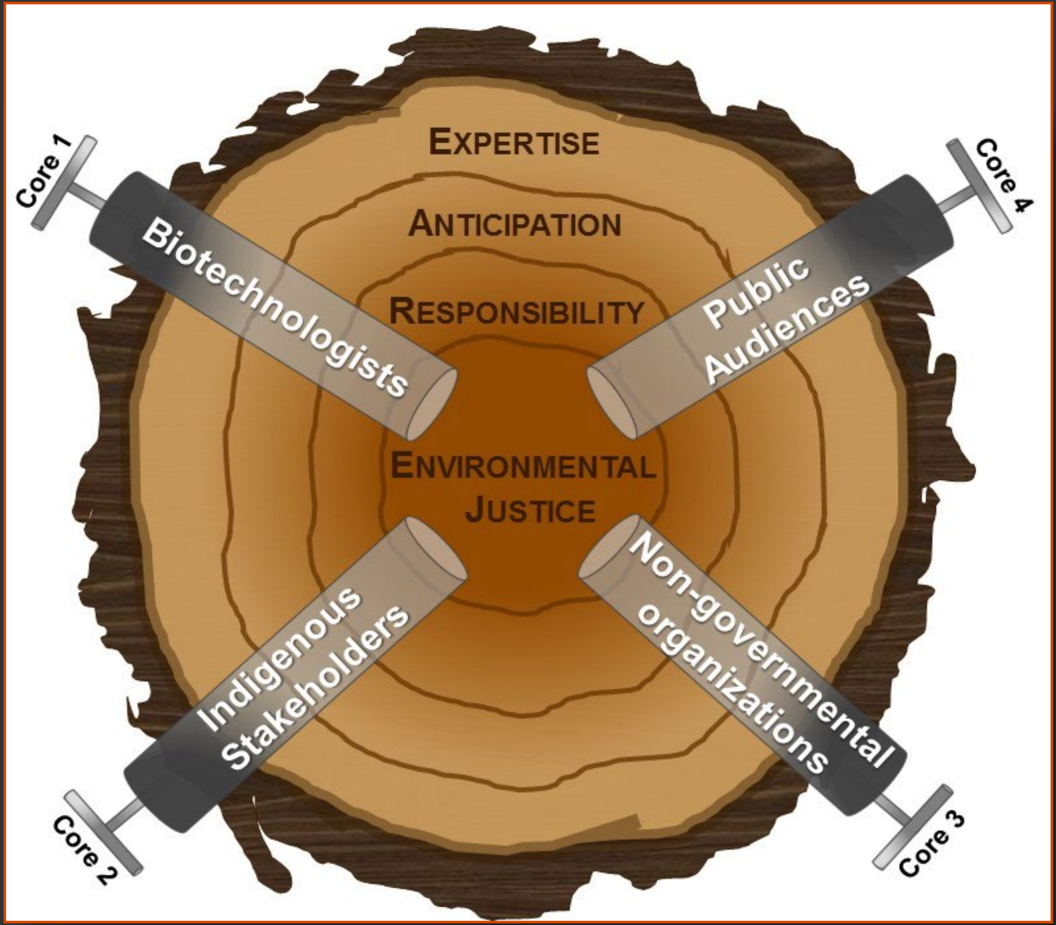

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Biodiversity and Conservation
https://doi.org/10.1007/s10531-019-01814-8

ORIGINAL PAPER

Check for updates

Rethinking restoration targets for American chestnut using species distribution modeling

Jessica Cavin Barnes[1,2] · Jason A. Delborne[1,2]

Received: 22 October 2018 / Revised: 23 June 2019 / Accepted: 27 June 2019

Abstract
Given the scale and speed of contemporary environmental changes, intensive conservation interventions are increasingly being proposed that would assist the evolution of adaptive traits in threatened species. The ambition of these projects is tempered by a number of concerns, including the potential maladaptation of manipulated organisms for contemporary and future climatic conditions in their historical ranges. Following the guidelines of the International Union for the Conservation of Nature, we use a species distribution model (SDM) to consider the potential impact of climate change on the distribution and quantity of suitable habitat for American chestnut (*Castanea dentata*), a functionally extinct forest species that has been the focus of various restoration efforts for over 100 years. Consistent with other SDMs for North American trees, our model shows contraction of climatically suitable habitat for American chestnut within the species' historical range and the expansion of climatically suitable habitat in regions to the north of it by 2080. These broad changes have significant implications for restoration practice. In particular, they highlight the importance of germplasm conservation, local adaptation, and addressing knowledge gaps about the interspecific interactions of American chestnut. More generally, this model demonstrates that the goals of assisted evolution projects, which often aim to maintain species in their native ranges, need to account for the uncertainty and novelty of future environmental conditions.

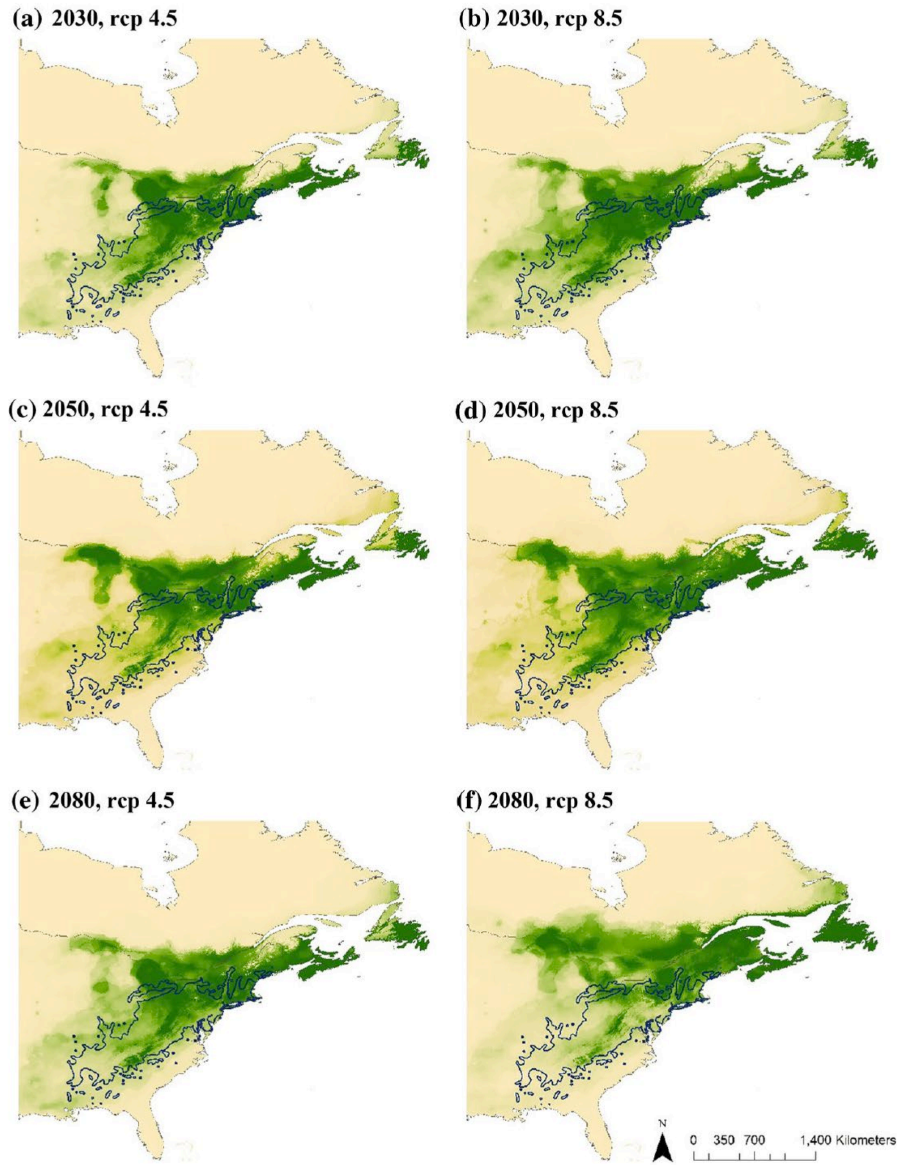

Fig. 3 **a–f** Future projections of species distribution model for American chestnut. Model was projected to 2030 (2a and 2b), 2050 (2c and 2d), and 2080 (2e and 2f) under the assumptions of rcp 4.5 (2a, c, e) and rcp 8.5 (2b, d, f). Darker regions indicate the most suitable habitat. Outline of historical species range (Little 1977) also shown

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Biological Conservation 232 (2019) 1–7

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Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

The genetically engineered American chestnut tree as opportunity for reciprocal restoration in Haudenosaunee communities☆

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Indigenous participation in governance

ABSTRACT

As genetic engineering becomes a part of the toolkit for the conservation and restoration of biodiversity, a broad range of social science frameworks are required to understand how different groups of people perceive these emerging technologies. Reciprocal restoration is one such framework that offers Indigenous-specific perspective on new applications of genetic engineering for conservation and restoration. The restoration plan for the American chestnut tree includes the potential wild release of a genetically engineered tree in close proximity to the sovereign Haudenosaunee communities of Central and Upstate New York. This paper uses reciprocal restoration as a framework for evaluating if a restoration project that uses a genetically engineered species could support broader cultural restoration efforts in these communities. Results are complex, but suggest that reciprocal restoration may be possible if certain foundational dimensions – such as kincentric relationships and spiritual responsibilities – are attended to. Reciprocal restoration also offers insight for future cases where Indigenous perspectives on the use of genetic engineering for conservation and restoration are important dimensions of broader governance considerations.

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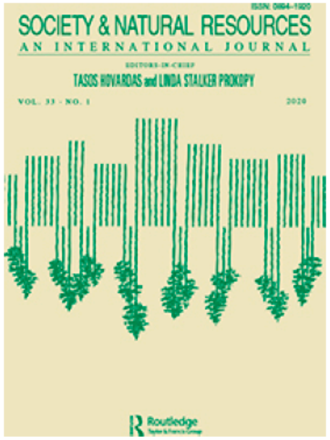

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Rooted in Recognition: Indigenous Environmental Justice and the Genetically Engineered American Chestnut Tree

S. Kathleen Barnhill-Dilling, Louie Rivers & Jason A. Delborne

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Stakeholder Workshop

Biotechnology, the American Chestnut Tree, and Public Engagement

North Carolina State University
April 25-26, 2018

Motivations

- Stakeholders + innovators
- Expand beyond "upstream"

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Forest Service U S Department of Agriculture

The Nature Conservancy

Chestnut Growers of America

WORKSHOP AGENDA

- Decision phases
  - Regulatory review
  - Deployment, management, and monitoring
  - Research and development
- Indigenous perspectives on chestnut restoration and biotech
- Interests and values
- Public perceptions research presentation
- Questions and knowledges
- Ideal engagement scenarios

Biotechnology, the American Chestnut Tree, and Public Engagement

Workshop Report

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Integrating scientific knowledge and public values in shaping the futures of biotechnology

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