



HARDWOOD TREE IMPROVEMENT
& REGENERATION CENTER

Strategic Plan

2017-2021

The *Hardwood Tree Improvement & Regeneration Center* mission is to advance the science and application of tree improvement, management, and protection of hardwood forests, with emphasis in the Central Hardwood Forest Region.

The HTIRC will accomplish its mission during 2017-21 through five strategic directions:

1. Produce hardwood trees with desirable traits, using both classical tree breeding and novel tree improvement techniques;
2. Improve management strategies and techniques to enhance the ecological sustainability and economic benefits of hardwood forests;
3. Develop and demonstrate strategies to address existing and emerging threats to hardwood forests;
4. Engage stakeholders and address their needs through communicating research findings and management recommendations; and
5. Educate future leaders in tree improvement, management, and protection of hardwood forests.

I. INTRODUCTION

The HTIRC is a collaborative partnership between the USDA Forest Service Northern Research Station and Purdue University — focused on the advancement of hardwood-focused research, development, and technology transfer in the Central Hardwood Forest Region (CHFR). Increased consumer demand for hardwood products makes it vital that we increase the quantity, quality, productivity, and health of forests within the CHFR.

From its beginning, the HTIRC has been unique in several ways. The HTIRC is:

1. Focused solely on hardwood forests and the associated hardwood products industry;
2. A university / federal partnership that includes close intellectual and financial collaborations with state, federal, and private organizations; and
3. Generating basic knowledge and technologies about hardwood tree genomics, improvement, regeneration, conservation, protection, and utilization for stakeholders throughout the CHFR.

Development of this Strategic Plan began in 2015 amid a time of change for the HTIRC. We were faced with the untimely death of Dr. Charles Michler, our founding center director, and a series of leadership changes. Scientists associated with the HTIRC lacked a cohesive sense of mission for the Center. The development of this strategic plan centered on four core questions:

- What should our mission be going forward?
- What research directions will best serve our stakeholders?
- How can we best accomplish these research goals?
- How can we tell if we have met the needs of our stakeholders?

The answers to these questions shaped the formation of this plan and defined the approach needed to meet the HTIRC's mission to advance the science and application of tree improvement, forest management, and protection of hardwood forests, with emphasis on forests of the CHFR.

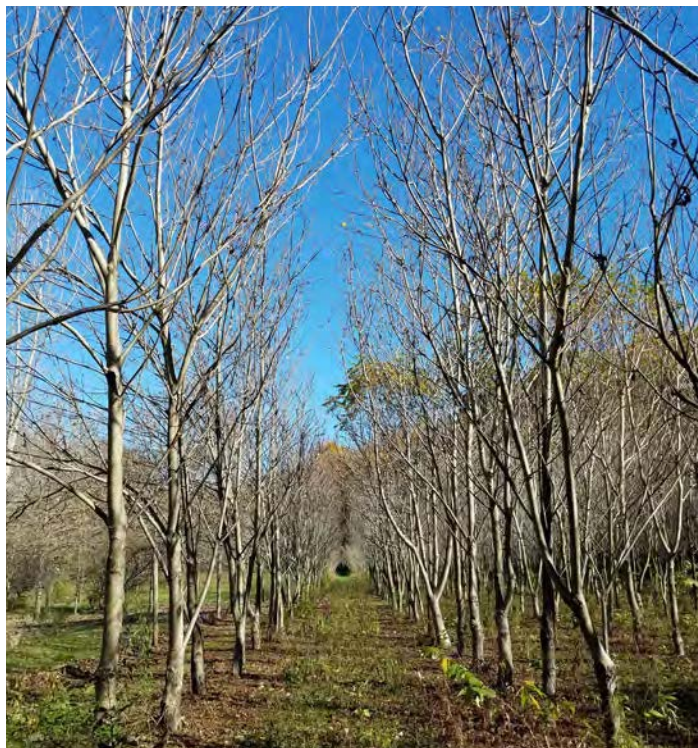
II. BACKGROUND

A. History of the HTIRC and Operating Environment

The HTIRC was conceived in 1998 to address a perceived void in hardwood tree improvement research in the CHFR. At that time, the region was experiencing a severe production shortage of hardwood tree seedlings, estimated from 25 to 50 million trees annually. The majority of seedlings being produced in state nurseries were also of unknown genetic origin; nurseries were largely relying upon seed collectors for material from wild populations. Thus, the majority of seedlings were unimproved and of unknown quality and genetic diversity.

The hardwood industry was also concerned about the future quantity and quality of the timber resource for its lumber and manufacturing sectors. Due to political and social pressures, federal forests had significantly reduced the annual volume of harvested hardwood timber — a reduction that continues to this day. Small, private woodlots now supply a significant amount of hardwood timber and veneer. However, they are not often managed in a sustainable manner because land-ownership tenure is short relative to timber rotation length, and parcel size decreases as forests become increasingly fragmented. Woodlots are also increasingly being converted for alternate uses, such as residential housing and commercial developments, or taken out of production and used solely for recreational purposes.





Forest managers also are concerned about loss of genetic quality in remaining hardwood woodlots and natural forests. They believe that trees being managed for future timber harvests are not as straight or vigorous as in previous generations and that past forest harvest practices, including continual selection of the “best” trees only, may have resulted in irreparable loss of genetic quality in the remaining stands.

In the years since the founding of HTIRC, new problems have arisen and others have become more urgent. For example, invasive plants and insects are changing the ecological dynamics of forest environments throughout the CHFR. Many hardwood species are threatened to become functionally extinct. Further, the ecology of our hardwood forests may be altered by climate change. Forest regeneration of high-valued hardwood species is being inhibited by heavy deer browsing and competition from invasive plants. These factors all result in a simplified forest condition. As a result, the forest products industry is gradually losing parts of the resource portfolio necessary for their desired product mix and profitability across market changes.

B. Importance of the CHFR

Consumer demands for quality hardwoods will, at some point, outstrip the productive capacity of the CHFR unless consumers are willing to accept substitute materials. Much of the U.S., European, and Asian

demand for hardwood lumber is currently met within the northern and central hardwood zones of the United States. The CHFR encompasses over 100 million acres, six major geologic zones, and all or part of 15 states. It is the hardwood timber-basket of North America, supplying the raw materials to a forest products industry valued at \$13.5 billion in Indiana alone (Indiana DNR, 2016). The hardwood resource supports industries in several U.S. states for producing dimensional lumber, veneer, and barrel staves.

Land ownership in this region is dominated by private landowners and secondarily by industry and public agencies. Landowners throughout the CHFR have a deep and longstanding interest in planting trees (afforestation). These efforts have focused on species that consistently return high economic value and / or wildlife value; oak, black cherry, and black walnut are commonly planted. The CHFR also provides habitat for a large number of threatened and endangered plant and animal species.

Agriculture is the biggest land-use competitor for forestry — with corn and soybean production dominating land-use practices and ~20% of the original forestland remaining in Indiana. Other states in the CHFR, such as Ohio, Illinois and Iowa, also support a strong agricultural sector that competes with forestry and other natural-resource management objectives.

Native forests of the CHFR tend to be diverse in species composition and age of trees present. Forests are often naturally regenerated following harvests or natural disturbance, but tree planting may provide some opportunities to control future forest composition when desirable regeneration is not present. Some forests in the CHFR are exploitatively harvested with commercial clearcutting or high-grading; these often result in poor regeneration of desirable trees or low-quality timber left on the site to grow once the quality trees are removed. Tree planting in the CHFR closely tracks conservation programs, where landowners receive federal funds to support the costs and maintenance of establishing and managing forest land.

C. Mission

The mission of the HTIRC is to *advance the science and application of tree improvement, management, and protection of hardwood forests, with emphasis in the Central Hardwood Forest Region*. We seek to develop research and technology-transfer programs that provide knowledge focused on the establishment and maintenance of sustainable, genetically diverse native

forests and the development of highly productive woodlands that provide a wide array of products and services.

III. ACCOMPLISHMENTS DURING 2011-2016

Under its 2011-2016 Strategic Plan, the HTIRC maintained important infrastructure (Pfendler Hall and the John S. Wright Forestry Center at Purdue), staffing, collaborative networks, and research / extension projects that contributed to its strategic directions and objectives. The advisory committee met annually, and research and extension outcomes were often accomplished in direct collaboration with partner agencies.

Specific HTIRC accomplishments from 2011 to 2016 include:

Hardwood Tree Improvement

- Established or maintained progeny tests of black walnut, including 70,000 trees from 100 walnut families at multiple sites predominantly in Indiana but including Michigan, Tennessee, Wisconsin, Missouri, Arkansas, and Washington.
- Established or maintained progeny tests of black cherry, red oak, and white oak.
- Identified and characterized genes upregulated in the transition zone of black walnut where heartwood development takes place.
- Developed and applied microsatellites and other genetic markers to identify hybrids between butternut and Japanese walnut.
- Demonstrated that genetics made a minimal contribution to differences in butternut canker susceptibility.
- Sequenced and published the complete chloroplast genome of red oak and used paternity analysis based on microsatellites to determine gene flow and factors influencing reproductive success in a red oak seed orchard.
- Developed tissue culture protocols in ash and cherry for clonal propagation of select lines.
- Installed long-term pruning trials in black walnut.

Forest Protection

- Established or maintained disease-resistance progeny trials for American chestnut and butternut. Disease inoculation methods were developed and refined for each species. Conducted silviculture and ecophysiology trials to aid in the deployment of disease-resistant material.

- Identified a suite of insects and phytopathogens associated with thousand cankers disease (TCD)-symptomatic walnuts. First to isolate pathogen from other potential phoretic vectors (e.g., *Xylosandrus crassiusculus* and *Xyleborinus saxeseni*).
- Offered science-based advice on managing TCD in the native range of black walnut. Discovered that *G. morbida* is a weak, annual canker pathogen on eastern black walnut and other native canker fungi are equally, or more, virulent than *G. morbida* within the native range.
- Applied next-generation sequencing to identify genetic regions in chestnut that influence domestication, contribute to resistance to chestnut blight, and influence squirrel dispersal.
- Tested mechanical and chemical-control systems for invasive honeysuckle.

Graduate Education and Professional Development

- Recruited and / or maintained professional staffing consisting of 14 research scientists, two extension specialists, two tree breeders, a data analyst, one laboratory manager, and an administrative assistant.
- Mentored and trained 13 graduate students (4 PhD; 9 MS), one post-doctoral scientist, and one visiting scientist in HTIRC mission-oriented work.

Organizational Leadership

- Participated in Phase II of the National Science Foundation Industry / University Cooperative Research Center's Center for Advanced Forestry Systems, a multidisciplinary center that bridges top forestry research programs from nine universities with industry members to solve complex, industry-wide problems. Conducted experiments, in collaboration with HTIRC industry partners and other universities, on black walnut crown ideotypes, nutrition, and drought responses.
- Collaborated with the Purdue Research Foundation to establish the GreatWoods Genetically Superior Hardwoods trademark (2012) and established license agreements for black walnut, black cherry, butternut, and red oak selections.
- Secured funding for HTIRC work from numerous sources, including: USDA Forest Service Northern Research Station; Purdue University; van Eck Forest Foundation; USDA Forest Service State and Private Forestry; USDA National Institute of Food and Agriculture; USDA National Resource Conservation Service; USDA McIntire-Stennis; U.S. Department of Interior Office of Surface Mining;

National Science Foundation; American Forest Management; ArborAmerica; American Chestnut Foundation; Indiana DNR Divisions of Forestry and Mine Reclamation; Indiana Forestry and Woodland Owners Association; Indiana Hardwood Lumbermen's Association; Nelson Irrigation; Steelcase, Inc.; and the Walnut Council.

- Coordinated and sponsored multiple extension workshops, field days, and research symposia (e.g., IUFRO 1st Restoring Forests Congress [Madrid, Spain, 2011]; IUFRO Nutrient Dynamics of Planted Forests [Vancouver, Washington, 2012]; North American Forest Ecology Workshop [Bloomington, Indiana, 2013]; IUFRO 2nd Restoring Forests Congress [Lafayette, Indiana, 2014]) to provide forums to share research discoveries among scientists and transfer technology to managers.
- Led development of a new HTIRC website (www.htirc.org).
- Distributed an HTIRC newsletter to ~450 partners and cooperators on a semi-annual basis, describing research results and other information relevant to management of Central Hardwood Forests.

IV. STRATEGIC PLAN

A. Formulation of Strategic Plan

The goal of the HTIRC strategic-planning process was to create a plan that sets the directions and focus of research, educational, and outreach programs that meet stakeholder needs for the five-year period from 2017 to 2021.

Our planning process began by soliciting input from our stakeholders and advisory committee members on their research, outreach, and extension priorities for the HTIRC in October 2015. HTIRC staff and scientists then met regularly during spring and summer 2016 to discuss the initial stakeholder feedback in light of ongoing and future research and extension activities. Results of those discussions led to development of a more formal, electronic survey of future / desired HTIRC research and extension needs and priorities, distributed in September 2016 to all stakeholders. Results of this survey were presented at a strategic planning meeting of HTIRC staff, held October 1, 2016. This session focused primarily on how to best share the results of the survey with stakeholders and define a process by which we would draft the Strategic Plan.

The results of the survey were then shared with the HTIRC Advisory Committee through a facilitated discussion at our annual meeting on October 26, 2016.

Topics identified from the survey and listening session were clarified and refined through a series of meetings with the HTIRC staff. This input was used to guide development of a new Strategic Plan and inform our revised mission statement and new research priorities. Individual topics were consolidated into five broad themes that form the basis of our strategic directions. Working groups were formed for each and tasked with articulating specific, measurable, and attainable objectives around those strategic directions. The results from each working group were then vetted as a group and this Strategic Plan was produced. We then solicited feedback on proposed research and development strategic directions from the Advisory Committee at our annual meeting on October 17, 2017.

B. Strategic Directions and Objectives for 2017-2021

The five strategic directions for the HTIRC are to:

1. Produce hardwood trees with desirable traits, using both classical tree breeding and novel tree improvement techniques;
2. Improve management strategies and techniques to enhance the ecological sustainability and economic benefits of hardwood forests;
3. Develop and demonstrate strategies to address existing and emerging threats to hardwood forests;
4. Engage stakeholders and address their needs through communicating research findings and management recommendations; and
5. Educate future leaders in tree improvement, management, and protection of hardwood forests.

STRATEGIC DIRECTIONS 1-3: RESEARCH AND DEVELOPMENT

These research and development objectives represent a balanced portfolio that includes low-risk projects that will provide short-term incremental gain and higher-risk projects that could lead to rapid and significant innovation. Research and development projects will be centered on improvement, management, and protection of hardwoods in the CHFR.

1. Improvement

There is a continuing need to identify robust genetic markers closely aligned with specific genes associated with important traits, such as pest / disease resistance and associated stress-response genes. In addition, a number of HTIRC plantings are mature enough to calculate genetic gains associated with metric traits such

as growth, form, and merchantable volume. Sustained improvement of the genetic quality and regeneration success of the fine hardwood tree species in the HTIRC portfolio will be realized through application of classical breeding, genomics, and seed production technologies — all of which will lead to healthier and more productive forests when combined with appropriate silviculture.

Understand the influence of gene function in hardwood trees as it relates to desirable traits

- Evaluate the utility of genetic markers as an aid in the development of increased resistance to chestnut blight in our breeding stock.
- Determine the relative importance of genotype and environment on development of heartwood formation in black walnut.
- Develop clonal propagation systems for both black walnut and oaks.

Explore the potential for biotic resistance in some important hardwood tree species

- Improve resistance screening of butternut to butternut canker disease.

Address the current lack of improved seed / propagule sources for important hardwood tree species in the CHFR

- Determine an action plan to identify which specific “common garden” plantings for each species should be retained in the future.
- Develop a breeding plan and strategies for deploying advanced-generation seed orchards for all species in the HTIRC portfolio, beginning with northern red oak, white oak, and black walnut.

Expected five-year activities and outputs in this strategic direction:

- Develop screening protocols to facilitate rapid identification of disease-tolerant individual American chestnut.
- Identify gene markers associated with chestnut blight resistance.
- Identify genes active during the regulation of heartwood formation in black walnut and understand the timing for their expression.
- Measure genetic gain and trait correlation estimates of trees currently within HTIRC tree-improvement programs.

- Develop new seed orchards from individual trees that exhibit outstanding growth and timber quality.

Long-term research and development outcomes in this strategic direction:

- Genomic tools will accelerate breeding for disease resistance in threatened species.
- Improved restoration success of threatened species.
- Control of heartwood will improve its color and percentage and reduce rotation age in plantation-grown black walnut.
- Genetic gains will be obtained through improved breeding, selection, and propagation techniques.
- Seed / propagule sources for improved hardwood tree species.
- Develop clonal propagation systems for black walnut, oaks, and butternut canker-resistant material.

2. Management

Successful, reliable regeneration of native hardwood stands with high-value tree species continues to elude stakeholders throughout the CHFR. Likewise, many plantations in the CHFR are reaching an age where thinning and other mid-rotation treatments should be applied. Tests of new approaches to silvicultural management of both native stands and plantations will be installed. Regeneration success of the fine hardwood tree species in the HTIRC portfolio will be realized



through application of both genetics and modeling to better develop refined management prescriptions.

Refine silvicultural methods to improve oak regeneration in natural stands

- Assess the effects of prescribed fire in mature oak-dominated stands being regenerated.
- Demonstrate novel gap-based approaches to regenerate oak.
- Test efficacy of underplanting and enrichment planting cultural regimes for hardwood forests.

Demonstrate early- to mid-rotation management practices in plantations and natural stands

- Determine effects of season, intensity, and style of pruning on growth and potential grade of black walnut.
- Demonstrate the use of pre-commercial crop tree release and thinning treatments in young stands and plantations.

Improve establishment practices of pure and mixed hardwood plantations

- Refine available soil suitability indices for black walnut and other fine hardwood species.
- Develop a “cultural options” model for plantation establishment.
- Quantify competition effects within mixed species plantations.

Expected five-year activities and outputs in this strategic direction:

- Elucidate the short-term economic and ecological tradeoffs in use of prescribed fire for oak regeneration in mature CHFR forests.
- Finish installing a replicated study of expanding group shelterwood systems in the CHFR as a means to successfully regenerate oak.
- Publish a web-based model of the marginal costs of plantation-establishment practices (e.g., fertilization, deer fencing) as affected by site quality and species.
- Develop guides to restore butternut and chestnut using enrichment plantings in intact forests.
- Improve recommendations for species selection in pure and mixed plantations on a variety of sites.
- Install hardwood mixed-species competition studies using novel experimental designs.

Long-term research and development outcomes in this strategic direction:

- Compare oak regeneration response in expanding group shelterwood systems to traditionally applied selection systems.
- Quantify ecological impact of prescribed fire on mature oak forests.
- Provide alternatives to traditional even- and uneven-aged silvicultural systems to improve ecosystem resiliency.
- Demonstrate increased growth, quality, and composition of hardwood plantations and enhanced end-of-rotation value.
- Refine recommendations of mixed-species plantings (i.e., proportion of each species and density of planting).

3. Protection

Forests throughout the CHFR are threatened by ever-increasing herbivore populations, invasive plants, pests, pathogens, and climate change. Active research to quantify the impacts of these agents on regeneration, health, and productivity of CHFR forests is critical to maintaining the economic and ecological services derived from these forests.

Develop and demonstrate strategies to address existing and emerging threats to hardwood forests

- Understand the etiology of thousand cankers disease (TCD) and factors influencing the resistance of black walnut to the disease within the native range.



- Determine the rates and patterns of spread and impacts (ecological and economic) of major introduced and / or invasive forest plants, insects, and pathogens.
- Identify the response of forests to overstory species loss resulting from invasive insects and disease.
- Develop techniques and materials based on ecophysiological characteristics to aid in the restoration of threatened hardwoods (e.g., butternut, chestnut, etc.).

Understand direct and indirect effects of high ungulate populations on plantations and native forest ecosystems

- Understand deer impacts on both natural and artificial regeneration.
- Quantify relationship between browse damage of several understory plant species and white-tail deer population numbers.

Expected five-year activities and outputs in this strategic direction:

- Determine the potential impact of TCD in the native range of black walnut.
- Create and implement an integrated pest management (IPM) strategy for TCD in plantations of eastern black walnut.
- Understand walnut twig beetle (WTB) population dynamics, especially in the eastern U.S., to better understand the level of threat the beetle poses to black walnut.
- Understand impacts on forest regeneration that will include both direct effects (e.g., mortality, competition) and indirect effects (elimination of competitors, changes in microenvironment, and alterations to ecosystem processes).
- Improve disease resistance of American chestnut and butternut, informed by a better understanding of ecophysiology (i.e., resistance to environmental stresses, including drought and frost, and site preferences).
- Develop browse indices that can be used as relative estimates of white-tail deer population numbers.
- Quantify deer impacts on tree regeneration and understory vegetation.



Long-term research and development outcomes in this strategic direction:

- Develop recommendations for limiting ungulate herbivory on natural and artificial regeneration.
- Produce a series of best management practices for TCD in black walnut plantations.
- Reduce species loss to pests, pathogens, and invasive competitors.
- Integrate remote sensing into currently available technologies and methods to improve pre-visual detection of pests and pathogens.

STRATEGIC DIRECTION 4: ENGAGEMENT AND EXTENSION

The role of HTIRC outreach is to connect our partners, collaborators, and stakeholders with the people, information, and products of the HTIRC. We also engage a broad audience to explain the benefits of forest research, management, and tree improvement for people and the environment.

We will achieve this goal both by communicating state-of-the-art, science-based information and technology and by linking stakeholder needs to the scientific community through:

1. Producing extension publications and other media that communicate current knowledge, technology, policy, and management practices for distribution to CHFR resource professionals and land managers;
2. Developing and distributing communication and marketing materials to engage partners, collaborators, and stakeholders to support and further the HTIRC mission; and

3. Becoming a regional leader by participating in, developing, and hosting national and international conferences related to the HTIRC mission.

Improved communications

- Highlight ongoing HTIRC activities and research results on our newly revised website, www.htirc.org.
- Review HTIRC extension publications to edit and update information that reflects current knowledge, resources, and recommendations available.
- Provide a semi-annual email newsletter and an annual report to partners and cooperators.
- Develop and conduct programs and workshops with cooperators in the CHFR to ensure relevance and visibility beyond Indiana.
- Streamline methods to distribute and access landowner resources and related HTIRC products (e.g., website, mailing lists, listserv).
- Connect to stakeholders through yearly survey to gather feedback regarding how our progress meets or exceeds their needs and expectations.

Increased visibility of the HTIRC

- Website updates with resources related to establishment and management of hardwood trees and forests.
- HTIRC faculty and staff videos and HTIRC lab and field site video tours.
- Participation with USFS communication and engagement.
- Provide video and in-person field demonstrations illustrating the value of select genetic seed sources, effects of deer browse, and other hardwood management and regeneration topics.

Expected five-year activities and outputs in this strategic direction:

- Materials illustrating the HTIRC walnut improvement program, selected traits and impacts.
- Newsletter articles and outreach presentations on effects of prescribed fires on hardwood timber quality and value.
- Enhance the current pruning publications and produce related extension videos.
- A literature review and summary of management recommendations to reduce deer herbivory damage of tree regeneration in hardwood plantations and natural forests.



- Host the 2018 Central Hardwood Forest Conference and several other regional, national, and / or international conferences.

Longer-term outcomes in this strategic direction:

- The HTIRC will become a leading source for information on the improvement, management, and protection of hardwood species throughout the CHFR.
- The HTIRC will be more relevant to the needs of landowners, nursery, and forest managers throughout the region.
- Improved decision-making in forest and plantation management.

STRATEGIC DIRECTION 5: EDUCATION

Developing future researchers and practitioners with expertise in the science and application of tree improvement, management, and protection of hardwood forests is a key objective of the HTIRC. This will be accomplished by promoting the education and professional development of undergraduate students, graduate students, and post-doctoral research fellows.

Students will be educated and trained through a combination of coursework, specialized research projects, and opportunities to present their research at scientific conferences and extension meetings. These students will become the next generation of leaders as extension professionals, forest ecologists, forest geneticists, forest-health specialists, nursery managers, propagators, silviculturists, and tree-improvement specialists. Exposure to interdisciplinary research initiatives — and to the broad range of end-goals of hardwood users (i.e., commercial, ecological, and conservation) — is a cornerstone of the HTIRC educational experience.



HTIRC students are defined as those students working with HTIRC principal investigators to accomplish HTIRC mission-oriented work as defined in this Strategic Plan. These students may be supported by a variety of funding sources, including department, college, university, and external fellowships or extramural funds. Students in the HTIRC benefit from links to the expertise of HTIRC faculty, staff, and partners, priority access to HTIRC resources (i.e., equipment, supplies, and field sites), and opportunities to present or publish their work in HTIRC-sponsored venues.

HTIRC graduate students, and especially van Eck Scholars, will be financially supported based on their interest and commitment to select research topics critical to this Strategic Plan. It is further expected that such students will work closely with both FNR and USFS scientists as they design and conduct their research.

Expected five-year educational activities and outputs:

- Educate and train 20 graduate students (as defined above), 10 undergraduate students (honors researchers) and five post-doctoral scientists at the HTIRC and prepare them for employment with universities, state and federal agencies, NGOs, and private industry.

Expected five-year educational outcomes:

- Nationally and internationally, students will recognize the HTIRC as a preferred organization from which to receive education and training.
- Former HTIRC graduate students and post-doctoral scientists will continue or establish hardwood research programs, thereby increasing the level of research on hardwood trees.
- Former HTIRC undergraduate and graduate students will become leaders in management of the hardwood resource across North America. They will play increasingly prominent roles in their organizations and professional societies.
- The diversity of graduate students recruited into HTIRC will rise by generating increased visibility of the HTIRC program nationwide. Emphasis will be on maintaining an equitable gender balance and increasing the proportion of applications, successful recruitment, and degree completion of under-represented minorities through active recruitment and mentoring.
- The overall quality of the HTIRC graduates will increase. Each M.S. student is expected to produce one refereed publication, and each Ph.D. student is expected to produce two peer-reviewed publications describing results of their research.

C. Organizational Objectives

Beyond these five strategic directions, the HTIRC has several objectives related to organizational function and structure. We believe that achieving these goals within the next five years are essential to the HTIRC's long-term viability.

1. Increase and expand HTIRC membership

There is a recognizable need to both renew emphasis on recruitment of new external HTIRC partners while working more closely with our existing partners. Specifically, we will develop a plan to enhance research, extension, and educational capacity of the HTIRC by including a broader range of expertise on the Advisory Board and framing our research directions based on their input. This expansion will enable us to be more responsive to our stakeholders, leading to the development and implementation of cutting-edge, integrated (education, outreach, and research / development) projects. Fostering and maintaining this enhanced level of communication with stakeholders and Advisory Board members will be a priority for HTIRC leadership and staff, with input from the Purdue University Forestry and Natural Resources Department Head.



2. Enhance delivery of germplasm

There is a strong need to develop a policy and implementation strategy for delivering genetically improved planting stock derived from HTIRC research efforts. To address this need, a standing committee, composed of representatives of HTIRC leadership and Advisory Committee members, will be created to define a distribution policy and make decisions on the release of HTIRC germplasm to various customers — including collaborating scientists, land managers (public vs. private), and other interested stakeholders.

3. Centralize and standardize data related to all HTIRC-installed plantings

To optimize research priorities based upon existing HTIRC plantings, we will complete development of a database encompassing all trees (~130,000) in all plantings (175) — including tree location, pedigree information, and available growth data. The long-term goal is to become a centralized repository for additional USDA Forest Service and Purdue tree plantings in the CHFR. Specific database management activities are highlighted below. All field plantings will be assessed for future utility (i.e., survival, growth, site adaptability) in ongoing and future improvement efforts. Re-measurement of retained plantings will be scheduled based on past history and specific traits of interest.

Complete centralization of all data related to HTIRC-installed field trials

Database completion will facilitate estimation of G x E effects in black walnut, red oak, white oak, black cherry, and butternut (data collated in the next year: 37 sites with eight-plus years of data).

Develop a data “hygiene” plan to standardize all HTIRC data

Develop archival-quality, long-term data / metadata storage to facilitate / enable future USFS future collaborative research across the CHFR.

Centralize other tree genetics databases

By centralizing other relevant tree genetics databases, we will:

1. Enhance future collaborations among other FS units and institutions;
2. Capitalize on the value represented by unique 50- to 90-year-old plantings to advance scientific research (i.e., tree physiology, tree genetics, forest ecology); and
3. Address current/future tree genetic conservation efforts.

4. Develop digital forestry technologies

We recognize the need to develop and refine forest improvement, regeneration, management, and protection tools that incorporate information from existing and emerging remote-sensing technologies (e.g., LiDAR, thermal, hyperspectral imagery) acquired from terrestrial, aerial, and satellite platforms. These technologies are becoming increasingly inexpensive and user-friendly and offer the potential to automate and standardize the many laborious and subjective forest measurements. Further, remote-sensing methods allow rapid scaling-up of plot and stand-level methods to the landscape level, improving forest management efforts. Effective integration of remote-sensing technologies can contribute to and accelerate successful delivery of many other HTIRC objectives.

V. ORGANIZATIONAL DESIGN

The HTIRC is centered on the Purdue University campus in West Lafayette, Indiana. It also includes close collaborations with the (FS) Northeastern Area State and Private Forestry; USDA Forest Service National Forests Region 9; Indiana Department of Natural Resources Division of Forestry; Indiana Hardwood Lumbermen's Association; National Hardwood Lumber

Association; ArborAmerica; Steelcase, Inc.; American Forest Management; Indiana Forestry and Woodland Owners Association; Walnut Council; the Fred M. van Eck Forest Foundation; and other organizations interested in improving the management of the Central Hardwood Forest.

A. Leadership

In close consultation with Dr. Robert Wagner, FNR Department Head at Purdue University, the HTIRC is led by two co-directors: Dr. Mark V. Coggeshall, USDA Forest Service Northern Research Station Project Leader of NRS14, based at Purdue University; and Dr. Matthew D. Ginzel, Associate Professor, Departments of Entomology and Forestry and Natural Resources. Both co-directors assumed their roles in early 2017. Together, Coggeshall and Ginzel seek to enable continued improvement of the HTIRC through active engagement with stakeholders, partners and researchers, and encouraging increased participation by the HTIRC Advisory Board.

B. Guiding Principles

HTIRC will be guided by the following principles as it conducts research to meet the objectives outlined in this plan:

- Research will focus primarily on information that HTIRC stakeholders can apply to the improvement, management, and protection of hardwood trees in the CHFR. Basic research closely aligned with applied research objectives is encouraged.
- We will maintain a high degree of collaboration, coordination, cooperation, resource-sharing, and communication among HTIRC researchers in meeting research objectives.
- Funding will be managed in a clear, transparent manner and directed toward supporting strategic directions.
- We will maintain close contact with Advisory Committee and cooperating organizations to communicate the latest research results, identify research needs, and examine emerging hardwood tree improvement, management, and protection issues.
- HTIRC research will strive to achieve the highest professional standards in experimental design, methods, and procedures.
- To achieve optimal results from field research, the HTIRC will encourage projects led by research teams that include integrated questions and collaboration.

- We will pursue research opportunities that leverage shared collaborations, in-kind contributions, and cooperative funding with other organizations that share common goals and / or have expertise.
- The HTIRC will rapidly communicate research results to stakeholders through the most effective means (including oral presentations at Advisory Committee meetings and workshops, as well as web-based publications). We will promptly submit completed research for publication in refereed scientific journals.

C. Operations / Administration

Advisory Board

The HTIRC Advisory Board is made up of individuals from HTIRC partner organizations, including industry, state government, landowners, foresters and scientists. The Advisory Board meets annually to receive updates on HTIRC research and provide input on research priorities. These meetings represent an important engagement and outreach effort for the HTIRC.

In addition to development of this new Strategic Plan, it is anticipated that new and more transparent funding mechanisms (i.e., small grants) will be developed to support both new and ongoing research efforts by HTIRC scientists, staff, postdocs, and graduate students. Development of these transparent mechanisms will rely upon active participation of the HTIRC Advisory Board.

For this Strategic Plan, it is envisioned that an Executive Committee, composed of five to six HTIRC Advisory Board members, will be identified. Responsibilities of this Executive Committee will include the timely oversight of all HTIRC activities, as well as providing input to the FNR Department Head and HTIRC leadership in the form of recommendations as they relate to annual research budget allocations. Such allocations may include (but are not limited to) graduate student and post-doctoral scientist support and funding of pilot-scale research projects. Lastly, this HTIRC Executive Committee will provide critical input to the HTIRC leadership on development of a robust plant material release policy for distribution of HTIRC materials to our stakeholders, industry partners, and supporting agencies.

Cooperative Model

Currently, some members of the Advisory Board fund specific projects related to their interests. These special-interest projects could be strengthened with leverage by cooperating entities. If developed, a cooperative model would provide a structure by which member contributions (or dues) are standardized



and expectations / deliverables are defined by the group. This structure, to balance contributions with deliverables, can facilitate expansion of our partners to include other states or sectors of the forest products industry. Membership benefits could include access to expertise and genetic material to develop seed orchards (improved material or merely source-identified), leveraged resources towards projects with regional impact, and early access to research findings. A committee to organize the HTIRC into a stakeholder-driven cooperative has been formed, and a cooperative structure is expected to be presented at an October 2018 HTIRC meeting.

HTIRC Staffing

To address the research priorities enumerated in this Strategic Plan, the HTIRC is composed of a diverse array of talented researchers, staff, post-doctoral associates, and graduate students, representing both the Purdue University FNR and Entomology Departments, as well as the USDA Forest Service Northern Research Station. During the 2016-2017 academic year, HTIRC staffing included 13 faculty, nine staff, two postdocs, and 18 graduate students. With the expertise represented by the HTIRC staff, we are ideally positioned to deliver the outcomes presented in this plan.

D. Funding

HTIRC core operating funds are provided by the Fred M. van Eck Forest Foundation, Purdue University Department of Forestry and Natural Resources and College of Agriculture, and the USDA Forest Service Northern Research Station. Funding for collaborative projects that advance the mission of HTIRC is provided by the USDA Forest Service Northeastern Area State and

Private Forestry, private forest landowners, the hardwood forest products industry, and other external sources.

Scientists within HTIRC are expected to apply for grants from federal agencies, including the National Science Foundation, National Aeronautics and Space Administration, Animal and Plant Health Inspection Service, United States Department of Energy, and United States Department of Agriculture. In addition, grants will be sought from programs such as the Hardwood Forestry Fund, Walnut Council Foundation, American Chestnut Foundation, and Consortium for Plant Biotechnology Research.

The Indiana Hardwood Lumbermen's Association, National Hardwood Lumber Association, and Indiana Forestry and Woodland Owners Association have each made funding commitments. Landowner groups and other hardwood and conservation associations may be approached in the future to provide funding support.

Several private citizens have also provided funds and land for endowments to fund scholarships, assistantships, and applied research. Future opportunities will be pursued as they arise. Moreover, funding sources for education (e.g., National Needs Fellowships and NSF-Research Experience for Undergraduates) will be explored.

New, incoming HTIRC graduate students, and especially van Eck Scholars, will be financially supported based on their interest and commitment to select research topics critical to this Strategic Plan. It is further expected that such students will work closely with both FNR and Forest Service scientists as they design and conduct their research.

E. Program Evaluation

A program review will be conducted in 2021 to assess how well HTIRC has met the above strategic objectives. As part of this review, input will be solicited from the HTIRC Advisory Board members, Purdue University FNR Department Head, Assistant Director for Research from the USDA Forest Service Northern Research Station, scientists, stakeholders, and others associated with HTIRC. In addition, the Advisory Committee will provide annual feedback on research priorities and will suggest re-prioritization of objectives as necessary.



**HARDWOOD TREE IMPROVEMENT
& REGENERATION CENTER**

Learn More about the **HTIRC**

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