FOREST HEALTH INITIATIVE: A RETROSPECTIVE LOOK

Rapid and Responsible Innovation

Science • Society • Policy

FORWARD

The USDA Forest Service works to sustain the health, diversity, and productivity of the nation's forests and grasslands to meet the needs of present and future generations. The U.S. Endowment for Forestry and Communities, a relatively new public charity, works collaboratively with partners in the public and private sectors to advance systemic, transformative and sustainable change for the health and vitality of the nation's working forests and forest-reliant communities. As partners both of our organizations are especially aligned around forest health. To address the burgeoning forest health crisis we began to ask several questions, among them:

- How are changing climates, global trade, and forest fragmentation accelerating forest health issues?
- How do we protect our forests for future generations?
- How do we accomplish this at a pace needed to be of impact?
- Could modern biotechnologies play a role in addressing endemic and exotic pests and diseases?

With the number of threats and the rate at which new ones are emerging, we determined that it was critical that we plumbed not only the scientific potential of technologies like genetic modification but to do so in ways that concurrently assessed relevant societal and regulatory issues. What emerged was the Forest Health Initiative (FHI) – a broad and open coalition of interests bound by a common concern for forests and the need to consider new tools to address needs. All agreed that new approaches were needed, among them, to look at all bottlenecks concurrently rather than the traditional piecemeal approach; to amass adequate funding to see the project through from start to desired objective (a "plantable" disease-resistant tree); to identify and select partners with proven experience and technical capabilities vs. the more traditional request for proposals process; and, a commitment to let data drive decisions.

The work described in this report is the culmination of these goals and more. The FHI process is a powerful example of what can be achieved in a relatively short period of time with highly motivated people who are the best in their field, operating transparently with all interests and needs being considered concurrently. By any number of measures this has been a successful effort that laid the groundwork for a new model that can be used with other threatened forest tree species.

We express our appreciation to all who gave of themselves in a non-traditional process founded on trust – scientists, environmental interests, advisors, regulatory agencies, and more. As we end this phase of work we look forward to seeing how the National Academy of Science, Engineering, and Medicine study initiated as a next step in the FHI process will add to thinking about how modern biotechnology might appropriately be considered and potentially deployed for healthy and vital forests for generations to come.

Mr. Carlton Owen
President & CEO
U.S. Endowment for Forestry
and Communities

Dr. Carlos Rodriguez-Franco
Deputy Chief for Research
and Development
USDA Forest Service

COVER PHOTO BY SUSAN MCCORD

FOREST HEALTH INITIATIVE: A RETROSPECTIVE LOOK

A new level of peril for our forests

The rate at which threats are impacting our forests is accelerating. Entire ecosystems in North America are under greater pressure from a growing number of pests, diseases, and other stresses – all exacerbated by shifting climates. Each year, millions of acres of native forests are impacted, leading to ecological disasters and significant economic losses.

America's once-dominant chestnut and elm forests have been virtually wiped out by invasive diseases. The eastern hemlocks of the Southern Appalachians, the ash forests of the Midwest and Northeast, and the conifer stands of the American west are being attacked by exotic or native pests. **We are losing these battles.** New options are needed to speed the pace of intervention for imperiled tree species.

The Forest Health Initiative[3] (FHI) was created to begin to find ways to address these forest health threats. It was a collaborative effort sponsored by the USDA Forest Service, the U.S. Endowment for Forestry and Communities, and Duke Energy to support groundbreaking research on the potential of biotechnology to protect or restore threatened forest species.

An effective way to explore the scientific, environmental, social, and regulatory challenges surrounding the use of biotechnology to protect natural forests is to develop a test case around a tree species that is being impacted by an existing forest health threat. The FHI supported an effort to see if it was possible to produce American chestnut trees with resistance to chestnut blight and *Phytophthora* (root rot) through rapid development and then test them using confined field trials of a safe and effective transgenic[4] variety.

"The sustainability of a modern society depends in large part on the health and wise use of its natural resources. The FHI has created a pioneering paradigm for the protection, restoration, and future health of the forests of the nation and the world. The FHI has developed a comprehensive strategy for addressing scientific issues as well as a roadmap for approaching the societal, legal, and economic factors on which forest health also depends."

– Dr. Ron Sederoff, North Carolina State University

Tree Pests Cost Taxpayers Billions

The cost of treating, removing, and replacing the 38 million ash trees in U.S. communities is estimated to be $25 billion, which does not include natural forest tree loss[1].

The value of standing black walnut in the U.S. exceeds $500 billion, yet there is no known resistance to thousand cankers disease, which is spreading throughout its range[2].

1 *https://www.nrs.fs.fed.us/pubs/jrnl/2010/nrs_2010_kovacs_001.pdf*

2 *http://agriculture.mo.gov/plants/pdf/tc_pathwayanalysis.pdf*

3 *https://foresthealthinitiative.org*

4 A transgenic organism contains a gene or genes which have been artificially inserted instead of the organism acquiring them through reproduction. *https://www.biology-online.org/dictionary/Transgenic_organisms*. FHI is using genes from Chinese chestnut and other plants to confer disease resistance.

A revolutionary approach to address forest health threats

Originally envisioned as a challenge grant from the U.S. Endowment for Forestry and Communities[5], the FHI was guided by a multi-stakeholder Steering Committee and supported work in a braided process where scientific study interacted with and operated in collaboration with social, environmental, and regulatory communities. This collaborative, inclusive, and holistic approach was inherent to the structure of the program.

The FHI worked to develop and assess the use of biotechnologies to conserve and/or protect native biodiversity. FHI participants were committed to:

1. Identifying science-based solutions[6].
2. Providing transparency throughout the process.
3. Fully conforming with existing regulations.
4. Understanding and being responsive to the environmental and social implications of biotechnology use.

PHOTO BY SARA KLOPF

More than 20 GM chestnut varieties have been tested across two locations. Among the genes tested, several are showing significant promise, including this CBS transgenic, which carries a gene thought to be involved in stress responses.

Dr. Jason Holiday – Virginia Tech University

The FHI established three working committees (Science; Policy & Regulatory; Social & Environmental) that collaboratively pursued the following:

1. Development of biotechnology tools and protocols for testing performance of transgenic forest trees.
2. Integration of biotechnology with traditional breeding and silvicultural practices and using each where most appropriate to improve forest health.
3. Creation of a dialogue with a broad group of stakeholders to better understand concerns, inform the FHI's science and regulatory efforts, and create a more informed citizenry about forest threats and opportunities to overcome them.
4. Engage policy experts and regulatory agency personnel from the onset of the research program in order to help inform the research agenda.
5. Ensuring open communication with regulators regarding the unique challenges of a biotech tree developed for public good.
6. Ensuring that research discoveries derived from the FHI are in the public domain, allowing for unrestricted access.

A hybrid funding model of both non-competitive and competitive grants allowed speed and flexibility when recruiting research talent. The need for speed demanded an integrated approach focused squarely on results. This effort was an interdisciplinary, multi-institutional program with individual labs following coordinated research agendas. It was a highly interactive data pipeline that allowed information to move freely among organizations. An independent committee of experts (Science Advisory Committee) provided oversight to ensure integration and evaluation of the results. The members of the committee were not financially compensated and operated at arm's-length of the research.

A three-year objective to broadly test advanced and emerging technologies for use in developing a pest-resistant variety of an imperiled forest tree species (American chestnut) made it essential to utilize all relevant knowledge and experience and include those responsible for past advances in the FHI process to the degree possible. That "leveling-up" strategy allowed rapid progress in developing blight-resistant American chestnut trees for testing in field trials. In keeping with the principles of the FHI, all FHI-sponsored scientific research was carried out with input and knowledge of the FHI Social & Environmental and Policy & Regulatory Committees.

[5] *http://usendowment.org*

[6] *https://www.foresthealthinitiative.org/resources/principles.pdf*

Furthermore, all funding for the FHI came from partners outside of any for-profit biotechnology companies to ensure the program's objectives of transparency, independence, and maximizing societal benefit. The first three-year phase focused on developing a diversity of potentially blight-resistant chestnut trees and tools for early detection of infection. This startup phase utilized $6 million in funding. The second phase addressed field-testing of these trees. In addition, a National Academies of Sciences, Engineering, and Medicine (NASEM) study focused on exploring the use of biotechnology for addressing forest health challenges was initiated – Potential for Biotechnology to Address Forest Health[7]. This study started in fall 2017 and will run for 12-18 months.

"Funding from the FHI enabled a proof-of-concept for genomic selection in American chestnut backcross populations. This led to the American Chestnut Foundation leveraging over $500,000 in additional funds for this research."

– Dr. Jared Westbrook, American Chestnut Foundation

The open, science-driven, collaborative approach pioneered by the FHI proved effective and is expected to be so in addressing other forest health challenges, *e.g.*, emerald ash borer, the hemlock woolly adelgid, and the thousand cankers disease affecting walnuts. This supposition will be explored as part of the NASEM study mentioned above.

Structure of the FHI

The entire effort was overseen by a multi-stakeholder Steering Committee. The Institute of Forest Biosciences (IFB)[8] served as the secretariat, with responsibility for project logistics and the three operational committees: Science Advisory; Social & Environmental; and Policy & Regulatory.

The Steering Committee was designed to include a representative from each sponsoring organization, a conservation organization, an environmental nongovernmental organization (NGO), and an academic expert.

Steering Committee Members:

- Carlton Owen, *Chair*, President & CEO, U.S. Endowment for Forestry & Communities; sponsor
- Dr. Carlos Rodriguez-Franco, Deputy Chief for Research and Development, USDA Forest Service; sponsor
- Dr. Steven Hamburg, Chief Scientist, Environmental Defense Fund
- Dr. John Davis, Professor, University of Florida
- Bill Toomey, Program Director, Forest Health Protection, The Nature Conservancy

Past Steering Committee Members:

- Dr. Ann Bartuska, Deputy Chief for Research and Development, USDA Forest Service; sponsor
- Dr. Jim Reaves, Deputy Chief for Research and Development, USDA Forest Service; sponsor
- Mariann Quinn, Director, EHS Policy and Strategy, Duke Energy; sponsor
- Dr. Peter Roussopoulos, Retired – USDA Forest Service
- Dr. Faith Campbell, Senior Policy Representative, The Nature Conservancy

[7] *https://nas-sites.org/dels/studies/forest-biotech*

[8] *https://forestbio.org*

The Science Advisory Committee worked with the science team to promote the overall goals of the program and help coordinate the work across each organization involved in research. The members of this committee were independent experts with expertise in forest biotechnology, forest ecology, and social science disciplines.

"As Chair of the FHI Science Advisory Committee, it was our task to help choose and guide research projects so they would be closely aligned to FHI goals for cutting-edge science, on-the-ground relevance, and social acceptability."

– Dr. Steve Strauss, Oregon State University

The Social & Environmental Committee was composed of representatives from 27 organizations ranging from NGOs, foundations, cooperatives, academia, government agencies, to industry. Central to ensuring the FHI's success was the understanding that policy-relevant science cannot be effectively addressed in a vacuum. Rather, it must be pursued in concert with societal considerations and broad stakeholder input. The committee produced materials to help guide scientific and regulatory agendas:

- Issues Report[9].
- Core Operating Principles[10].
- Introductory video[11] for outreach.
- Public survey on the use of biotechnology for forest health[12].

The FHI recognized that genetic solutions to the threats forests were facing from pests and pathogens required that we communicate broadly with stakeholders. We encouraged the discussion of various options, including doing nothing, in a way that stakeholders were integral to the decision process.

Patricia Layton – Clemson University and Society of American Foresters

The Policy & Regulatory Committee explored issues with the use of advanced biotechnology, including genetic engineering[13] (GE), to address forest health issues. This exploration focused on safety and efficacy. It was predicated on the core operating values of the FHI including that the public owns the intellectual property created by FHI-sponsored research. This committee developed the Policy Response Plan[14] for the FHI, which included:

- A review of associated intellectual property holdings.
- A biological dossier of American chestnut to aid the regulatory agencies in determining impacts.
- A review of the regulatory landscape to help inform science and research agendas.
- Regulatory agency Q&A to define a regulatory course.

[9] *https://foresthealthinitiative.org/resources/issuespaper.pdf*

[10] *https://www.foresthealthinitiative.org/resources/principles.pdf*

[11] *https://vimeo.com/33030953*

[12] *http://foresthealthinitiative.org/social_env.html*

[13] A genetically engineered (GE) tree is created through a process that either alters the genetic make-up of the tree by removing or introducing DNA, or has DNA that has been precisely altered using transgenic or intragenic techniques.

[14] *http://foresthealthinitiative.org/resources/policyplan.pdf*

Accomplishments across the three committees

Roadmap

A roadmap[15] was developed that includes all information generated by the FHI. It is a guide to a series of science-based questions to evaluate the best available options for addressing forest health challenges.

The goal of the roadmap is to support civil discourse and inform effective decisions to current and potential forest health threats. It was envisioned as a tool to help users decide if and how to act or intervene, with a focus on when genetic and biotechnology approaches might be effectively pursued. The roadmap might, for example, guide an analysis of research options for a public-sector agency such as the USDA Forest Service, a conservation organization considering the development of a transgenic resistant tree, or the decision of a certification system choosing whether to endorse commercial deployment.

The roadmap first considers the state of knowledge concerning a forest health threat. Secondly, it evaluates the various kinds of breeding research and tree genetic tools that might be employed to ameliorate the threat. Genetic options include conventional breeding and diverse biotechnologies, including GE. Third, the roadmap helps to determine whether the release of the GE tree into wild or planted forests is appropriate.

Biotech tree development (Phase 1)

A research pipeline was established by the Science Advisory Committee in collaboration with the biological science research team and approved by the Steering Committee. The pipeline integrated work across biotechnologies, including genome sequencing and bioinformatics, population genotyping for breeding, early screening for disease resistance, micropropagation of the best genetic material, and transformation of native genotypes with resistance genes from related species (transgenic). All information generated by FHI-sponsored research is in the public domain and readily available for reference and use. The research goals included:

- Developing a complete reference genome sequence for Chinese chestnut to advance identification of blight-resistant genes[16].
- Identifying and introducing candidate genes for blight resistance into American chestnut lines for testing and scaling of transformation productivity.
- Developing somatic embryogenesis technologies to accelerate tree production via cloning.
- Using marker-aided selection for more efficient breeding of blight-resistant trees.
- Developing early blight resistance screening protocols and early flowering gene tests that compress the timeline for determining if a tree is blight resistant[17].
- Establishing field sites with first-generation transgenic trees.

The FHI produced and distributed hybrid and large surviving American chestnuts to cooperators for their programs.

Field trials (Phase 2)

While the FHI Phase 1 work to evaluate transgenic trees to determine if they are appropriate from scientific, social, and regulatory standpoints continued, the second three-year phase was focused on what would be necessary to develop a tree ready for planting in a forest landscape. This work included:

- Determining which disease resistance genes work best, leading to improved selection for resistance.

[15] *https://www.foresthealthinitiative.org/roadmap.html*

[16] *https://hardwoodgenomics.org/Genome-assembly/1962958*

[17] Newhouse, A., Spitzer, J., Maynard, C., & Powell, W. A. (2013). Chestnut Leaf Inoculation Assay as a Rapid Predictor of Blight Susceptibility. Plant Disease, 130618120737007.

- Determining how these genes can best be used to scale up numbers of plantings while ensuring genetic diversity.
- Working with the three regulatory agencies (USDA/APHIS, EPA, and FDA) that have oversight of GE trees.
- Establishing field trials in two different ecological zones; one in a mountainous region in western Virginia on a reclaimed coal mine site, and one located on a research farm in the Piedmont region near Blacksburg, VA.
- Conducting social science research to determine the extent and conditions under which the public might support deployment of biotechnology to reduce threats to forest health.

"The FHI is a unique partnership among stakeholders who recognize the significant threat presented by pests and pathogens to forest health, and the potential of genetic modification and genome-enabled breeding to combat these threats."

– Dr. Jason Holiday, Virginia Tech University

PHOTO BY JOHN BOND

FHI demonstrated that we could develop a clonal propagation protocol for a highly recalcitrant forest tree and not only extend it to propagate hybrid backcross and transgenic chestnuts, but combine it with bioreactor technology to greatly scale-up production.

Dr. Scott Merkle – University of Georgia

General policy response plan

The following eight components were identified by the FHI as integral to development of a policy plan that could quickly respond to forest health threats and would consider deploying biotechnology tools. The process is the product of many discussions with collaborators from academia, industry, government, and non-profit organizations. Some of these steps can be undertaken concurrently.

1. Open lines of communication with policy stakeholders

Communicating with key policy stakeholders is critical because it helps guide subsequent steps that have regulatory implications. The earlier an initial communication is made, the better it can inform future decisions while fostering collaboration with the agency.

2. Engage a wide spectrum of civil society stakeholders

Creating a positive, collaborative dialogue with many types of stakeholders is critical because healthy forests are a social good. Topics should include the environmental, social, and economic impacts of the forest health threat, and the possible corrective options available.

3. Review intellectual property

Intellectual Property (IP) holders are stakeholders with legal recourse based on patents they own[18]. IP reviews, also referred to as patent landscapes, help researchers determine what direction research is moving in the field, can help identify competitors or potential collaborators, and determine the geographic areas where research is occurring. More specifically, a patent landscape can be used to identify potential problems that may interfere with future research. However, a patent landscape is not a legal opinion on freedom to operate[19].

[18] *https://foresthealthinitiative.org/resources/intellectualpropertyreview.pdf*

[19] *http://www.bios.net/daisy/patentlens/2768.html*

4. Assemble a biological dossier

A detailed document covering both the forest health threat and the tree species in danger helps regulatory agencies, stakeholders, and research scientists communicate more effectively by referring to reliable common information[20]. This information is useful in making environmental assessments and regulatory decisions.

5. Review the regulatory and legal landscape

A review of the current state of regulations and related lawsuits helps plan an efficient regulatory course[21]. This step also helps guide scientific efforts and public interactions. In the U.S., there are three government agencies that can have jurisdiction over the development and deployment of GE trees (USDA APHIS, EPA, and FDA):

- The Animal Plant Health Inspection Service (APHIS) that is part of the U.S. Department of Agriculture (USDA) has oversight on where GE plants can be grown and how they affect the environment.
- U.S. Environmental Protection Agency (EPA) has oversight when a GE tree involves a plant-incorporated protectant (PIP), such as a pesticide. This can include any substance or mixture intended to prevent, destroy, repel, or mitigate a pest.
- U.S. Department of Health and Human Services' Food and Drug Administration (FDA) oversees GE trees that bear fruit or nuts with regard to food and feed safety.

6. Query agencies to define a regulatory course

Multiple interactions with regulatory agencies are necessary to develop a concrete plan to use a GE tree for forest health. Because regulators are mandated to respond to discrete requests, this step often involves questions and answers with the agency in an iterative process.

7. Preparation of an environmental report

The U.S. National Environmental Policy Act (NEPA) applies to all three regulatory agencies in situations with potential for significant effects on the environment. It is likely that NEPA will play a major role in the future regulation of GE trees. Preparing an environmental report is a major step in addressing NEPA issues. In addition, this document is a useful tool to engage regulatory and public stakeholders on project details.

FHI collaborators produced dozens of peer-reviewed publications and have given hundreds of scientific and outreach presentations

8. Interaction with agencies on future regulations

Regulations change slowly over time, whereas forest health threats often move quickly. Many environmentally focused stakeholders believe that helping agencies evolve their regulations is critically important to ensure that the risks of advanced biotechnologies are reduced, while the potential benefits from these technologies are increased.

Public survey

A statistically representative survey of the U.S. public and a survey of experts from agencies, NGOs, academia, and industry were undertaken. The goal was to examine support of biotechnological and non-biotechnological interventions for addressing forest health impacts[22].

Primary findings indicate that: (a) support for interventions was higher for specific and tangible threats (chestnut blight) than general and less tangible threats (climate change), (b) support for intervention methods varied with lowest support for GE from distantly related species, and (c) support for interventions, especially GE, was influenced by

[20] *https://foresthealthinitiative.org/resources/chestnutdossier.pdf*

[21] *https://foresthealthinitiative.org/resources/Legal_Barriers_and_Potential_Benefits_of_Biotech_Trees.pdf*

[22] *https://www.foresthealthinitiative.org/resources/biotech_public_acceptance_Needham.pptx*

drivers such as environmental values, perceptions of risk, and a few demographic characteristics.

A National Academies of Science, Engineering, and Medicine study is underway that will review and expand on the FHI findings.

A follow-up experimental survey was then conducted to examine possible effects of scientific information and message framing for biotechnological interventions to address chestnut blight. Main findings from both within-subjects and between-subjects experiments showed that: (a) support for interventions increased when factual scientific information was provided, (b) framing using pejorative vs. positive terminology influenced support for interventions, and (c) including measures to address the balance fallacy phenomenon[23] was extremely important. Support increased when respondents were provided with scientific information, pro arguments, and a statement that a large percentage of scientists agree the intervention is safe and effective.

"The FHI committee members, program managers, and scientific team leaders asked the most important questions, implemented the most rigorous and contemporary approaches for addressing these questions, and challenged others to think critically about innovative ways for addressing these forest health threats."

– Dr. Mark Needham, Oregon State University

Where we are today

The FHI set out to test the premise that an understanding of the role and potential use of biotechnology might be effective in addressing some of today's most pressing forest health challenges. The FHI addressed more than its original goal. Using existing and new technologies/methods available, there are diverse genotypes of chestnut trees in the ground, across the species range being tested for both chestnut blight resistance and root rot resistance. In addition, a genomic map of chestnut, early screening tests, and scaling of progeny production using somatic embryogenesis provide the information needed to move the broader research community forward toward restoration of American chestnut.

Not only have direct research benefits accrued, the FHI has expanded the community of people interested in exploring the suitability of addressing forest health problems with advanced technologies. The large and diverse community of individuals interested in restoration of the American chestnut was a major asset in the success of this initiative.

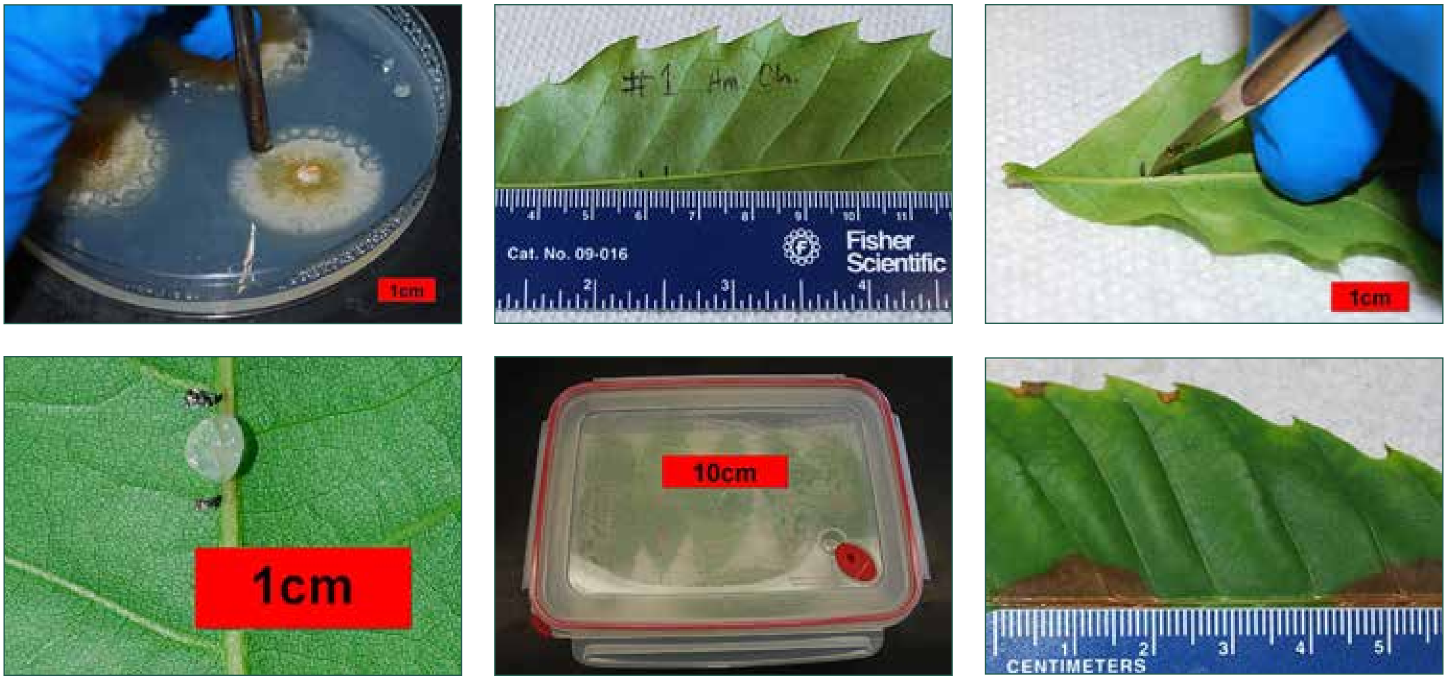
Scientific outcomes

Some of the most important outcomes include:

- **Public support:** Results of the public survey showed that the majority of the public across the country support using some genetic interventions for addressing forest health threats such as chestnut blight.
- **Genomic resources:** Sequencing of the Chinese chestnut (*Castanea mollissima*) genome[24] allows the use of genomic tools for faster research, breeding, and selection for resistance.
- **Protocol development:** The development of an early screening technique for blight resistance that reduces five years of field screening to one year of screening in the laboratory. Markers for *Phytophthora* resistance would similarly enable identification, selection, and breeding of root rot-resistant trees. Transgenic and conventional acceleration of early flowering enables greater diversity of planting stock.

[23] *https://undsci.berkeley.edu/article/sciencetoolkit_04*

[24] *https://hardwoodgenomics.org*



PHOTOS BY ANDY NEWHOUSE

- **FHI-enabled trees:** Production of the first proof-of-concept genetically engineered trees with blight resistance that equals or exceeds the resistance in Chinese chestnut as determined from leaf assays.
- **Accelerated breeding:** Developed genomic and genetic resources to produce American chestnuts with Chinese chestnut blight resistance in fewer and shorter generations. This has the potential to condense 50 years of breeding into 15 years using somatic embryogenesis.
- **Transformation pipeline:** 27 chestnut candidate genes from Chinese chestnut and 6 genes from other plants that have the potential to enhance resistance to blight or root rot have been identified, isolated, and inserted into American chestnut. This approach has created the potential for >99.999% pure American chestnut with Chinese chestnut blight resistance candidates within 15 months. Transformation system improvements shortened the time to produce potted transgenic plants from over two years to under one year.
- **Durable resistance:** Continued testing of American chestnut resistance genes, which have been carefully selected to convey multiple independent resistance mechanisms, thus providing durable, multiple-gene based resistance against blight and root rot.

Using previous methods, trees were grown for three or more years to test if a candidate gene enhanced blight resistance. Leaf assay results can be obtained within a few months. Without the development of a quick assay such as this, higher throughput screening of many candidate genes would not be possible.

Dr. William Powell – SUNY College of Environmental Science and Forestry

"FHI has shown just how much progress can be made on a massive forest health problem when the right people, resources and team attitude are brought together to focus on the problem. Accomplishing this in less than a decade, is stunning."

– Dr. Scott Merkle, University of Georgia

Moving toward adaptive management of field trials

One of the main objectives of the FHI has been to explore how the three regulatory agencies with authority over transgenic trees might respond to a tree developed solely for forest health reasons, not for commercial purposes. For seven years, the FHI worked closely with the regulatory agencies to explore approaches that do not seek unrestricted use via conventional deregulation of GE products. As such, the FHI continues exploring field trials that include locations ranging from natural forests to highly managed environments. These field trials look to the agencies to extend the scope of current regulatory requirements of containment and monitoring to allow for implementation of more adaptive management approaches.

The FHI Policy & Regulatory Committee has made great advances in understanding among researchers, government agencies, and NGOs. Some of the milestones achieved by this committee include:

- Two active field sites in Virginia that have permits for flowering of transgenic chestnuts.
- Finding that drones can be used to monitor and track flowering instead of more expensive conventional methods.
- Finding that physical barriers around field sites are only necessary to keep deer and other animals from destroying the trees, not as a precaution for human safety.
- Approval by the Virginia Department of Conservation and Recreation to plant two trials in a naturalized area, one located in a field and one near a hiking trail.

The next step in the FHI's strategy to gain progressively more adaptive management regulation of transgenic forest trees would be to test a limited number of trees under close to natural conditions for chestnuts. These naturalized field trials would adhere to all regulatory requirements extending what is possible and safe. The naturalized field trials are intended to have the following characteristics:

- Little to no physical barriers around them.
- Be surrounded by natural vegetation instead of control trees or areas devoid of trees.
- A scientific testing and monitoring agenda informed by forest ecologists.

National Academies of Sciences, Engineering, and Medicine (NASEM) Study

Members of the FHI Steering Committee and IFB staff, working with The National Academies of Sciences, Engineering, and Medicine, developed a study plan to examine the potential use of biotechnology for mitigating threats to forest health[25]. The study will identify the potential ecological, economic, and social implications of deploying biotechnology in forests, and develop a research agenda to address knowledge gaps in its potential application. The study will look at a minimum of two cases that consider the use of biotechnology to protect a tree species from an insect or disease where negative consequences for forest health are anticipated.

This study is being sponsored by the USDA Forest Service, USDA APHIS, USDA Agricultural Research Service, National Institute of Food and Agriculture, Environmental Protection Agency, and the U.S. Endowment for Forestry and Communities. It is expected to be completed by summer 2019.

[25] *https://nas-sites.org/dels/studies/forest-biotech*

Building on success

The success of the science team has been reinforced by the integrated work of the Social & Environmental and Policy & Regulatory Committees. The agreed principles under which the research was done, the iterative meetings with regulatory agencies, the public survey insight, and the roadmap development all laid the groundwork for a transparent and inclusive process, leading to informed outcomes and future opportunities.

Building on the work of the FHI, next steps might be:

- Increasing the scale of the chestnut test case,
- Addressing the potential of biotechnology to be used to address pest/pathogen interactions in other threatened tree species, and
- Evaluating additional technologies that might be used to fight the loss of forest species.

Forest.Health: sustaining and expanding the effort

The stress and impacts on our forests from diseases and pests continue to mount. Dead trees left in these pests' wake contribute to large-scale forest fires. In addition, the positive correlation between human health and exposure to natural environments, particularly trees, is lost where trees have been killed by pests.

The pioneering work accomplished by the FHI would need to be expanded to address other threatened trees species. Initial work is being undertaken by the Forest.Health project.

Forest.Health is following a process based on the roadmap developed by the FHI to launch a rapid response plan to address one or more forest health threats. This plan includes engagement of experts in the target species and key stakeholders who can provide input on a scale needed for an intervention strategy. Species prioritization will use the US Forest Service CAPTURE[26] model, which provides a strong, science-based indicator of the level of threat to individual tree species. CAPTURE identifies the most imperiled species using a methodology based on exposure and susceptibility to pests and pathogens, expected climate change pressure, and adaptive capacity.

A Planning Committee has been formed to guide this process. The first round of threat prioritization was accomplished with input from 21 forest health-related professionals using CAPTURE. A smaller group of experts will incorporate criteria such as ecological and socio-economic importance, regional considerations, and the potential for significant progress to further narrow the number of trees under consideration.

The Planning Committee will bring stakeholders together to develop research and funding agendas, which include development of a broad base of support to sustain the effort. A compilation of papers and outcomes from the meeting will be published and will form the basis of the future work on forest health.

Similar to the FHI, all intellectual property generated through this research will be made available to the public at the website *forest.health.*

[26] Potter, Kevin, Crane, Barbara, and Hipkins, Valerie. Project CAPTURE: A National Prioritization Assessment of Tree Species for Conservation, Management, and Restoration.

APPENDIX

FHI Committees

Steering Committee Members:

Carlton Owen, *Chair*, President & CEO, U.S. Endowment for Forestry & Communities; sponsor

Dr. Carlos Rodriguez-Franco, Deputy Chief for Research and Development, USDA Forest Service; sponsor

Dr. Steven Hamburg, Chief Scientist, Environmental Defense Fund

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Dr. Peter Roussopoulos, Retired – USDA Forest Service

Dr. Faith Campbell, Senior Policy Representative, The Nature Conservancy

FHI Program Management Committee Members

Susan McCord, Executive Director, Institute of Forest Biosciences

Adam Costanza, President, Institute of Forest Biosciences

Science Advisory Committee Members

Steven H. Strauss, Committee Chair and Professor, Dept. of Forest Ecosystems and Society, Oregon State University

Steven Handel, Professor, Department of Ecology, Evolution and Natural Resources, Rutgers University

Shorna Allred, Associate Professor, Department of Natural Resources, Cornell University

Stephen Difazio, Assistant Professor, Department of Biology, West Virginia University

Ronald Sederoff, Distinguished University Professor of Forestry (retired), NC State University

Previous Members

Dr. John Davis, Professor, University of Florida

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