a. Project title

Defining methods for reintroducing American chestnut to oak-hickory forests of the Allegheny Plateau

b. Summary (100 word cap)

This study will examine the establishment success of BC_3F_3 hybrid American chestnut seed and seedlings planted following each of the three cuts of the three-stage shelterwood sequence commonly used to regenerate oak on the Allegheny plateau of western Pennsylvania. The results of this study will help refine our understanding of the growth, survival, and competitive ability of chestnut planted across a gradient of light and competition intensities. This information will help managers incorporate chestnut reintroduction into oak regeneration management activities.

c. Principal Investigators and Institutional Affiliations

Cornelia (Leila) Pinchot
Research Ecologist
Northern Research Station
USDA Forest Service

Scott Tepke
Forester – Certified Silviculturist
Allegheny National Forest
USDA Forest Service

Scott E. Schlarbaum
Professor and Director
Department of Forestry, Wildlife & Fisheries
The University of Tennessee, Knoxville

d. Duration of project

Early results from this study will be produced by year three, however we plan to follow the study for 10+ years.

e. Total amount requested

We requested and received a total of $1,650 for year one. In this proposal, we request a total of $5,200 for year two. If funded this year, we anticipate that we will request an additional $3,000 in 2017. Additionally, we request 540 seeds from three BC_3F_3 families in the fall of 2016 to use for this study.

f. Short and long-term goals:

- **Short term (3 years):** compare the early survival and growth of BC_3F_3 chestnuts planted as seeds and seedlings across three silvicultural treatments.
- **Long-term (10 years):** evaluate the effects of biotic (competing vegetation, seedling quality) and abiotic (available light) factors on long-term chestnut survival, growth, and competitive ability. Evaluate success of chestnuts planted as seeds vs. seedlings. Develop practical guidelines for reintroducing American chestnut to oak-hickory stands in the Allegheny Plateau.

g. Narrative:

Managers on the Allegheny National Forest are eagerly anticipating the availability of blight-resistant chestnut seedlings for reintroduction onto the Forest. Incorporating American chestnut restoration into management strategies for more expansive management goals such as oak regeneration will give foresters more flexibility in planning chestnut reintroduction. We are planning the establishment of a study to evaluate the long-term growth and survival of hybrid American chestnut seed and seedlings planted in each stage of the three-stage shelterwood system used to regenerate oak.

While much of the Allegheny National Forest (ANF) is comprised of northern hardwood forest stands, oak-hickory forest communities are found on dry slopes and ridges in the southern parts of the forest (Braun 1950). American chestnut historically was found in these forests; Braun (1950) notes that chestnut comprised between 4.4 and 11.2 percent of canopy trees located on study sites in Clarion and Forest counties, PA. Merging chestnut reintroduction with other forest management goals will help National Forests make the most use of their limited resources, which will ultimately lead to increased efforts for chestnut restoration. Regenerating oak in oak-hickory forests throughout much of Pennsylvania has become increasingly challenging due to various factors including increased deer populations and associated browsing of seedlings. With the goal of increasing oak regeneration, a three-stage shelterwood system has become the predominant silvicultural tool in oak-hickory forests on the ANF. The shelterwood system involves a preparatory cut (prep-cut) from below in a fully-stocked stand with intact canopy in order to reduce the stand to approximately 70 percent relative density. The purpose of this cut is to increase light availability for acorns to germinate and become established, while discouraging fast-growing shade-intolerant species. Once the oak regeneration on site has developed a root collar of one-quarter inch in diameter, on average, the site is ready for the shelterwood seed cut, which will leave about 50 percent relative density. This cut serves to increase light availability to develop oak seedlings large enough to compete with shade intolerant regeneration that developed in response to the prep-cut. Finally, once oak-seedlings are three feet in height on average, the removal cut will occur, removing most of the residual trees and releasing the developed regeneration to full sunlight. At this point the established oak seedlings have a very good chance

of growing into dominant canopy positions. The entire three-stage sequence takes approximately fifteen to twenty years to complete.

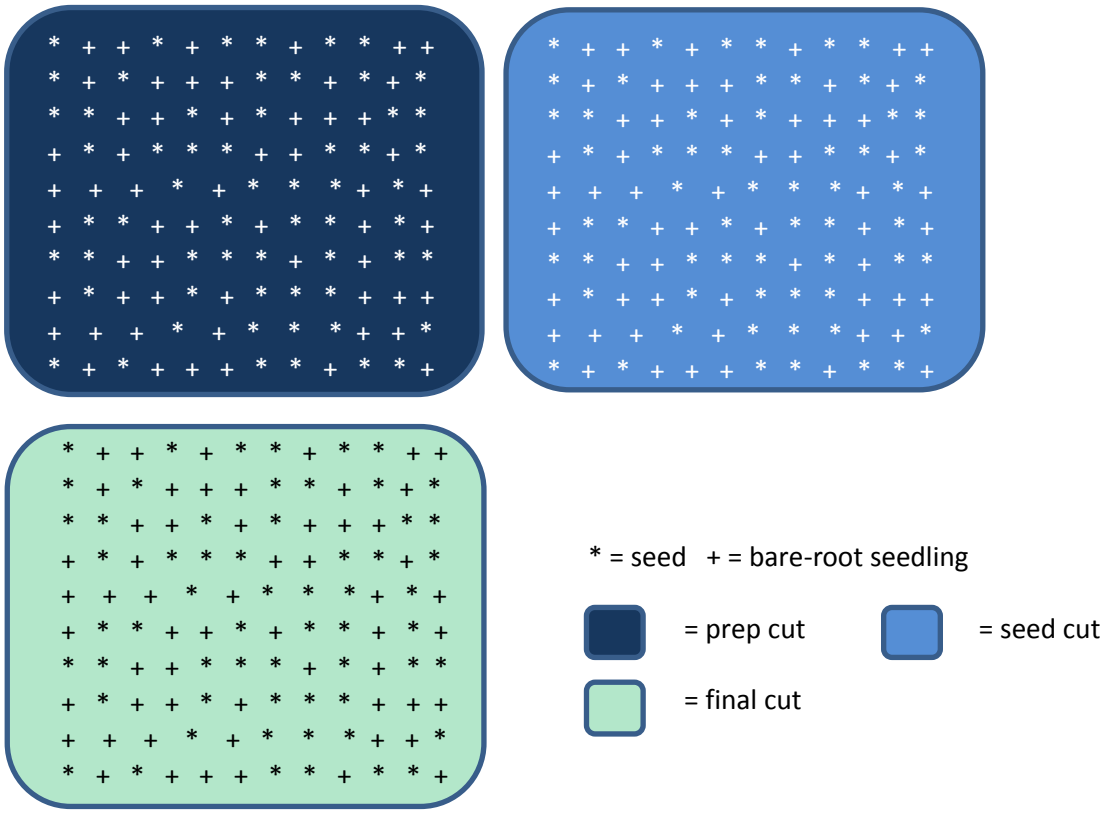
This three-stage shelterwood system was developed for oak seedlings which, in general, are intermediate in their tolerance of shade (Burns and Honkala 1990). American chestnut is categorized as shade tolerant (*c.f.* Wang et al. 2013), and can survive for long periods of time in shade (Ashe 1911, Paillet, 1984). Several recent studies have evaluated the establishment success of American and hybrid chestnut seedling planted under various silvicultural treatments. Three studies compare chestnut establishment in midstory removal treatments to various shelterwood systems leaving residual relative density of between 23 and 35 percent (Rhoades et al. 2009; Clark et al. 2012; Pinchot et al. 2014). These studies found that chestnut seedlings growing in shelterwood harvests added substantially more height and diameter growth than those in harvests with less light, while early survival (two to five years after planting) was not affected by light level. No studies that we are aware of have evaluated the ability of bare-root seedling or direct-seeded chestnuts to survive for long periods of time under low light conditions. Research shows chestnut stump sprouts can survive for decades under low light, and respond quickly to a gap in the canopy by growing from adventitious buds (Paillet 1984). Planted seedlings may differ in their ability to survive under shade, as they do not have the large carbohydrate-rich root systems that chestnut sprouts do. No studies have evaluated how planted chestnut seedlings will respond to a release after becoming established in low-light conditions. Our proposed study will evaluate long-term (10+ year) survival and growth of chestnut seed and seedlings planted in each of the three stages of the three-stage shelterwood harvest system commonly used to regenerate oak in the Allegheny plateau region. These treatments will create a gradient of light availability and competition from sprouts and seedlings of other hardwood species. Results will help determine how long planted chestnut seedlings can survive in low light conditions while still retaining the ability to respond quickly to increased light due to harvest, how well chestnuts compete with other vegetation in varying light levels, and will help managers decide at what point in the 20-year shelterwood system sequence to plant chestnut seedlings.

Methods:

This study will take place on the Allegheny National Forest in northwestern Pennsylvania. In the fall of 2016, 1,600 BC_3F_3 hybrid American chestnut seeds were hand planted in the Vallonia nursery in Vallonia, Indiana. The resulting seedlings will be lifted in the spring of 2017. This summer three shelterwood and three overstory removal sites were selected for the study. While four sites per treatment was the original goal, availability of suitable sites was limited. Three prep-cut sites will be selected by mid-November, 2016. In April, 2017, five-hundred and forty of the largest chestnut seedlings as well as chestnut seed (also BC_3F_3) will be planted on a 12’ x 12’ grid, with 60 seed and 60 seedlings planted in each of three replicates of the three silvicultural treatments for a total of 1,080 chestnuts (Figure 1; this is fewer than the 1,600 specified in the 2015 proposal due to space constraints in the available sites). All chestnuts will be protected from browsing using five foot-tall tree shelters. In five to seven years, depending on

density of competing stems, chestnuts planted in the final removal cut sites will be manually released using cutting and/or herbicide treatments. During the first and fifth growing seasons, hemispherical photos will be taken adjacent to each living chestnut seedling to evaluate light availability. At the end of the first five growing seasons, height and diameter of each seedling will be recorded, as well as height and species of the tallest competing seedling. At the end of the second and fourth growing seasons, 12 direct-seed seedlings from each of the three shelterwood harvest treatments will be carefully harvested to evaluate root development. Taproot length and stem and root dry mass will be measured to evaluate the effect of silvicultural treatment on chestnut root development.

Figure 1. One replicate of each of the silvicultural treatments. Each replicate of the three silvicultural treatments: prep-cut, shelterwood, and overstory removal, will be planted with 60 seeds and 60 seedlings, for a total of 120 chestnuts. The entire study will consist of 3 replicates of each of the treatments = 1,080 chestnuts.



h. Timeline

Timeline	Activity
Completed	Hand plant seeds at Vallonia Nursery
Summer/fall 2016	Identify prep-cut planting sites (have identified shelterwood and removal sites)
Early spring 2017	Lift seedlings at Vallonia Nursery
Spring 2017	Plant seeds and seedlings
Summer 2017 and 2021	Take hemispherical photos over each seedling
Late summer 2017 - 2021	Collect end of season growth and survival measurements
Fall 2018, 2010	Harvest seedlings for root development evaluation

i. How results will be measured and reported

Our goal is to report results in at least one peer-reviewed publication. Results will also be disseminated to the public and TACF through presentations and written reports. A report of progress to date can be found on page 6.

j. Breakdown of how and when funds will be spent

We received $1,650 for year one from TACF's external grants program, $800 of which has been spent on salary for a technician to assist with site selection for the study and the remainder of which will be used for this same purpose this fall. For year two we request $5,200 to cover the cost of two technicians to collect first year data and hemispherical photos. Matching funds from USFS Northern Research Station, the Allegheny National Forest, and the National Forest Foundation in the form of scientist, technician and forester salary and travel (seedling lifting, planting, monitoring), equipment and supplies (tree shelters, pin flags, tree tags, etc.) total $27,500 for years 1 and 2.

Year	Expense	Requested funding	Contributed funding
One	Salary	$1,600	$3,600
	Travel costs		$780
Two	Salary	$5,200	$12,400
	Travel costs		$2,773
	Supplies		$8,007
Three	Salary	$3,000	$3,600
	Travel		$480

Progress report
August, 2016

Title: Defining methods for reintroducing American chestnut to oak-hickory forests of the Allegheny Plateau study

Progress to date:

- TACF donated 2000 seeds from five BC_3F_3 families (D3-27-46, D5-28-88, W2-21-29, W4-32-87, and W5-12-148) for the use in this study. The seeds were hand planted at the Vallonia Nursery in Vallonia, Indiana on November 13, 2015. A quick tally in late May, 2016 showed about 65% germination success of the seedlings. There is no cost for us associated with the seedling production.

- In June, 2016, three shelterwood and three overstory removal sites on the Allegheny National Forest were selected for this study. These sites, selected from a larger pool of sites, were chosen based on year of treatment (between 2015 and 2016), similarity of density and height of competing vegetation, and ease of access. While four sites per treatment was the original goal, availability of suitable sites is limited. Three prep-cut sites will be selected by mid-November. The salary for a field technician to assist with the site selection cost $850. The remaining $800 will be used to cover the cost of a technician to assist with the selection of the prep-cut sites this fall.

k. Principal Investigator CVs

Curriculum Vitae: **Cornelia (Leila) Pinchot**

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Education:
University of Tennessee, Knoxville, TN, Natural resources Ph.D., 2011
Yale School of Forestry and Environmental Studies, New Haven, CT, Master of Forestry, 2008
Oberlin College, Oberlin, OH, Biology, BA, 2003

Professional Experience:
2014 to present: Research Ecologist, USDA FS, Northern Research Station, Delaware, OH
2012 – 2014: Research Fellow, The Pinchot Institute for Conservation, Milford, PA
2011-2012: Postdoctoral Fellow, The University of Tennessee, Knoxville, TN
2008-2011: Graduate Teaching Assistant, The University of Tennessee, Knoxville, TN
2006-2008: New England Regional Science Coordinator, The American Chestnut Foundation, New Haven, CT
2004-2005: Research Technician, University of Tennessee Tree Improvement Program, Grand Junction, TN.

Grants Received:
2015: Restoring Dutch elm-disease tolerant American elm in the Eastern United States. Funded by the Manton Foundation in the amount of $1,432,609. Co-investigator.
2015: Defining methods for reintroducing American chestnut to oak-hickory forests of the Allegheny Plateau (year 1). Funded by The American Chestnut Foundation in the amount of $1,650. Co-investigator.
2016: Planting American Chestnut Trees in National Forests. Submitted by The American Chestnut Foundation. Funded by the National Forest Foundation in the amount of $4,807. Collaborator.

Refereed Publications:
Pinchot, C. C., Clark, S. L., Schlarbaum, S. E., Saxton, A. M., Sung, S. J. S., & Hebard, F. V. 2015. Effects of Temporal Dynamics, Nut Weight and Nut Size on Growth of American Chestnut, Chinese Chestnut and Backcross Generations in a Commercial Nursery. Forests, 6(5):1537-1556.

Clark, S. L., Schlarbaum, S. E., Pinchot, C.C., Anagnostakis, S.L., Saunders, M. R., Thomas-Van Gundy, M., Schaberg, P.G., McKenna, J., Bard, J., Berrang, P., Casey, D.M., Casey, C.E., Crane, B., Jackson, B. Kochenderfer, J., Lewis, R., MacFarlane, R., Makowski, R., Miller, M., Rodrigue, J., Stelock, J.,Thornton, C., and Williamson, T. 2014. Reintroduction of American Chestnut in the National Forest System. J Forest 112(5): 501-512.

Pinchot. C.C., Schlarbaum, S.E., Clark, S.L., Schweitzer, C., Saxton, A.M., and Hebard, F.V. 2014. Impact of Silvicultural Treatment and Seedling Quality on Chestnut Seedling Growth and Survival. In: Proceedings of the Fifth International Chestnut Symposium, September 4 – 8 2012. Double, M.L., and MacDonald, W.L. (eds.), West Virginia University. Acta Hort. (ISHS) 1019:205-209.

Anagnostakis, S.L. and Pinchot, C.C. 2014. Restoration of chestnuts as a timber crop in Connecticut. In: Proceedings of the Fifth International Chestnut Symposium, September 4 - 8 2012. Double, M.L., and MacDonald, W.L. (eds.), West Virginia University. Acta Hort. (ISHS) 1019:17-19

Pinchot, C. C., Schlarbaum, S.E., Franklin, J.A., Buckley, D.S., Clark, S.L., Schweitzer, C. J.; Saxton, A.M.; Hebard, F.V. 2012. Early results of a chestnut planting in eastern Kentucky illustrate reintroduction challenges. In: Butnor, John R., ed. Proceedings of The 16th Biennial Southern Silvicultural Research Conference. e-Gen. Tech. Rep. SRS-156. Asheville, NC: U.S.

Pinchot, C.C., Schlarbaum, S.C., Saxton, A.M., Clark, S.L., Schweitzer, C.L., Smith, D.R., Mangini, A.M. and Hebard, F.V. 2011. Incidence of *Craesus Castanea* Rohwer (Insecta: Hymenoptera: Tenthredinidae) on chestnut seedlings planted in the Daniel Boone National Forest, Kentucky. J. Entomological Sci. 46(3): 265-268.

Popular Press Articles

Pinchot, Leila. 2014. American chestnut: A test case for genetic engineering? Forest Wisdom: 2014(3)

Pinchot, Leila. 2012. Reproduction in the American chestnut – an overview, Journal of the American Chestnut Foundation, Issue. 2, volume 27, July – August, 2012.

Pinchot, Leila. 2008. American chestnut – the return of an American legacy, Forest Wisdom: 2008(3).

Selected Presentations

Pinchot, C.C., Schlarbaum, S.E., Anagnostakis, S.L., and Saxton, A.M. Practical aspects of reintroducing hybrid chestnut to the eastern US. IUFRO Restoring Forests Congress, Lafayette, IN, October 16, 2014.

Pinchot, C.C. Reintroducing American chestnut to the forests of the eastern US. Ohio chapter of The American Chestnut Foundation's Annual Meeting, Newark, OH, September 7, 2014.

Pinchot, C.C. Reintroducing American chestnut to the eastern US. Ohio Botany Research Symposium, Delaware, OH, March 29, 2014

Pinchot, C.C. Reintroducing American chestnut to the Northeast: some thoughts, Connecticut Chapter of The American Chestnut Foundation Annual Meeting, Middletown, CT, April, 2013.

Pinchot, C.C. American chestnut reintroduction at the Milford Experimental Forest, Yale School of Forestry and Environmental Studies Forest Forum Seminar, New Haven, CT, February, 2013.

Irwin, H., Fitzsimmons, S., and Pinchot, C.C. The Identification of Priority Forest Sites for Chestnut Restoration – First Approximation. 21st Annual Southern Appalachian Man and the Biosphere (SAMAB) Conference, Gatlinburg, TN, Nov 16 – 18. 2010. Presented by Hugh Irwin.

Curriculum Vitae: **Scott H. Tepke**

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Education:
Southern Illinois University at Carbondale, Carbondale, IL, Forestry, BS, Forest Resource Management, Specialization, 1984

Professional Experience:
2002 to present: Forester – Silviculture, USDA FS, Allegheny NF, Marienville, PA
1998 to 2002: Forester – Inventory, USDA FS, Allegheny NF, Marienville, PA
1988 to 1998: Forester, USDA FS, Northeastern Forest Experiment Station, Newtown Square, PA
1985 to 1988: Forest Technician, USDA FS, Northeastern Forest Experiment Station, Broomall, PA

Certifications:
Certified Forest Service Silviculturist, January 2014 to December 2017
Certified Public Pesticide Applicator, Pennsylvania, October 2013 to September 2016

Curriculum Vitae: **Scott E. Schlarbaum**

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Education:

Colorado State University, College of Forestry, Department of Forest Science. B.S. Forest Biology (1974).
University of Nebraska, Institute of Agriculture, Department of Horticulture, M.S. Horticulture (1977).
Colorado State University, College of Agriculture, Department of Agronomy, Ph.D. Plant Genetics (1980)

Experience:

Postdoctoral Research Associate, Department of Plant Pathology, Kansas State University, Manhattan, 1981-1983.

Professor of Forest Genetics, Department of Forestry, Wildlife and Fisheries, The University of Tennessee and Director of the University of Tennessee's Tree Improvement Program. Current position.

Selected Publications:

Case, Ashley E., Albert E. Mayfield III, Stacy L. Clark, **Scott E. Schlarbaum**, and Barbara C. Reynolds. 2016. Frequency and Abundance of Asiatic Oak Weevil (*Cyrtepistomus castaneus)* on American, Chinese, and Hybrid Chestnut (*Castanea*) Seedlings. J. Entomol. Sci. 00:00-00. (In press).

Clark, Stacy L., **Scott E. Schlarbaum**, and Callie J. Schweitzer. 2015. Effects of visual grading on northern red oak (*Quercus rubra* L.) seedlings planted in two shelterwood stands on the Cumberland Plateau of Tennessee, USA. Forests 6: 3779-3798; DOI:10.3390/f6103779.

Clark, Stacy L., **Scott E. Schlarbaum**, Arnold M. Saxton, and Frederick V. Hebard. 2015. Field performance of American chestnuts planted in forests of the southeastern United States. New Forests DOI 10.1007/s11056-015-9512-6.

Pinchot, Cornelia C., Stacy L. Clark, **Scott E. Schlarbaum**, Arnold M. Saxton, Shi-Jean S. Sung, and Frederick V. Hebard. 2015. Effects of temporal dynamics and nut weight and size effects on growth of American chestnut, Chinese chestnut, and backcross generations in a commercial nursery. Forests 6: 1537-1556; doi:10.3390/f6051537

Clark, S. L., **Scott E. Schlarbaum**, Cornelia C. Pinchot, Sandra L. Anagnostakis, Michael R. Saunders, Melissa Thomas-Van Gundy, Paul G. Schaberg, Jim McKenna, Jane Bard, Paul Berrang, David M. Casey, Chris E. Casey, Barbara Crane, Brian Jackson, Jeff Kochenderfer, Robert Lewis, Russ MacFarlane, Robert Makowski, Mark Miller, Jason Rodrigue, Jim Stelick, Chris Thornton, and Tyler Williamson. 2014. American Chestnut Restoration in the National Forest System. J. For. DOI: http://dx.doi.org/10.5849/jof.13-106

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Clark, S., McNab, H., Loftis, D. and Zarnoch, S. 2012. American chestnut growth and survival five years after planting in two silvicultural treatments in the southern Appalachians, USA. *Forests* 3(4):1017-1033.

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Rhoades C., Loftis, D., Lewis, J. and Clark, S.L. 2009. The influence of silviculture treatments and site conditions on American chestnut (*Castanea dentata*) seedling establishment in eastern Kentucky, USA. *Forest Ecology and Management* 258:1211- 1218.

Wang, G.G., Knapp, B.O., Clark, S.L., and Mudder, B.T. 2013. The silvics of *Castanea dentata* (Marsh.) Borkh., American chestnut, Fagaceae (beech family). Gen. Tech. Rep. SRS-GTR-173. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 18 p.