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Sponsored Program Services

August 29, 2018

The American Chestnut Foundation
Externalgrants@acf.org

Proposal Title: Below ground competition of American chestnut
Period of Performance: 1/1/19 – 12/31/19
Requested Amount: $9,951

Dear Sir or Madam:

Please accept the enclosed proposal submitted on behalf of Purdue University. The research for this proposal will be directed by Dr. Douglas Jacobs. This application has been administratively reviewed and approved by the appropriate officials.

Any agreement or award resulting from this proposal submission should reference the proposal number 00080512 and be made to the following address: 155 S. Grant Street, West Lafayette, IN 47907-2114.

Purdue University's institutional administrative information is available at:
http://www.purdue.edu/business/sps/preaward/external.html

Commonly requested information includes:

DUNS number: 07-205-1394 | Cage Code: 6D418
EIN: 1356002041A1 | Congressional District: IN-004

Please contact the principal investigator, Dr. Jacobs, at 765-494-3608 or djacobs@purdue.edu regarding technical aspects of the proposal. Fiscal questions should be directed to the pre-award specialist, Jenny Thayer, at 765-494-5745 or jlthayer@purdue.edu.

We look forward to your favorable review.

Sincerely,

Bryan Scott
Pre-Award Center Manager
agpreaward@purdue.edu

Project Title: Belowground competition of American chestnut

Summary: Below-ground dynamics of American chestnut have received little attention. A 12-year-old experiment of American chestnut, northern red oak, and black cherry planted as monocultures and species mixtures at varying densities is now a closed canopy forest, and provides a unique opportunity to explore the long-term performance of American chestnut. We propose to leverage ongoing studies of species diversity and ecosystem productivity, and add measurements of belowground productivity, and functional and chemical traits. These results will improve knowledge of American chestnut development in co-occurrence with other species and inform land managers how to best incorporate American chestnut into afforestation strategies.

Principal Investigators

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John Couture (Co-PI), Assistant Professor, Entomology, Purdue University

Brady Hardiman (Co-PI), Assistant Professor, Forestry and Natural Resources, Purdue University

Gordon McNickle (Co-PI), Assistant Professor, Botany and Plant Pathology, Purdue University

Project Duration: January – December 2019

Funding Request: $9,951 (see statement of matching funds below)

Short-term Project Goals:

1. Characterize belowground root production under varying plantation density and species mixtures.
2. Identify relative effects of competitor species on the root system productivity of American chestnut.
3. Investigate belowground root chemistry to complement ongoing analyses of aboveground foliar chemistry in these mixed species plantation stands.

Long-term Project Goals:

1. Determine optimal planting densities and species mixtures of American chestnut in both pure and mixed species plantations.
2. Help ensure useful silvicultural guidelines prior to reintroduction, through increased knowledge of the ecology of American chestnut.
3. Seek a mechanistic understanding of the causes of the positive correlation between productivity – diversity to increase profitability of forest plantations.

Project Narrative:

Introduction

Prior to the introduction of the chestnut blight, American chestnut was an important tree species throughout the eastern US deciduous forest (Braun 1950; Keever 1953). The loss of this species influenced myriad associated ecosystem services (Keever 1953; McCormick and Platt 1980; Diamond et al. 2000; Pierson et al. 2007; Jacobs et al. 2013). This included landscape wide reductions in photosynthesis, productivity, and carbon sequestration, as well as increased leaching of nutrients and alterations of microhabitats (Lovett et al. 2006). In addition, forest structure and tree species composition were altered, with co-occurring species shifting into the dominant and co-dominant canopy positions due to the release caused by the decline of American chestnut (Smith 2009).

In response to this ecological catastrophe, considerable efforts have been directed at American chestnut restoration. During the last decades, significant progress has been made toward the goal of developing a blight-resistant hybrid chestnut, through crosses with Chinese chestnut (*Castanea mollissima* Blume) (Hebard 2006). Here, phenotypic characteristics of American chestnut are regained through a series of backcrosses to American parents, reducing the proportion of Chinese alleles. The third-generation backcross (BC_3) has been shown to retain American chestnut morphological characteristics through juvenile stages, with testing ongoing (Diskin et al. 2006; Steiner et al. 2017).

Blight resistant chestnut has the potential to become an important tree species for forest restoration (Jacobs et al. 2013). Contemporary research suggests that American chestnut is adapted to a wide range of site conditions and light environments, and is reported to be a fast-growing species with desirable timber (Jacobs and Severeid 2004; McEwan et al. 2006; Jacobs et al. 2009). Thus, chestnut should be an attractive tree species for many private landowners in eastern North America. While knowledge of chestnut's silvical characteristics in field settings has improved over the past decade (Jacobs 2007; Jacobs et al. 2013; Wang et al. 2013), **its competitiveness in mixed species stands has been the focus of very few studies**. Mixed plantations have been identified as an important tool for forest restoration as they serve a wide variety of social, economic, and environmental objectives in comparison with monocultures (Paquette and Messier 2010). Successful mixed plantations can take advantage of complimentary characteristics of the assemblage of species, such as varying shade tolerance that facilitates a stratified canopy, or by combining species with alternative strategies for scavenging nutrients and water (Kelty 1992; Nichols et al. 2006). Of particular note to American chestnut is that high diversity can actually reduce disease risk through a phenomenon called the dilution effect, which is literally the simple dilution of probability of infection caused by high species diversity (Schmidt and Ostfeld 2001; Keesing et al. 2006).

Rationale and Objectives

Blight-resistant hybrid chestnut seedlings will become available for future reforestation efforts. Further insight into the silvical and ecological characteristics of American chestnut is thus needed to establish guidelines that will aid restoration efforts. The most common silvicultural manipulation of forest stands and plantations is change in density (spacing). It therefore stands to reason that further understanding of the long-term performance of American chestnut at various spacings is needed. At higher densities, competition for above and belowground resources can be limiting, eventually leading to mortality of less competitive individuals. However, the well understood dilution effect also means that a factorial design that crosses spacing and species diversity may yield important new insights into the long-term performance of American chestnut. Competition for light is largely determined by growing space occupancy, as trees with larger crowns have greater ability to intercept more sunlight. An additional benefit of diverse plantations is that species frequently differ in traits, which allows diverse assemblages to be more productive than monocultures (Tilman et al. 2001; Liang et al. 2016). Understanding how American chestnut responds to density-induced stress will allow forest managers to make more informed decisions in their efforts to reintroduce the species across the landscape.

The aim of this study is to gain further knowledge regarding factors that influence the growth and competitiveness of American chestnut grown alone and in combination with associated hardwood species, in an effort to ensure successful outplanting of chestnut in the future. While recent studies have improved our understanding of above-ground competition of American chestnut, belowground dynamics have received relatively little attention. This knowledge is important because aboveground growth and productivity often does not explain belowground processes, especially under intra vs. interspecific competiton (i.e., moncoultures vs. mixed plantations). Root growth and root-soil interactions have important implications in carbon cycling, interactions with mycorrhizal communities, nutrient / water competition, and allelopathy. Roots are difficult to study, yet we have assembled a diverse research team with expertise in modern analyical techniques that can provide important insights into American chestnut belowground development. Thus, *our specific objective is to evaluate root system productivity and root-soil chemistry interactions of American chestnut under varying spacings and species mixtures.*

Methodology:

<u>Study Site</u>: This study will be carried out at a previously established competition trial planted by PI-Jacobs and colleagues in 2007 and located at Martell Forest, Purdue University's primary research forest located in West Lafayette, Indiana. We planted stands of American chestnut (*Castanea dentata* (Marsh.) Borkh.), northern red oak (*Quercus rubra* L.) and black cherry (*Prunus serotina* Ehrh.) as monocultures, two species mixtures and all three species together, at three different densities (1m, 2m or 3m spacing between trees). Early growth and physiological data after five years were published previously (Gauthier et al. 2013). This 12-year-old experiment is now a closed canopy forest (Fig 1), and provides a unique opportunity to explore productivity – diversity relationships in an experimentally manipulated plantation forest.

FIGURE 1: *Closed canopy experimental plantations of American chestnut, northern red oak, and black cherry.*

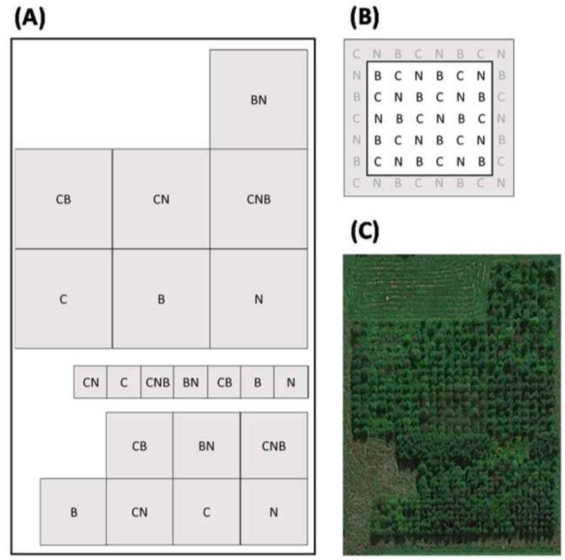

FIGURE 2: (A) *Layout of treatments within 1 of the 3 replicate blocks,* ***(B)*** *layout of planted trees within a plot, and* ***(C)*** *a satellite photo of one block. Three species were planted either as monocultures (C, N, or B), 2-species mixtures (CN, CB, or BN) or as three species mixtures (CNB). Each plot was planted with 56 trees that were spaced either 1m, 2m or 3m apart resulting in different sized plots (6x8m, 12x16m or 24x32m). A buffer row 1 tree wide was planted around all plots, leaving 30 focal trees in the center of each plot.*

<u>Experimental Design</u>: The experimental design was inspired by traditional competition experiments (Radosevich et al. 1997) and more recent studies and reviews on mixed plantings (Kerr 2004; Vanclay 2006). The split-split plot design consists of three different species (sub-sub plot) randomized within seven different mixtures (sub-plot). In turn, mixtures are randomized within three different spacings (main plot). Spacings were randomized within each block. Three blocks were installed in the spring of 2007, taking up approximately 2.4 ha. The seven mixtures were as follows: 1) 100% black cherry (B), 2) 100% American chestnut (C), 3) 100% northern red oak (N), 4) 50% cherry and 50% chestnut (BC), 5) 50% cherry and 50% oak (BN), 6) 50% oak and 50% chestnut (NC), 7) one-third of each species (NBC) (Fig 2a). All plots are 8 trees by 7 trees square, but differ in the spacing between trees, with a buffer of 1 tree row around the perimeter to minimize edge effects (Fig 2b). Spacings used for this study are 1 m (10000 stems ha^{-1}), 2 m (2500 stems ha^{-1}), and 3 m (1111 stems ha^{-1}). The experimental unit (EU) is the average of each species in each mixture and spacing combination, excluding the buffer row (n=108). Thus, all EUs were composed of 30 seedlings, providing at least 10 seedlings per species in each EU. For plots with two or more species, each species was planted alternately in each row, similar to a checkerboard pattern. A total of 1800 bareroot seedlings (1+0) of each species were purchased from Cascade Forest Nursery in Cascade, Iowa, USA.

Seedlings of all species were grown on the same site and subjected to the same fertilization, irrigation, and root culture regimes under standard nursery conditions. Northern red oak and black cherry were from seed sources local to the nursery. Pure American chestnut seeds were collected from a stand of trees > 100 years of age near Galesville, Wisconsin, USA. The experimental design is illustrated in Figure 1.

<u>Measurements:</u> We have an ongoing series of funded experiments in these stands to assess productivity-diversity relationships aboveground by measuring physiological, morphological, chemical, and structural functional traits. For example, litter traps are deployed under the canopy to collect falling leaves. Wood growth is estimated by measuring the diameter at breast height of all trees in the experiment. Soil nutrient availability is estimated using ion-exchange resin membrane methods. The soil moisture and understory light environment is estimated using automated data loggers. Canopy structure is characterized using ground-based portable canopy lidar and high-resolution hemispherical photography. Foliar primary and secondary metabolites are quantified using standard analytical approaches. Thus, we have comprehensive data and knowledge regarding the aboveground characteristics of the forest, as well as detailed information of the above and belowground environmental conditions in these stands. Because of the additional effort and expense required to study roots, we were unable to include this in the budget of our ongoing project. Here we propose to leverage our existing funding, to add a belowground component to our ongoing measurements.

We propose to evaluate belowground productivity using in-growth cores to estimate root system growth (Stevens and Jones 2006). A problem with studying root production in forests is that production is typically biomass produced per year, but the perennial roots of trees mean that one cannot assess productivity by measuring standing root biomass because standing roots represent an unknown mixture of many years growth. In-growth cores involve four steps: (*i*) extract a core of soil from the ground, and remove all existing roots from the soil; (*ii*) place the soil inside a cylindrical mesh bag, and place the bag inside the hole in the ground. The mesh is large enough to allow roots to grow inside, and simply facilitates retrieval; (*iii*) allow one growing season of root growth; (*iv*) retrieve the in-growth cores, wash away soil, and perform measurements on the roots produced during exactly one growing season. The different tree spacing treatments vary in plot size (Fig 2A), and thus we will deploy one ingrowth core in each 1m spaced subplot, two ingrowth cores in each 2m spaced plot, and three ingrowth cores in each 3m spaced subplot. Ingrowth cores will not be placed in the buffer rows, and will be randomly located within each subplot, but equidistant from trees. In-growth cores will be 5 cm in diameter, and 0.5 m deep to capture the surficial fine roots. This will give us a total of 126 ingrowth cores across the experiment, representing approximately 126 L of soil. Upon retrieval, soil will be washed from roots on a 0.5 mm mesh. Roots will be retained to and scanned fresh to estimate total length, then dried using silica gel and weighed to asses production of root biomass. A sub-sample will be analysed for chemical traits (details below), and another subsample for DNA analysis to identify species.

Unlike aboveground parts of plants which can be visually identified to species, the roots of most plants are visually indistinguishable. However, the molecular biology revolution solved this problem via DNA sequencing (McNickle et al. 2008; Taggart et al. 2011; Miller et al. 2014; Lamb et al. 2016). To identify species, we will use a high-throughput species identification method that has been shown to be capable of generating species abundance data from root samples (Lamb et al. 2016). First, we can build a reference library of trnL gene sequences for our study species using the GeneBank database. The trnL region is advantageous because it has four neutral spacer regions that vary in length and sequence among species (Taggart et al. 2011). Second, we will use next generation sequencing to estimate the abundance of each species in the mixed root samples from the root samples using methods described in the literature (Lamb et al. 2016). Briefly, genomic DNA will be extracted using Qiagen PowerPlant Pro DNA extraction kits that include a phenolic separation solution step because roots are well known to contain a high concentration of phenolics that inhibit downstream reactions (McNickle et al. 2008). The trnL region will be amplified using PCR, using from primers with Illumina adapter overhang modifications and Illumina adapters with barcodes will be added with a second PCR reaction. Finally, PCR samples will be cleaned up with Beckman Coulter AmPURE XP magnetic beads, pooled and sequenced with MiSeq. PI McNickle has done this work before, and has access to molecular facilities for these reactions. The sequencing will be done at the Purdue Genomics Core Facility. Each MiSeq run will generate millions of reads, and require post-processing via bioinformatics pipelines. These pipelines have three basic steps: i) sequence quality screening; ii) clustering of DNA sequences, and; iii) taxonomic assignment. We have access to expertise at the Purdue Bioinformatics Core Facility to develop the informatics pipeline.

Root samples will be analyzed for the same suite of primary and secondary metabolites that are quantified in leaf tissue. Standard analytical determination of foliar carbon (C) and nitrogen (N) will be performed using a Thermo Finnigan Flash 1112 elemental analyzer (San Jose, CA, USA). Simple sugars and starch will be determined spectrophotometrically using a modified dinitrosalicyclic acid assay (Lindroth et al. 2002). Total phenolics and tannins will be determined spectrophotometrically using a modified Folin-Ciocalteu assay (Chauvin et al. 2018) while flavonoids and small phenolic acids will be quantified using high performance liquid chromatography with gradient elution and diode array detection (Nour et al. 2013). Lignin levels will be quantified spectrophotometrically using an acetyl bromide method (Moreira-Vilar et al. 2014).

Analysis of variance will be used to examine significant ($p<0.05$) differences in root biomass as a function of spacing and proportion of each species. The average of each species per plot will be used as the experimental unit, providing three replicates per spacing and species combination ($n=63$). Linear regression will be used to determine relationships between species-level annual root biomass production rates and the biodiversity and density experimental treatments. All analyses will be carried out using R software.

Timeline:

2019	**Jan**	**Feb**	**Mar**	**Apr**	**Mar**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Install in-growth cores	-------------											
Growing season			--									
Retrieve and wash in-growth cores										-----		
DNA and chemistry measurements										----		
Data analysis											----	
Submission of report											----	
Prepare refereed article												----

Measuring and reporting of results: Specific measurements will be recorded and analyzed as described in the methods above. A final financial report and a final project report will be submitted to the American Chestnut Foundation at the end of the project. Project results will contribute to research presentations to be made at relevant meetings (e.g., American Chestnut Foundation, Society for Ecological Restoration, Ecological Society of America, and Society of American Foresters). We will encourage the undergraduate student researcher(s) involved in this project to deliver these presentations. In addition, a comprehensive manuscript will be authored and submitted to refereed journals such as *Plant and Soil* or *Forest Ecology and Management*.

Breakdown of expenditures

Undergraduate student salary for field data collection, lab work:	$ 6,280
Undergraduate student fringe benefits	$ 521
DNA extraction from root growth cores	$ 1,200
DNA Sequencing	$ 1,350
Travel expenses:	$ 600
Total Project Request from TACF:	**$ 9,951**

Matching funds: The PI and Co-PI's for this project were awarded an Agricultural Science and Extension for Economic Development (AgSEED) in 2018 from an internal Purdue University competition. This competition was established through Crossroads funding from the Indiana Legislature to foster the state's leadership in plant and animal agriculture and rural growth. This funding was used to support technician, lab supplies, and travel to generate the aforementioned data related to physiological, morphological, chemical, and structural functional traits. Co-PI McNickle and Couture each have stocks of consumables and reagents from laboratory start-up funds, which can also be leveraged to perform the wet-lab work proposed here. The new funds we are requesting from TACF to assess below ground dynamics will thus be strongly leveraged. This does not justify auditable cost share by Purdue University

Statement of Conflict of Interest or Commitment: There is no known COI or COC.

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BIOGRAPHICAL SKETCH

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Professional preparation

Oregon State University	Ph.D. in Forest Science	2001
University of Georgia	M.S. in Forest Resources	1998
Emory University	B.A. in Ecology	1993

Recent Appointments

2017-current	Director, Tropical Hardwood Tree Improvement and Regeneration Center
2015-2017	Co-Director, Hardwood Tree Improvement and Regeneration Center
2014-current	Associate Head of Research. FNR, Purdue University
2012-current	Fred M. van Eck Endowed Chair of Forest Biology, FNR, Purdue University
2011-current	Professor FNR, Purdue University
2016	Visiting Professor, University of Hawaii at Manoa
2016	Visiting Scientist, Institute of Pacific Islands Forestry, USDA Forest Service
2006-2011	Associate Professor, FNR, Purdue University
2008-2009	Visiting Professor, Technological University of Madrid, Spain
2001-2006	Assistant Professor, FNR, Purdue University
1998-2001	Research Assistant, Department of Forest Science, Oregon State University
2000	Instructor, Department of Forest Science, Oregon State University

Recent Publications Related to Project

1. Gustafson EJ, Sturtevant BR, de Bruijn AMG, Lichti NI, Jacobs, DF, Kashian DM, Miranda BR, Townsend PA. 2018. Forecasting effects of tree species reintroduction strategies on carbon stocks in a future without historical analog. *Global Change Biology* DOI: 10.1111/gcb.14397
2. Skousen J, Dallaire K, Scagline S, Monteleone A, Wilson-Kokes L, Joyce J, Thomas C, Keene T, DeLong C, Cook T, Jacobs DF. 2018. Plantation performance of chestnut hybrids and progenitors on reclaimed Appalachian surface mines. *New Forests* 49:599-611.
3. Gustafson, E.J., de Bruijn, A., Lichti, N.I., Jacobs, D.F. Sturtevant, B.R., Foster, J.R., Miranda, B.R., and Dalgleish, H.J. 2017. The implications of American chestnut re-introduction on landscape dynamics and carbon storage. Ecosphere 8:e01773.
4. Owings, C.F., Jacobs, D.F., Shields, J.M., Saunders, M.R., and Jenkins, M.A. 2017. Individual and interactive effects of white-tailed deer and an exotic shrub on artificial and natural regeneration in mixed hardwood forests. AoB Plants 9: plx024.
5. Dalgleish HJ, Nelson CD, Scrivani JA, Jacobs DF. 2016. Consequences of shifts in abundance and distribution of American chestnut for reintroduction of a foundation forest tree. *Forests* 7, 4.
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7. Gauthier, M.M., Zellers, K.E., Löf, M., and Jacobs, D.F. 2013. Inter- and intra-specific competitiveness of plantation-grown American chestnut (*Castanea dentata*). *Forest Ecology and Management* 291:289-299.
8. de Bruijn, A., Gustafson, E.J., Kashian, D.M., Dalgleish, H.J., Sturtevant, B.R., and *Jacobs, D.F. 2014. Decomposition rates of American chestnut (*Castanea dentata*) wood and implications for coarse woody debris pools. Canadian Journal of Forest Research 44:1575-1585.
9. Jacobs, D.F., Dalgleish, H.J., and Nelson, C.D. 2013. A conceptual framework for restoration of threatened plants: the effective model of American chestnut (*Castanea dentata*) reintroduction. *New Phytologist* 197:378-393.
10. Jacobs, D.F., Selig, M.F., and Severeid, L.R. 2009. Aboveground carbon biomass of plantation-grown American chestnut (*Castanea dentata*) in absence of blight. *Forest Ecology and Management* 258:288-294.

Recent Grants Received

2018	Implementing a disease resistance program for Rapid Ohia Death. USDA Forest Service (co-PI)	$64,000
2015	Interactions of nursery stocktypes and site preparation on mine reclamation success. Indiana Department of Natural Resources, Division of Reclamation (PI)	$80,308
2015	Optimizing nursery photoperiod to promote root growth of forest tree seedlings after planting. USDA Forest Service (PI)	$30,000
2014	Prediction and management of American chestnut natural regeneration and blight-induced mortality USDA NIFA, Fellowship Grant Program (co-PI)	$149,983
2014	Integrating spatial processes and tree seed dispersal and insect population dynamics within LANDIS-II, USDA Forest Service (PI)	$19,409
2013	Silvicultural applications to mitigate animal browse damage of forest regeneration on mine reclamation sites. Indiana Department of Natural Resources, Division of Reclamation (PI)	$80,460
2012	Collaborative research: Center for Advanced Forestry Phase II. NSF (PI)	$208,000
2012	Chemical repellents to deter hebivory of planted forest trees. USDA, Forest Service (PI)	$55,000
2011	Forecasting carbon storage of eastern forests: Can American chestnut restoration improve storage potential in an uncertain future? USDA NIFA, Climate Change: Carbon Cycle (PI)	$681,743
2011	Controlled-release fertilization to improve fertilizer use efficiency and optimize growth of tree seedlings on reclaimed oil sands. Suncor Energy, Inc. (PI)	$274,756
2010	Use of stable isotopes to trace the fate of applied nitrogen in forest plantations. NSF (co-PI)	$195,078
2010	Phytotoxicity associated with competition control for establishment of American chestnut and oaks on reclaimed mine sites. Indiana DNR, Division of Reclamation (PI)	$76,913
2009	Integrating the forestry reclamation approach for mine reclamation in the Mid-Continent Region. USDI, Office of Surface Mining (co-PI)	$168,864

Biographical Sketch

John J. Couture **Assistant Professor**
Purdue University
Departments of Entomology and Forest & Natural Resources

Professional Preparation

Western Michigan University, Kalamazoo, MI Biology B.S., 2001
Western Michigan University, Kalamazoo, MI Biological Sciences M.S., 2005
University of Wisconsin-Madison, Madison, WI Entomology Ph.D., 2011
University of Wisconsin-Madison, Madison WI Postdoctoral Research Assistant, 09/11-08/12
Forest and Wildlife Ecology
University of Wisconsin-Madison, Madison WI Postdoctoral Fellow, 08/12-08/14
Forest and Wildlife Ecology

Appointments

Purdue University
Assistant Professor, 08/16-present
Departments of Entomology and Forest & Natural Resources

University of Wisconsin-Madison
Assistant Scientist, 08/14-8/16
Department of Forest and Wildlife Ecology

Five products most closely related

Cotrozi L, Townsend PA, Pellegrini E, Nalia C, **Couture JJ** (2017) Reflectance spectroscopy: a novel approach to better understand and monitor the impact of air pollution on Mediterranean plants. Environmental Science and Pollution Research. *In press.* doi: 10.1007/s11356-017-9568-2

Cotrozzi L, **Couture JJ**, Cavender-Bares J, Kingdon CC, Fallon B, Pilz G, Pellegrini E, Nali C, Townsend PA (2017) Using foliar spectral properties to assess the effects of drought on plant water potential. Tree Physiology. *In press.* doi: 10.1093/treephys/tpx106

Couture JJ, Singh A, Rubert-Nason KF, Serbin SP, Lindroth RL, Townsend PA (2016) Spectroscopic determination of ecologically relevant plant secondary metabolites**.** Methods in Ecology and Evolution 7: 1402-1412. doi: 10.1111/2041-210X.12596

Cavender-Bares J, Meireles JE, **Couture JJ,** Kaproth M, Singh A, Kingdon CC, Center A, Zuniga E, Pilz G, Townsend PA (2016) Associations of leaf spectra with genotypic and phylogenetic variation in oaks: prospects for remote detection of biodiversity. Journal of Remote Sensing, 221. doi: 10.3390/rs8030221

Couture JJ, Serbin SP, Townsend PA (2013) Spectroscopic sensitivity of real-time, rapidly induced phytochemical change in response to damage. New Phytologist 198: 311-319. doi: 10.1111/nph.12159

Five additional related products

Rubert-Nason KF, **Couture JJ,** Gryzmala EA, Townsend PA, Lindroth RL (2017) Vernal freeze damage and genetic variability alter tree growth, chemistry, and insect interactions. **Plant, Cell, and Environment** doi: 10.1111/pce.13042

Couture JJ, Meehan TD, Rubert-Nason KF, Lindroth RL (2017) Effects of elevated carbon dioxide and ozone on foliar quality of trembling aspen (*Populus tremuloides*) and paper birch (*Betula papyrifera*). Journal of Chemical Ecology 43:26-38. doi: 10.1007/s10886-016-0798-4

Couture JJ, Meehan TD, Kruger EL, Lindroth RL (2015). Insect herbivory alters impact of atmospheric change on northern temperate forests. Nature Plants 15016. doi: 10.1038/nplants.2015.16

Couture JJ, Holeski LM, Lindroth RL (2014) Impacts of long-term exposure to elevated CO_2 and O_3 on aspen foliar chemistry across multiple developmental stages. Plant, Cell, and Environment 37: 758-765. doi: **10.1111/pce.12195**

Couture JJ, Serbin SP, Townsend PA (2015) Elevated temperature and periodic water stress alter growth and quality of common milkweed (*Asclepias syriaca*) and monarch (*Danaus plexippus*) larval performance. Arthropod-Plant Interactions 9: 149-161. doi:10.1007/s11829-015-9367-y

Synergistic Activities:

Member: Entomological Society of America

Faculty member: Purdue Center for Plant Biology, Purdue Climate Change Research Center

Mentoring and training activities:

<u>Purdue University:</u>

<u>Postdoctoral Scholars:</u>

Lorenzo Cotrozzi, P.hD. University of Pisa, Pisa, Italy

<u>Current Graduate Students:</u>

Marguerite Bolt, M.S., Purdue University, Entomology

Raquel Peron, P.hD., Purdue University, Purdue Life Science Education and Entomology

Taylor Nelson, M.S., Purdue University, Entomology

<u>Graduate Student Committees:</u>

Christie Shee, P.hD., Entomology

Thorsten Hansen, P.hD, Entomology

<u>Previous Graduate Students Committees:</u>

Veronica Campos Medina, P.hD., Entomology

<u>Undergraduate Mentoring:</u>

Entomology undergraduate faculty mentor

Horizon Student Support Services Faculty Mentor

Research mentor for 15 undergraduate students in Entomology, Forestry and Natural Resources, Botany and Plant Pathology

<u>High School Mentoring</u>

Pre-college Molecular Agricultural Science Initiative (PMASI)

Brady S Hardiman, Assistant Professor
Purdue University, 715 West State Street, West Lafayette, IN 47907
Phone: (765)-494-3593 Email: bhardima@purdue.edu

Professional Preparation

Ashland University	Ashland, OH	Biology	B.S., 2003
Ohio State University	Columbus, OH	Forest ecology	Ph.D., 2012
Boston University	Boston, MA	Forest, urban ecology	Postdoc, 2012-16

Appointments

01/2016-present: Assistant Professor; Purdue U.; Dept. of Forestry and Natural Resources & Division of Environmental and Ecological Engineering

Products

i. Five products most closely related

1. **Hardiman, B.S.**, Gough, C.M., Butnor, J.R., Bohrer, G., Detto, M., Curtis, P.S., 2017. Coupling Fine-Scale Root and Canopy Structure Using Ground-Based Remote Sensing. Remote Sens. 9, 182.

2. Gough, C.M., Curtis, P.S., **Hardiman, B.S.**, Scheuermann, C., Bond-Lamberty, B., 2016. INNOVATIVE VIEWPOINT: Disturbance, complexity, and succession of net ecosystem production in North America's temperate deciduous forests. *Ecosphere*. 7(6).

3. **Hardiman, B. S.**, Bohrer, G., Gough, C. M., Vogel, C. S., & Curtis, P. S. 2011. The role of canopy structural complexity in wood net primary production of a maturing northern deciduous forest. *Ecology*, *92*(9), 1818–27.

4. Atkins, J.W., Fahey, R., **Hardiman, B.S.**, and Gough, C.M. Forest structural complexity predicts canopy light absorption at the sub-continental scale. Journal of Geophysical Research - Biogeosciences. doi.org/10.1002/2017JG004256

5. **Hardiman, B.S.**, Wang, J., Hutyra, L.R., Gately, C., Getson, J., Friedl, M., 2017. Accounting for urban biogenic fluxes in regional carbon budgets. Science of the Total Environment doi:10.1016/j.scitotenv.2017.03.028

ii. Other significant products

1. **Hardiman, B. S.**, Gough, C. M., Halperin, A., Hofmeister, K. L., Nave, L. E., Bohrer, G., & Curtis, P. S. 2013. Maintaining high rates of carbon storage in old forests: A mechanism linking canopy structure to forest function. *Forest Ecology and Management*, *298*, 111–119.

2. Hardiman, **B.S.**, Bohrer, G., Gough, C.M., Curtis, P.S. 2013. Canopy structural changes following widespread mortality of canopy dominant trees. *Forests 4 (3), 537-552.*

3. Gough, C. M., **Hardiman, B. S.**, Nave L.E., Bohrer G., Maurer K.D., Vogel C.S., Nadelhoffer KJ, Curtis P.S. 2013. Sustained carbon uptake and storage following moderate disturbance in a Great Lakes forest. *Ecological Applications 23:*1202–1215.

4. Nguyen, H.T., Hutyra, L.R., **Hardiman, B.S.**, Raciti, S.M., 2016. Characterizing forest structure variations across an intact tropical peat dome using field samplings and airborne LiDAR. Ecol. Appl. 26, 587–601. doi:10.1890/15-0017

5. Viskari, T.T., **Hardiman, B.S.**, Desai, A.R., Dietze, M.C., 2015. Model-data assimilation of multiple phenological observations to constrain and predict leaf area index. Ecol. Appl. 25, 546–558. doi:10.1890/14-0497.1

(d) Synergistic Activities

i. I am a named participant in an NSF-funded Remote Collaboration Network (RCN; RCN-IBDR: Coordinating the Development of Terrestrial Lidar Scanning for Aboveground Biomass and Ecological Applications; Award # 1455636, PI: Alan Strahler) focused on development and dissemination of terrestrial lidar systems (TLS). This RCN includes participants from across North America, Europe, and Australia spread among disciplines including ecology (empirical and theoretical), remote sensing, engineering, and computer programming. As part of this RCN, I lead Working Group 4: Ecological Applications of TLS.

ii. I have convened sessions at the 2014/15/16 Fall Meetings of the American Geophysical Union (AGU) on Advancing Understanding of Ecosystem Structure and Function through Remote Sensing that brought together leading scientists studying the influence of canopy structure on forest ecosystem function. I am co-convening a session at the 2018 Ecological Society of America (ESA) meeting on Cutting-Edge Remote Sensing Applications in Ecology: Spanning Scales, Sensors, and Ecosystems

iii. I am a lead collaborator on a project fusing novel landcover maps, ecosystem models, and emissions inventories to characterize the role of vegetation in the urban carbon cycle; this project will improve understanding of biogenic carbon fluxes as an integral component of the urban carbon budget.

iv. Mentoring of researchers
   - I have contributed to the mentoring of three participants in the University of Michigan Biological Station’s NSF REU program (“Biosphere-Atmosphere Studies in a Changing Global Environment”). Two peer-reviewed publications co-authored by undergraduates resulted from these collaborations.
   - I have mentored four undergraduates conducting independent research in my lab since joining Purdue University in January 2016.
   - I am the primary advisor for two PhD and one Master’s graduate student, including two underrepresented minority students.
   - I currently mentor two postdoctoral researchers including one underrepresented minority researcher.

Gordon G McNickle

PROFESSIONAL PREPARATION

Undergraduate institution	University of Toronto	Ecology/philosophy	Hon. B.Sc., 2004
Graduate institution	University of Alberta	Ecology	Ph.D., 2010
Postdoctoral institutions	University of Illinois at Chicago	Evolutionary game theory	2011-2013
	Wilfrid Laurier University	Evolutionary ecology	2013-2015

APPOINTMENTS

Assistant Professor, Botany and Plant Pathology, Purdue University, 2015-present.
Member, Centre for plant biology, Purdue University, 2016-present.

PRODUCTS

<u>Products most closely related</u>

1. Christie, M.R., **McNickle, G.G.,** French, R.A., and Blouin M.S. (2018) Life history variation is maintained by fitness trade-offs and negative frequency dependent selection. Proceedings of the National Academy of Sciences of the USA. 115(17): 4441-4446.

2. **McNickle, G.G.**, Gonzalez-Meler M.A., Lynch, D.J., Baltzer, J.L. and Brown J.S. 2016. The world's biomes and primary production as a triple tragedy of the commons foraging game played among plants. Proc. R. Soc. B. 283(1842).

3. **McNickle, G.G.,** Lamb, E.G., Lavender, M., Cahill, J.F. Jr.4, Schamp, B.S., Siciliano, S.D., Condit, R., Hubbell, S.P., and Baltzer, J.L. (2018) Checkerboard score-area relationships reveal spatial scales of plant community structure. Oikos. 127: 415-426.

4. **McNickle, G.G.** and Brown J.S. 2014. An ideal free distribution explains the root production of plants that do not engage in a tragedy of the commons game. Journal of Ecology. 102(4): 963–971. http://dx.doi.org/10.1111/1365-2745.12259

5. Sniderhan, A.E. **McNickle, G.G**., and Baltzer, J.L. (2018) A common garden experiment reveals local adaptation in black spruce (Picea mariana) populations from across western Canada. AoB Plants. 10: ply004;

<u>Other significant products</u>

1. **McNickle, G.G**., Cahill, J.F. Jr. and Deyholos M.K. (2008) A PCR based method for the identification of mixed root samples of 10 co-occuring grassland species. Botany. 86: 485-490.

2. Taggart, J.M., Cahill, J.F. Jr., **McNickle, G.G.**, and Hall, J.C. (2011) Molecular identification of roots from a grassland community using size differences in fluorescently labeled PCR amplicons of three cpDNA regions. Molecular Ecology Resources. 11(1): 185-195.

3. **McNickle, G.G.**, Deyholos, M.K. and Cahill, J.F. 2016. Nutrient foraging behaviour of four co-occurring perennial grassland plant species alone does not predict behaviour with neighbours. Functional Ecology. 30: 420-430. http://dx.doi.org/10.1111/1365-2435.12508

4. Cahill, J.F. Jr, **McNickle, G.G.**, Haag, J.J., Lamb, E.G., Nyanumba, S.M, St Clair, C.C. 2010. Plants integrate information about neighbours and nutrients. Science. 328: 1657.

5. **McNickle, G.G.**, and Cahill, J.F. Jr. 2009. Plant root growth and the marginal value theorem. Proceedings of the National Academy of Sciences USA. 106(12): 4747-4751. http://dx.doi.org/10.1073/pnas.0807971106

SYNERGISTIC ACTIVITIES

1. Graduate admissions committee: Botany and Plant Pathology, Purdue University
   - Reviewed applications.
   - Worked on initiative to partner Purdue with historically black colleges in Indiana.

2. Mentoring of researchers
   - I have mentored two post-doctoral scholars during my time as an assistant professor at Purdue university.
   - 11 undergraduate researchers have done independent experiments in my group at Purdue University since 2015. Each student executes an independent experiment in the greenhouse over the course of the semester. They present in lab meeting, at a departmental poster session and we coauthor a manuscript based on the experiment.
   - I have recruited two graduate students who will begin in the autumn of 2017 under my mentorship. One of them, Kliffi Blackstone, has interests in line with this project.

3. Ad-hoc external reviewer for grant proposals and journals:
   - Department of Energy grant panel: DE-FOA-0001855. 2018
   - Ad hoc proposal reviews for: National Science Foundation, Division of Environmental Biology Panel; Hungarian Scientific Research Fund
   - Ad hoc manuscript reviews for: *Nature, Proceedings of the Royal Society B, American Naturalist, Ecology, Journal of Ecology, Evolutionary Ecology, Functional Ecology, Molecular Ecology Resources, Acta Oecologia, Basic and Applied Ecology, Biological Invasions, Ecological Research, Oecologia, OIKOS, Oxford Bibliographies, Plant and Soil, Fronteirs in Ecology and Evolution, PLoS ONE, Ecology and evolution*

5. Membership in professional societies:
   - Canadian Society for Ecology and Evolution
   - Ecological Society of America
   - International Society for Dynamical Games