CENTER FOR AGROFORESTRY
ANNUAL REPORT 2019

Center for Agroforestry
University of Missouri

USDA Agricultural Research Service

ABOUT THE CENTER

THE CENTER FOR AGROFORESTRY AT THE UNIVERSITY OF MISSOURI

UMCA is one of the world's leading centers contributing to the science underlying agroforestry. UMCA, established in 1998, has been supported by significant collaborative funding from the USDA-ARS. Interdisciplinary research conducted by faculty, research specialists, graduate and undergraduate students, provides sound science that uncovers new environmental and economic benefits from agroforestry practices and solves production challenges.

Linked to the Center's solid science and research programs are numerous partnerships with landowners, natural resource professionals, federal and state agencies and non-profit organizations. Through these critical relationships, UMCA and its partners produce an array of positive outcomes for landowners, businesses, the natural environment and society as a whole.

UMCA Mission

To support the long-term future of rural and urban working farms and forests to achieve economic, environmental and social sustainability. The Center's long-term research, teaching, outreach and economic development efforts help make a better Missouri, USA and world by:

- Discovering, integrating and applying new agroforestry knowledge and technologies to promote economic, environmental, and social vitality;
- Educating and training students, professionals, scientists, leaders, landowners and the general public who are empowered to make a difference locally, regionally, and globally.

To accomplish our mission, UMCA:

- Conducts, coordinates and promotes interdisciplinary research on agroforestry practices to improve the productive and protective functions of agricultural and forest lands.
- Conducts, coordinates and promotes interdisciplinary research on the social, economic and market dimensions of agroforestry.
- Conducts an active outreach program including the annual Agroforestry Academy, that increases the awareness and adoption of agroforestry practices.
- Conducts, coordinates and promotes interdisciplinary research on the policy dimensions of agroforestry.
- Provides opportunities for formal education via an integrated series of online courses. In addition to campus-base graduate degree programs, both a graduate certificate and/or master's degree in agroforestry are available through MizzouOnline at the University of Missouri.
- Develops and carries out a collaborative international agroforestry program in the areas of instruction, research and outreach.

Edited by Sarah T. Lovell, Michael A. Gold & Hannah L. Hemmelgarn
Design and Layout by Caroline S. Todd

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MESSAGE FROM THE DIRECTOR

University of Missouri Land of the Osages Research Center grand opening in Gravois Mills. Left to right: Sarah Lovell, Osage Chief Geoffrey Standing Bear, Osage Traditional Cultural Advisors chairman Norman Akers, MU Chancellor Alexander Cartwright, Osage Speaker of Congress Joe Tillman, CAFNR Vice Chancellor and Dean Chris Daubert.

For the Center for Agroforestry, 2019 was a year of growth with the addition of new faculty, research projects, outreach formats, and experimental field sites. I could not be more inspired and honored to become a part of this progress toward sustainable productive land use.

Prior to my start, the Center welcomed Dr. Ronald Revord to continue the legacy of breeding tree nuts for the Midwest. Ron completed his PhD at the University of Illinois as my graduate student, working on the characterization of American hazelnut germplasm for resistance to eastern filbert blight. I am thrilled to have the opportunity to continue working with him.

In late August, Dr. Ashley Conway joined our group to establish a new research program on silvopasture. Ashely received her PhD in Animal Science from the University of Nebraska-Lincoln. She brings previous experience in agroforestry from growing up on a small diversified crop-livestock farm in the Pacific Northwest, as well as serving as a US Peace Corps volunteer in Zambia.

I began my new role as Director in August, after ten years at the University of Illinois and a previous three years at University of Vermont. I bring a background in agronomy and landscape architecture, that I have applied to a research program focusing on the analysis and design of multifunctional landscapes that blend production, conservation, and human dimensions. Agroforestry is a perfect application of this approach, and the Center for Agroforestry provides me with the greatest resources anywhere in the world to continue my work. The Center also offers a platform to communicate and engage in visionary proposals for a transformation of our food production system.

The months since my start have been filled with extraordinary opportunities, the most remarkable being the grand opening the Land of the Osages Research Center. This new research center was made possible as a very generous gift from Doug Allen, after a decade-long relationship with the Center for Agroforestry. The special celebration of the opening included delegates of the Osage Nation, visiting from Oklahoma and other areas. We will continue working with them to develop the programming for the site.

Our research programming, coupled with our long-term efforts in economic development and technology transfer, continues to push new boundaries and to strengthen the science of agroforestry in support of on-the -ground practice. Our graduate programs, both on campus and online, are thriving with strong enrollment from top quality graduate students. In addition, our outreach programming, anchored by the annual agroforestry academy, is helping to create, build and shape a strong learning network across the USA. The new Agroforestry Podcast series has offered a new format to share our message, and the library of great topics continues to grow!

Our group has spent much of the 2019 fall semester working through a baseline assessment (5-year review) of the Center, which will serve as the catalyst for our work on a Strategic Plan to guide our efforts in the coming years. As part of that effort, I have been meeting with many of our partners and stakeholders. One consistent theme is the quality, commitment, and loyalty of our people. I look forward to the years to come working with this amazing team on our shared goals!

-Sarah

Sarah T. Lovell, Ph.D.
Research Professor and Director
Center for Agroforestry at the University of Missouri

Temperate Agroforestry in a Nutshell

What defines agroforestry? In essence, agroforestry is the *intentional integration* of trees and/or shrubs with crops and/or livestock, where *intensive* management of *interactions* between these components yields economic and environmental benefits.

LAND ACKNOWLEDGEMENT

The Center for Agroforestry wishes to recognize that many of the concepts we now embrace have evolved from the traditions of indigenous peoples. We are particularly grateful to those tribes whose ancestral lands we now occupy in the place we know as Missouri, including the Mississippian era Siouan peoples, notably the Osage (Wha-zha-zhe) and Otoe-Missouria (Nutachi) Nations. Agroforestry applications continue to evolve and adjust to modern demands, as we learn from practitioners and researchers in a dynamic world. Temperate agroforestry typically includes the following set of practices, which may be combined or creatively adapted to each unique farm context.

Forest Farming is the intentional and sustainable cultivation of marketable non-timber forest products (NTFP) in woodlands with suitable shade and site conditions. High value NTFP crops include medicinal plants such as ginseng and goldenseal, culinary or medicinal mushrooms such as truffles and shiitakes, decorative plants or specialty wood and the value-added products that may be derived from these harvests.

Alley Cropping is the planting of two or more sets of single or multiple rows of trees or shrubs at wide spacings, creating alleys within which agricultural, horticultural, or forage crops may be cultivated. Alley cropping can diversify farm income, improve crop production, and provide conservation benefits to the farm system. Trees selected for this practice often include valuable hardwood species, nut or fruit trees.

Silvopasture is the intentional combination of trees, forage and rotationally grazed livestock managed as a single integrated practice. Widely spaced rows of trees may be planted into an existing pasture with perennial grasses or a grass/legume mix; or an existing forest edge may be thinned to reflect the needed spacing and species mix for the grazing animals' living forage. In this practice, trees provide shelter, forage, and a possible timber or nut harvest.

Riparian Forest & Upland Buffers are living filters of trees, shrubs, grasses, forbs and bioengineered structures adjacent to, or within, a stream channel that mitigate land use impacts on the water body. They are designed to enhance filtration of nutrients from surface runoff and shallow groundwater, to control erosion, and provide habitat for wildlife, and may provide additional income from harvestable products in the managed buffer zone.

Windbreaks, also known as shelterbelts, timber belts, hedgerows, or living fences, are living barriers that reduce the impact of wind by creating a wind shadow that can protect crops, soil, and livestock. Windbreaks, like other perennial plant corridors, may also provide excellent wildlife habitat, and may also include a harvestable product.

Food Forests are also on the temperate agroforestry menu of practices. Food forests are typically smaller in scale and equally relevant to urban and suburban communities, where park and garden spaces may include multiple levels of perennial production. These "forests" often resemble early succession woodlands, and can offer aesthetic benefits, community gathering spaces, and education opportunities in addition to providing food and craft materials.

Center for Agroforestry Recognized as an MU Program Of Distinction

Revised from original article by Logan Jackson, MU Agricultural Research Center News Strategist

The University of Missouri College of Agriculture, Food and Natural Resources (CAFNR) has numerous existing research, teaching and extension programs that are nationally and internationally recognized. To highlight the recognized strength of existing and future programs, CAFNR has established criteria for Programs of Distinction, a select collection of programs that exemplify CAFNR's drive to distinction. CAFNR's Programs of Distinction, together with academic programs, define current impact on Missouri's agriculture and natural resource economies, providing understanding for how CAFNR is addressing challenges facing Missouri agriculture and natural resources.

In line with CAFNR's new strategic plan, the College has designated seven existing programs as Programs of Distinction: Center for Agroforestry, the Food and Agriculture Policy Research Institute, the Interdisciplinary Plant Group, the Interdisciplinary Reproduction and Health Group, the MU Forage-Livestock Group, the MU Livestock Engineering Ream and the Show-Me-Select Replacement Heifer Program.

The goal of the University of Missouri Center for Agroforestry is to initiate, coordinate and enhance agroforestry activities to meet the environmental, social and economic needs of land management worldwide. It is focused on serving as a preeminent global center in agroforestry research, education, outreach and technology transfer with comprehensive programs that encompass ecological and economic sustainability, specialty crop and commodity production, environmental conservation and stewardship, and integrated management.

The Center, created in 1998, supports the long-term future of rural and urban working farms and forests by achieving economic, environmental and social sustainability. Interdisciplinary collaboration is one of the most notable hallmarks of the Center. Since its inception, the Center has brought in more than $55 million in grants and contracts to support its mission.

Dr. Sarah Lovell Named as Center for Agroforestry's Endowed Chair Professor and Director

Beginning in August of 2019, Dr. Sarah Lovell became the next Endowed Chair Professor and Director, Center for Agroforestry, University of Missouri. Dr. Lovell was an Associate Professor of Landscape Agroecology, Dept. of Crop Sciences at the University of Illinois, Champaign-Urbana. Over the past twenty years, Dr. Lovell has developed a robust research program designed to advance the understanding of agricultural sustainability through the design of multifunctional food production systems. She has assembled strong interdisciplinary research teams to accomplish her research goals. Her research has helped to transform our scientific thinking on the integration of ecological principles and agriculture production at varying scales.

Over the course of her career, Dr. Lovell has established a national and international reputation as an integrator of complex multi-disciplinary questions related to the design of multifunctional food production systems. She has demonstrated her ability to advance those concepts through a combined body of peer-reviewed publications and competitive grant funding.

Over the past decade, Dr. Lovell has received in excess of $4.7 million funding from competitive federal grant programs. A highlight among Dr. Lovell's funding is a grant obtained from the highly competitive USDA National Institute of Food and Agriculture (NIFA) Competitive Grants Foundational Program. The project, entitled "Multifunctional Woody Polyculture for Sustainable Food Production" was built upon a series of previous awards from the USDA Specialty Crops Research Initiative, National Science Foundation, and regional and local sources. Her funding track record supports Dr. Lovell's strategic collaborative research approach and predicts future success in continuing to attract competitive funding at the University of Missouri Center for Agroforestry.

A series of scholarly peer-reviewed publications over the past eight years define her exceptional talent, including: "Multi-functional urban agriculture for sustainable land use planning" (published 2010), "Environmental challenges threatening the growth of urban agriculture in the United States" (2013), "Agroforestry – The next step in sustainable and resilient agriculture" (2016), "Frontiers in alley cropping: Transformative solutions for temperate agriculture" (2017), and "Temperate Agroforestry Research – Considering multifunctional woody polycultures and the design of long0term field trials" (2017).

Through her research program, she has mentored 7 MS, 5 PhD, and 1 postdoctoral scientists, and published 54 peer-reviewed articles in a broad range of high profile journals. Her funded projects have been collaborative and interdisciplinary and have drawn from a diverse group of faculty and institutions. MU is glad to welcome Dr. Lovell!

RESEARCH CLUSTERS

UMCA's interdisciplinary research program continues to work in clusters to create more synergy among scientists, enhance the Center's research creativity and productivity, and achieve better integration among diverse PIs and disciplines. Clusters serve as the vehicle to achieve an in-depth systems level understandings of agroforestry; enable UMCA and partner scientists to be more efficient in sharing resources (fiscal, physical and human), ideas and spawn new proposals to successfully leverage core funding.

Ecosystem services/ Phytoremediation

Focus is to quantify fate and environmental benefits of woody/ grass buffers on rural nonpoint source pollutants and bioremediation connected to urban wastewater treatment plants. Includes paired watershed studies focused on biomass crops and livestock, farm-focused edge-of-field monitoring as part of the NRCS Missouri River Healthy Watershed Basin Initiative.

Grad student Van Ho presenting at the 2019 North American Agroforestry conference in Corvallis, Oregon.

Socio-economic-marketing

The cluster's integrated approach works to understand the social and economic dimensions of a given enterprise, including institutions, networks, market, consumer and non-market valuation and the development of financial decision support tools. Research activities provide an understanding of factors that facilitate or constrain in agroforestry adoption.

Entrepreneurship

Taking research developed by Center research teams from the field and lab to the market. Focused on conducting research and promoting discovery along with applications for the technologies and intellectual property that result from our work.

Biomass/Biofuels

Focus is to quantify production of *Populus* clones, biomass sorghum, switchgrass and other species for biomass production and flood tolerance**.** Focus includes a flood tolerance research facility to study the effects of short- and long-term flooding on woody and non woody biomass species. Linked to ongoing efforts in entrepreneurship and phytochemistry to convert field research into lucrative business enterprises.

Specialty crops

Includes research involved in pecan, black walnut, chestnut, elderberry pawpaw, etc. Foci for all specialty crop species include field studies, market, consumer and financial research and outreach.

Tree/crop interactions

Focus is on multiple above and below ground interactions between trees and crops and also includes insect predator-prey dynamics.

Education

The Center's education efforts focus on an innovative, on campus, and online agroforestry MS degree and graduate certificate. UMCA's online agroforestry MS was ranked the #1 best value online Environmental Science MS program.

Outreach

The Center's diverse outreach program is centered on and adjacent to five outlying research properties with ongoing agroforestry research (HARC, Greenley, Wurdack, SW Center, Allen Research Center), and building out from these strengths.

Phytochemistry/Medicinals

This cluster is focused on the elucidation and utilization of phytochemicals derived from a wide array of plant materials to be used in the health, nutrition and personal care industries.

Silvopasture/Shade tolerance

Integration of silvopasture into managed intensive grazing forage-livestock production systems. Objectives include: research on the integration of silvopastoral practices into unimproved, standing timber; studying the effects of silvopasture practices on survival and growth of under planted white oak; impact of shade on animal welfare shade tolerance; studies on big bluestem accessions and performance of big bluestem under a canopy of cherry bark oak and shortleaf pine.

Bioremediation

Systematic integration of the plants, microbes and engineered enzymes for ecological restoration of the sites contaminated with organic pesticides, petroleum contaminants, endocrine disruptors, munitions explosives, personal care products and pharmaceuticals.

2019 New Faculty Members

We welcome Dr. Ron Revord to the UMCA faculty. Dr. Revord took over the work of Dr. Mark Coggeshall, who led the Center's tree improvement and genetics research from 2000 – 2017. Dr. Coggeshall is currently the Research Leader at the US Forest Service Hardwood Tree Improvement Research Center based at Purdue University.

Dr. Revord's responsibilities include the continuance of ongoing applied breeding programs for Chinese chestnut, pecan, and black walnut, along with new initiatives related to restoration of the Ozark chinquapin and initiation of new (for UMCA) work with hybrid hazelnut. The long-term goal of the Center's tree improvement research is to release stable and reliable tree crop varieties to Missouri growers while continuing to grow a base of genetic resources and knowledge that will enable the successful inheritance of this program and its multigenerational success.

At the University of Illinois, Dr. Revord completed his Ph.D. in the Department of Crop Sciences and was involved with the multifunctional woody polyculture for sustainable food production research program. His research focus was on hazelnut, and the systematic exploitation of the wild American hazelnut (*Corylus americana*) as a source of eastern filbert blight (EFB) resistance, genetic diversity, and climatic adaptability.

In 2016 Dr. Revord received his M.S. in Natural Resources and Environmental Sciences from the University of Illinois and his B.S. in Molecular and Cellular Biology in 2012.

Dr. Revord is also a co-founder and the past Chair of the Board of the Directors for the Savanna Institute (SI), a 501c3 non-profit organization dedicated to participatory agroforestry research in the Midwest U.S. SI works with farmers to build upon agroforestry science and aid adoption.

We welcome Assistant Research Professor Dr. Ashley Conway is a recent graduate from the University of Nebraska-Lincoln where she completed a Ph.D. in Animal Science this year. Prior to her Ph.D., she obtained an M.S. and B.S. in Animal Science at Washington State University. Following her B.S. degree, she worked from 2010-2012 as an agroforestry/agriculture extension volunteer in Zambia, Africa for the Peace Corps.

Ashley grew up on a small family farm, Conway Family Farms, LLC, located in Camas, Washington State. The farm has a family-managed herd of dairy goats (25-40) for Grade 'A' raw and pasteurized milk and an artisan creamery. They also maintain a small flock of wool sheep, chickens, and bees, cultivated commercial blueberries, lavender, and vegetables for income generation.

Dr. Conway will focus her research on silvopasture, the intensively integrated tree-forage-livestock systems in order to raise livestock more sustainably, and specifically, understanding livestock interactions with forage, crops and trees in silvopasture systems. Her primary goal is to develop a research program investigating the logistical, economic, environmental, and social dynamics of silvopasture systems in Missouri and the Midwest through the lens of efficient and responsible animal production. Her program will work to better understand how to optimize animal performance and nutrition using silvopastoral production practices while maintaining or enhancing ecosystem services and tree performance. A systems-level approach will be used to measure animal performance, health and welfare, and environmental impact. With this information, Dr. Conway's goal is to develop scientifically-supported recommendations to producers to support silvopasture adoption.

In November, Shibu Jose, pictured on the left, was appointed the MU Extension Associate Dean for Research and Director of the Ag Experiment Stations after serving as the Interim Director. In 2017—2018 Jose was the Director of the MU School of Natural of Resources, after eight years as the Endowed Chair Professor and Director of the Center for Agroforestry.

Awards in 2019

UMCA Director, Dr. Sarah Lovell, (with Badege Bishaw (at left) and Gary Wyatt (at right)) received the Association for Temperate Agroforestry's **Research Award** for outstanding accomplishments in the field of agroforestry at the 16th Biennial North American Agroforestry Conference at Oregon State University, Corvallis, OR. Dr. Lovell's outstanding research has focused on multifunctional landscapes, urban agriculture, and productive agroforestry systems.

Novianus Efrat: 1st prize in poster competition at the 16th Association for Temperate Agroforestry Biennial Conference. His poster descried his research on Switchgrass (*Panicum virgatum*) bioactive compounds profiling through untargeted and targeted analysis.

Patents & Trademarks

George Stewart, Brain Thompson, Chung-Ho Lin. Bacillus Based Delivery System and Methods of Use, 2019 U.S. Patent No. 10,081,790

Chung-Ho Lin, Tiger Energy Solutions. Multi-Enzyme Platform Production of Specialty Chemicals, Biofuels, and Blood Type Conversion. 2019 (patent submitted)

Hsin-Yeh Hsieh, Chung-Ho Lin, George C. Stewart, Mason W. Schellenberg, Shibu Jose. Method and Systems for Drawn Fused Filament Fabrication Printing for Construction of Enzymatic Reactor Systems. 2019 Patent 62/783,996


American Society of Agricultural and Biological Engineers

ASABE

Superior Paper Award

G. M. M. M. Anomaa Senaviratne, Claire Baffaut, John A. Lory, Ranjith P. Udawatta, Nathan O. Nelson, Jimmy R. Williams, and Stephen H. Anderson

Monday, July 8th, 2019

In recognition of their exceptional contribution to agricultural and biological engineering literature:

Imposed APEX Model Simulation of Buffer Water Quality Benefits at Field Scale

Ranjith Udawatta, his co-authors G.M.M.M. Anomaa Senaviratne, Claire Baffaut, John A. Lory, Nathan O. Nelson, Jimmy R. Williams, Stephen H. Anderson: 2019 American Society of Agricultural and Biological Engineers (ASABE) Superior Paper Award, honored at the General Session Recognition Program during the ASABE Annual International meeting.

UMCA Ph.D. student Lalith Rankoth was awarded the MU School of Natural Resources Outstanding Graduate Student.

Land of the Osages Research Center

Opportunity and Partnership at the Center for Agroforestry

Doug Allen, pictured right, was a tremendous friend and supporter of the Center for Agroforestry. On his passing, he bequeathed his farm and an endowment to support the farm to the University of Missouri Center for Agroforestry. This farm, now officially named the Land of the Osages Research Center, is the first new MU research center farm in over 30 years.

Doug's wishes for the farm to be a point of connection between the Center for Agroforestry and the people Native to this land is guiding the direction of this special place. On Tuesday, October 29th, MU and the Center for Agroforestry, with delegates from the Osage Nation including Chief Standing Bear and several members of the Osage Congress and Traditional Cultural Advisors, came together at the Land of the Osages Research Center to formally recognize this important new relationship. The event featured an opening ceremony that paid tribute to the Center's partnership with the Osage Nation, including prayers from Osage singers, insightful and inspiring words from Chief Geoffrey Standing Bear, Osage Speaker Joe Tillman, Osage Traditional Cultural Advisors Chairman Norman Akers, MU Chancellor Alexander Cartwright, CAFNR Dean Chris Daubert, and UMCA Director Sarah Lovell. Christopher Daubert, Dean of the College of Agriculture, Food and Natural Resources shared that "CAFNR is so proud to be opening the Land of the Osages Research Center… [the donor] wished to build a partnership between the Osage Nation and agroforestry, which is something CAFNR is thrilled to continue". Despite below freezing temperatures, nearly 200 people including representation from MU, the nearby community, supporters of the Center for Agroforestry, and the Osage Nation attended the morning grand opening ceremonies, a warm hearty lunch, and an afternoon field day, abbreviated due to weather.

"This is such an exciting day, and we're so thankful for Doug's willingness to pave the way for this center to become a reality" said Sarah Lovell, co-superintendent of the research center with Dusty Walter, and director of the University of Missouri Center for Agroforestry. "His gift will allow us to further our already strong agroforestry programs and research, as well as build collaborations with the Osage Nation." Lovell is also the current H.E. Garrett Endowed Chair Professor, established by Doug Allen in 2006. Future plans for the 550 acre Ozark farm include demonstration trials, internship opportunities and workshops with relevance to Osage partners and rural Missouri communities.

Scenes from the Grand Opening Ceremony Oct. 29 at the Land of the Osages Research Center. Photos by Logan Jackson.

PARTNERSHIPS

To accomplish our mission, the Center for Agroforestry at the University of Missouri partners with universities, natural resource agencies, agricultural organizations, nonprofits, and landowners across our state and the globe to foster an integrated approach to farming across diverse landscapes.

MU Collaborations

Ag Systems Mgt., Food Systems & Bioengineering
Bioinformatics Institute
College of Agriculture, Food & Natural Resources
Dalton Cardiovascular Research Center
School of Medicine: OB., Gyn. & Women's Health; Reproductive Medicine and Fertility & Andrology Lab; Family & Community Medicine Dept.; School of Natural Resources; University of Missouri Extension, Mizzou Advantage
Partnerships with MU faculty: Agronomy; Animal Model Core; Biochemistry; Cell & Immunobiology Core; Center for Family & Policy Research; Children & Family Across Cultures; Civil & Enviro. Engineering; Fisheries & Wildlife; Forestry; Horticulture; Human Development & Family Sciences; Life Science Center; Metabolomics Center; Metagenomics Center; Molecular Microbiology & Immunology; NMR Core; Plant Sciences; Physics; Proteomics Core; Rural Sociology; Soil, Environmental & Atmospheric Sciences; Veterinary Pathobiology
MU AES Centers: Bradford Research & Extension Center; Greenley Memorial Research Center; Horticulture & Agroforestry Research Center; South Farm Research Center; Southwest Research Center; Thompson Research Center; Wurdack Farm

External University Collaborations

Jesup Scott Honors College, Kansas State University, Lincoln University, Michigan State University, Missouri State University, Pennsylvania State University, Purdue University, Universities of California: Davis & San Francisco; University of Florida, University of Illinois, University of Kansas; University of Minnesota, University of Notre Dame, University of Tennessee, University of Toledo Dept. of Environmental Science

Federal and State Agency Partnerships

Missouri Department of Agriculture
Missouri Department of Conservation
Missouri Department of Natural Resources
Missouri Natural Resources Conservation Service
Missouri Soil & Water Conservation Districts
USDA National Agroforestry Center, Lincoln, Neb.
USDA ARS Cropping Systems & Water Quality Research
USDA ARS - Dale Bumpers Small Farms Research Center, Booneville, Ark.
USFS - Central Hardwoods Research Unit, Columbia, Mo.
USDA Forest Service Northern Research Station
USDA Hardwood Tree Improvement Research Center, Lafayette, In.
USDA Natural Resources Conservation Service
USGS Columbia Environmental Research Center

Professional Associations and Businesses

Association for Temperate Agroforestry
Chestnut Growers of America
Commonweal Foundation
Cummings, Cummings & Dudenhefer Law Firm
Danforth Center of St. Louis
Elemental Enzymes, Inc.
Forest & Woodland Association of Missouri
Forest ReLeaf of Missouri
Forrest Keeling Nursery
Green Lands Blue Waters
Hammons Products Company
Metabolon
Mid America Agroforestry Working Group
Missouri Chapter Walnut Council
Missouri Christmas Tree Association
Missouri Consulting Foresters Association
Missouri Farm Bureau
Missouri Forest Advisory Council (MOFRAC)
Missouri Forest Products Association
Missouri Northern Pecan Growers, LLC
Missouri Nut Growers Association
Missouri Prairie Foundation
Missouri Society of American Foresters
Missouri Tree Farm System
MS-Omics
National Aviary
Nutrapetsystems, LLC
Roeslein Alternative Energy, St. Louis
Savanna Institute
Thar, Inc.
Tiger Energy Solutions, LLC

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Bill and Sue Ellen Stouffer, Cedar Hill Farm

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Center for International Forestry Research, (CIFOR)
Bogor, Indonesia
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Institute Pertanian Bogor, Indonesia
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University of Costa Rica
University of Pretoria, South Africa
University of Udayana, Bali, Indonesia
World Agroforestry Centre, Nairobi, Kenya
National Sun Yat-sen University, Kaohsiung, Taiwan
Zhejiang Gongshang University, Zhe Jiang Province, China

STAFF & COLLABORATORS

Director Sarah T. Lovell, Ph.D.

UMCA Faculty & Staff
Sougata Bardhan, Ph.D., Asst. Res. Professor
Zhen Cai, Ph.D., Asst. Res. Professor
Ashley C. Conway, Ph.D. Assistant Res. Professor
Michael A. Gold, Ph.D., Associate Director
Hannah Hemmelgarn, M.S., Education Program Coord.
Summer Higdon, M.S., Research Specialist
Chung-Ho Lin, Ph.D., Associate Res. Professor
Gregory Ormsby Mori, MPH, Outreach Coordinator
Ronald Revord, Ph.D. Assistant Res. Professor
Caroline Todd, B.S., Business Specialist
Phuc Vo, Research Lab Manager
Ranjith Udawatta, Ph.D., Research Professor

HARC Farm Staff
Barry Eschenbrenner, B.S., Co– Superintendent
Sarah Lovell, Ph.D., Co-Superintendent
Cliff McGee, Lab Technician
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Aaron Templemire, M.S., UMCA Sr. Lab Technician

Associate Faculty & Staff at MU
Francisco Aguilar, Ph.D., Forestry
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Felix Fritschi, Ph.D., Plant Sciences
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Hong He, Ph.D., Forestry
Zhiqiang 'Zack' Hu, Ph.D., Civil/Enviro Engineering
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Jeanne Mihail, Ph.D., Plant Pathology
Peter Motavalli, Ph.D., SEAS
Susan Nagel, Ph.D., Ob, Gyn & Women's Health
Henry T. Nguyen, Ph.D., Plant Sciences
Francisco Palermo, Ph.D., Family & Policy Research
Bob Pierce, Ph.D., Fisheries & Wildlife
Tim Reinbott, Ph.D., Director AES Field Ops
Mike Stambaugh, Ph.D., Forestry
Hank Stelzer, Ph.D., Forestry Extension
George Stewart, Ph.D. Veterinary Pathobiologist
Andrew Thomas, M.S., Plant Science, Southwest Center
Corinne Valdivia, Ph.D., Ag Applied Economics
Dusty Walter, Ph.D., Ag Exp. Station
Michele Warmund, Ph.D., Plant Sciences
Patrick Westhoff, Ph.D., Ag Applied Economics
Xiaoqin Zou, Ph.D., Dalton Cardio Research Center

External Collaborators
Lisa Allen, Missouri Dept. of Conservation
Joe Alley, MO NRCS
Heidi Appel, University of Toledo
Claire Baffaut, USDA ARS
Charles Barden, Kansas State University
Gary Bentrup, USDA/NAC
Deborah Brennan, USDA ARS
Karen Brinkman, MO NRCS
Scott Brundage, Missouri Consulting Foresters
Lauren Cartwright, Missouri NRCS
Melis Cercioglu, Postdoc, Dumlupinar Univ. Turkey
Gregory Cuomo, University of Minnesota

COLLABORATORS & GRADUATE STUDENTS

External Collaborators ~ *continued*

Daniel C. Dey, USDA Forest Service
Natalie Diesel, MDC
Jeanne Dollinger, Ph.D., French Institute Ag Research
Annie Donoghue, USDA ARS, Fayetteville, Ark.
Dwaine Gelner, Missouri NRCS
Larry Godsey, Missouri Valley College
Nate Goodrich, Missouri NRCS
Robert Harrison, University of California
Steve Hefner, NRCS
Jason Hubbart, Ph.D., W. Virginia Univ.
Abua Ikem, Lincoln University
Newell Kitchen, USDA ARS
Steven Latta, National Aviary
Robert Lerch, USDA ARS
Kate MacFarland, USDA/NAC
Erin Meier, Green Lands Blue Waters
Allison Miller, St. Louis University
Phillip Moore, USDA ARS, Fayetteville, Ark.
Mel Oliver, USDA ARS
Phillip Owens, USDA ARS Booneville, Ark.
Sharyle Patton, Commonweal Foundation
Charlotte Clifford-Rathert, USDA APHIS
Adolfo Rosati, Council for Ag Research & Econ, Spoleto, Italy
Jason Rowntree, Michigan State University
Anuradha Roy, University of Kansas
John Sadler, USDA ARS
Michael Sadowsky, University of Minnesota
Tom Sauer, USDA ARS, Ames, Iowa
Jack Schultz, University of Toledo
Brian Schweiss, Missouri Dept. of Conservation
Ajay Sharma, University of Florida
Craig Sheaffer, University of Minnesota
David Stanley, USDA ARS
Susan Stein, USDA/NAC
Richard Straight, USDA/NAC
Donald Tillitt, USGS
Jerry VanSambeek, USDA Forest Service
Wilfred Vermerris, University of Florida
Kristen Veum, USDA ARS
Doug Wallace, Missouri NRCS
Ronald S. Zalesny, Jr., USFS
Diomy Zamora, University of Minnesota

Graduate Students 2019

Salah Alagele, MS Thesis
Daniel Allen, Online MS
Lindsay Allen, Online MS
Jonathan Aylward, Online MS
Jacob Barker, Online MS
Pamela R. Bergstrom, Online MS
Cody Beus, Online MS
Michael Borucke, Ph.D.
Brenda Brinkhous-Hatch, Online MS
Michael Cooley, Online MS
Donna J. Davis, Online MS
Brent DeBauche, Online MS
Ryan Dibala, Ph.D.
Amanda Dwikarina, MS Thesis
Katherine Favor, Online MS
David Ferrell, Online Graduate Certificate
Dienda Hendrawan, MS Thesis
Summer Higdon, Graduate Certificate
Van Khanh Ho, Ph.D.
Shu Yu Hsu, Ph.D.
Lia Kellogg, Online MS
Raelin Kronenberg, MS Thesis
Dorin Kusumawardani, MS Thesis
Erike Lehtinen, Online MS
Anna Maassell, Online MS
Nicholas Mangili, Online MS
Sophie Mendelson, MS Thesis
Sidath Mendis, MS Thesis
Muhamad Nugraha, MS Thesis
Gregory Ormsby Mori, Online MS
Lalith Rankoth, Ph.D. Thesis
Tyler Reece, Graduate Certificate
Elizabeth Rogers, Ph.D.
Olga Romanova, MS, Fulbright
Miguel Salceda, Ph.D. Fulbright
Sam Sergent, MS Thesis
Priyanka Sharma, Ph.D.
Dayu Soraya, MS Thesis
Amanda Jo Talbot, MS Thesis
Jodi Trendler, Graduate Certificate
Ashley warriner, Graduate Certificate
Bennett E. Wickenhauser, Online MS
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Search for Silvopasture Questions and Answers in the Woods

Author: Ashley C. Conway, Assistant Research Professor, Silvopasture

In its 20+ year history, UMCA faculty, staff, and students have worked hard to develop quality research exploring silvopasture systems. As an agroforestry practice, the integration of livestock with trees and forage holds enormous potential to be agriculturally productive, economically viable, and environmentally sustainable. Previous work done by researchers with UMCA has explored several different aspects of silvopasture systems, including: cattle performance; forage productivity in shade; nutrient content of various fodder species; and ecosystem impacts, such as water quality and insect populations.

In August of 2019, Dr. Ashley Conway joined the UMCA to build on these findings as the new silvopasture faculty researcher. She has quickly observed the substantial interest and opportunity among Missouri landowners to enhance their land utilization with silvopasture, particularly with regards to woodlands. According to the USDA 2017 census, the average farm size in Missouri was 291 acres (Figure 1). Additionally, the vast majority of farms in Missouri, regardless of acreage, are considered small farms based on income, with 92% of farms generating less than $250,000 of revenue annually. With the average farm generating $113,824 of revenue, and nearly one third of farms producing less than $2,500 annually, it is clear that small farms are the root and heart of Missouri agriculture.

Furthermore, nearly half of agricultural sales (48%) are from livestock, poultry, and animal products. Cattle are the top livestock commodity,

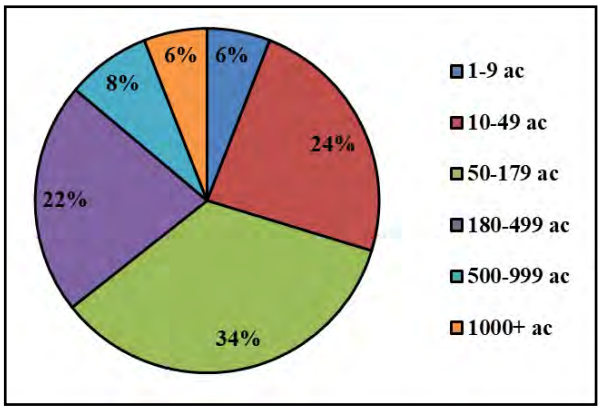

Figure 1. Distribution of Farm Size (in acres) in Missouri according to the 2017 USDA Agriculture Census.

followed closely by poultry and eggs. With nearly 6.5 million cattle in the state, cows and calves make up roughly two thirds of that inventory (approximately 4.0-4.2 million). Although not every cattle operation

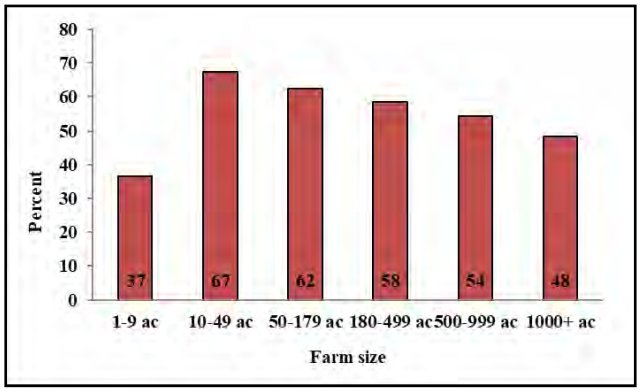

Figure 2. Proportion of farms reporting cattle income that also pasture in woodlots calculated from 2017 USDA Agriculture Census.

has wooded areas, Figure 2 suggests that the majority of Missouri farmers who raise cattle on more than 10 acres will pasture cattle in their wooded areas if these places exist on their farms. Additionally, producers with smaller acreage will be more inclined to graze livestock in wooded areas, likely to maximize their more limited land base to maintain productivity (Figure 3).

Grazing livestock, particularly cattle, in woodlands has been generally discouraged by both forest and livestock advisors due to the potentially damaging effects on the woodlands coupled with (at times) poor animal performance. However, management is the key between a detrimental woodland grazing situation and a productive, holistic and beneficial silvopasture system. At this time, there is no way to differentiate silvopasture acreage from less desirable woodland grazing in the statistics presented here, but it does suggest that there is a need among small farmers with livestock and limited land availability to utilize their woodland acreage in conjunction with their animals. The opportunity to promote silvopasture as a solution to unmanaged woodland grazing is substantial in Missouri.

While previous research has shown the potential of silvopasture in a variety of production situations, very little work has been done to understand how best to convert and manage a woodland silvopasture system. The lack of research has thus far made it difficult to provide the best recommendations to producers who are interested in adopting this type of system. Producer questions such as: “How many trees per acre should I leave for the best forage production?”; “What is the idea forage species to plant in my silvopasture?”; “How well will my animals perform in in this system, and will I need to supplement

them?"; "What impact will my animals have on my trees and soil?" are all important questions that need vigorous research to help answer.

Knowing that producers require useful answers to practical questions with scientific support, developing a silvopasture research program at UMCA that is rooted trying to answer these questions is Dr. Conway's top priority. When looking forward to the coming years at UMCA, conducting applicable and realist studies to meet producer needs is both exciting and critically necessary.

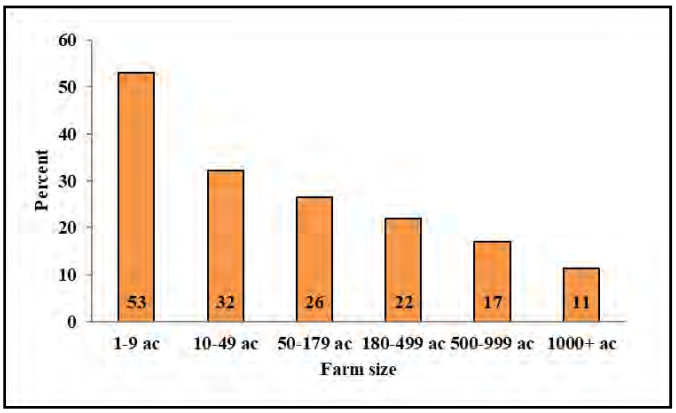

Figure 3. Estimated percent of farm acreage that is pastured woodland by average farm size calculated from 2017 USDA Agriculture Census.

The Establishment of Native Plant species for Livestock Forage & Wildlife Habitat in Silvopasture Systems

Author: Amanda Jo Talbot –Schreiber, MS Candidate, Plant Science

Incorporating sustainable agriculture practices and environmental stewardship into existing forage-livestock systems is growing in popularity. Developing systems that include multiple species of cool and warm season grasses, forbs, and legumes introduces diversity to the system, promoting a plant community that contributes to both livestock forage and wildlife habitat. This project aims to evaluate the establishment of native plant species for livestock forage and wildlife habitat in a silvopasture system using a mix of native cool and warm season grasses, forbs, and legumes, planted in two treatments (black walnut and pitch-loblolly pine) of mature silvopasture systems. Previous research has been conducted at the University of Missouri in Pine-Walnut silvopasture systems. This project takes a novel approach compared to previous studies by incorporating native rather than introduced forage species.

Sensor system.

The purpose of this project is to determine: 1. the success of establishment of native cool season and warm season grasses, and native forb and legume species in two different silvopasture systems; a black walnut silvopasture and a pitch-loblolly pine silvopasture and 2. How the difference in environmental factors (PAR, temperature and soil moisture) associated with each tree type used for silvopasture affect the establishment of native plant species and their quality as a livestock forage. The native species selected have a two-fold purpose: to provide quality forage to grazing livestock while promoting species diversity within the system in order to provide a habitat for local wildlife and pollinators.

In September of 2019 the project was initiated with the planting of the cool season grass species. Preliminary emergence data were collected along with environmental data using the HOBO data logger system. In December, the warm season grass species, legumes, and forbs were frost-seeded. Data collection will resume with spring emergence in 2020.

The main outcome is to provide farmers with recommendations for establishing native plant species in silvopasture and which species perform best in different shade environments based on the project results.

This paper would provide a point of reference for future studies in the areas of silvopasture, native plant establishment, pollinator attraction, and grazing systems.

Tree Nut Breeding

Continuing pecan and chestnut genetic improvement for Missouri growers.

Author: Ronald S. Revord, Assistant Research Professor, Tree Geneticist

Missouri is home to regional tree nut markets for pecan and Chinese chestnut, which each offer potential for diversification using a high-value specialty crop. Acreage of both pecan and Chinese chestnut are expanding in the region, and the UMCA continues to grow its genetic improvement efforts for these tree nut species with the goal of developing improved varieties that meet growers' needs and support continued industry growth. Accordingly, UMCA faculty are developing new research for tree species with respect to the most opportune ways to leverage existing germplasm.

Pecan. Pecan cultivars trials were resumed this year, focusing on 9 individuals from UMCA's collection that remain the most promising for grower adoption under low-input conditions. Most namely, these are highly scab-tolerant cultivars that do not require a spray regime in our region. Yield data was taken this fall and sub-samples have been retained for quality scoring (e.g. kernel size, color). In Missouri, the number of acres planted to pecan cultivars increased 39% from 2012 to 2017, with 773 acres of new orchards planted. Given the growing market of pecan, we expect this trend to continue, and our cultivar trial data (taken over multiple years) will provide growers current recommendations for cultivars that maintain high-quality kernel production under low-cost management practices.
In parallel with cultivar evaluation, UMCA faculty are planning new research to evaluate pecan germplasm for potential as flood tolerant rootstock.

Pecans shaken onto tarps before they are cleaned.
Photo by Aaron Templemire, UMCA Research Technician

While pecan cultivation is adapted to the flood plain environment and is generally tolerance to intermittent, seasonal flooding, trees cannot tolerate a submerged or saturated environment for prolonged periods of time. Physiological costs to the tree can begin as early as 5-days, and the trees are vulnerable to damage when nearing 30-days of soil saturation.

This year's flooding conditions emphasize the importance of understanding the genetic variation of flood tolerance in pecan, with many growers experiencing flooding throughout the growing season. In 2020, UMCA researchers will begin screening seedling material to ascertain the available genetic variation for the trait and how it might be exploited for applied rootstock development.

Chestnut. In Missouri and across the Midwest U.S., grassroots development of chestnut over the past decade has led to the successful establishment of multiple farmer cooperatives (e.g., Route 9 Cooperative, Prairie Grove Chestnut Growers) and in turn many new local and regional markets. Regional industries leaders indicate that growth in demand outpaces supply and that chestnut cultivation needs to expand accordingly. In fact, the number of chestnut farms in the U.S. grew by 57% from 2012 to 2017, with over 400 new chestnut farmers in midwestern and neighboring states.

Chestnut orchards are predominantly composed of seedling families from open-pollinated traditional Chinese chestnut varieties. While suitable for first-generation production, as a whole these plant materials represent the floor for genetic improvement and intentionally serve the dual purpose of pre-breeding – to identify superior individuals (or crosses) that have recombined desirable traits and improved adaptability. There are over 7,000 chestnut trees from 20 half-sibling families on farms in the Midwest, and this germplasm offers an extraordinary opportunity to assemble the improved plant materials required for establishing a dedicated chestnut breeding program for this region. Building genetic improvement efforts from this pre-existing on-farm material is of the upmost importance as it builds on several decades of farmer investments and evaluations.

UMCA has begun to work with chestnut growers to outline a participatory breeding program, with the goals of characterizing on-farm germplasm and

and assembling core breeding parents.

Accordingly, the research program has three objectives: **(i)** characterize the phenotypic diversity of the germplasm, as guided by growers; **(ii)** conserve the selected elite individuals in a centralized location; and **(iii)** use genetic fingerprinting to study the genetic diversity and parentage of the selections. Packaged together, this body of work will guide the foundation and structuring of the next generation of chestnut variety development in the Midwest U.S.

The participatory breeding program will be comprised of an institutional arm housed at the UMCA and a farmer arm composed of the network of participating growers. In future years, the network will be used to decentralize evaluation of the program's new breeding progenies back to the participating farms. This structure helps ensure that the breeding gains are relevant to the geographic range of the participants and that the grassroots development of high-quality chestnut kernel production can maintain its form.

Mike Gold, UMCA Associate Director giving a tour of the chestnut orchard to Carley Esser at the MU Horticulture and Agroforestry Research Center in New Franklin, MO.

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14th Annual Missouri Chestnut Roast Festival

Saturday, October 3, 2020 10am to 4pm

Horticulture & Agroforestry Research Center, New Franklin, Missouri

Free and Open to the Public! Rain or Shine

https://harc.missouri.edu/events

Black Walnut *Health-promoting benefits & bioactive compounds.*

Author: Khanh-Van Ho, UMCA Ph.D. Candidate

Black walnuts (Juglans nigra L.) are a major industry in the Midwest, with up to 25 million pounds processed annually in Missouri alone. Native Americans traditionally valued black walnut as an excellent food source and utilized leaves for medical purposes. It is believed that consumption of black walnuts has been linked to many health benefits stemming from its phytochemical composition and medicinal properties, but these effects have not been systematically studied or characterized. In addition, while many tree nuts, such as another common Juglans species, English walnuts (J. regia L.), have received attention for their nutritional benefits, comparatively little research has focused on Missouri's native black walnuts.

This project aimed to identify health-promoting properties (e.g., anti-inflammatory, antimicrobial, antioxidant) and bioactive compounds in 22 black walnut cultivars selected for nut production by UMCA. By identifying the novel applications of the black walnut and its byproducts, this study will provide the opportunities to turn abundant, low-value, renewable materials into profitable value-added products for industry in Missouri. It also will explore market potential of those value-added organic person care products and dietary supplements. This project will contribute to the income growth of participants involved in the black walnut industry, organic products production, consumption, and sustainable rural communities in Missouri. The project will help increase the overall revenues of the chain production by identifying the new application (e.g., dietary supplement, skin care products).

Van Ho harvesting black walnuts at HARC.in New Franklin, MO.

Key Findings

- Bioactive compounds (anti-inflammatory, antimicrobial, and antioxidant) of black walnuts were successfully identified and characterized. Many black walnut cultivars possess multiple bioactive capacities. The cultivars Mystry and Surprise exhibited the strongest antioxidant and antibacterial activities, whereas Sparrow and Surprise represent promising preventive agents for inflammatory diseases.
- Health-promoting bioactive compounds in black walnuts were identified through targeted and non-targeted global metabolite profiling analyses.
- Six major bioactive compounds responsible for antimicrobial activity were successfully identified utilizing the metabolomics analysis coupled to bioassay-guided purification strategy. Glansreginin A, azelaic acid, quercetin, and eriodictyol-7-O-glucoside are novel antibacterial compounds found in the kernels of black walnuts. This is the first report for antibacterial activity of Glansreginin A, the most abundant antibacterial compound in black walnut.

Pawpaw Named Missouri State Fruit Tree

On July 11, 2019, Governor Mike Parson signed Senate Bill 210 designating the pawpaw (*Asimina triloba*) as the Missouri state fruit tree, among other new designations. Sponsored by Senator Karla May and Representative Jeffery Justus, this bipartisan legislation was recommended by students at a St. Louis elementary school. The students suggested that the pawpaw has merit as a symbol for Missouri given that pawpaws are native to Missouri, and their nutritious fruits ripen in August, when the state was founded.

This new accolade for pawpaw is likely to raise awareness about this delicious native fruit (pictured, right), and the Center for Agroforestry is prepared to support this growing interest. Pawpaw is a high value specialty crop that can address conservation and financial objectives on Missouri farms. With support from a Missouri Department of Agriculture Specialty Crop Block Grant, the Center will assess consumer preferences for pawpaw and offer pawpaw cultivation workshops 2019-2020.

Avery Thomas harvesting pawpaws at the MU Southwest Research Center in Mt. Vernon.

Two mature grafted pawpaw cultivar orchards are maintained at the University of Missouri's Southwest Research Center and the Horticulture and Agroforestry Research Center where information collected about their management, yields, cultivar selections and marketing strategies.

For more information about pawpaw in Missouri: http://www.centerforagroforestry.org/pubs/pawpaws.pdf

(by Hannah Hemmelgarn; revised from original article, Action in Agroforestry E-News)

Entrepreneurship

More Festival Visitors and Increased Public Preferences for Value-added Chestnut Products ~ 2019 Missouri Chestnut Roast Festival Report

Author: Dr. Zhen Cai, Assistant Professor, Economics

University of Missouri Center for Agroforestry (UMCA) and the MU Horticulture and Agroforestry Research Center (HARC) hosted the 13th Missouri Chestnut Roast Festival (MCRF) on October 5th, 2019, at HARC, New Franklin, MO.

This year's festival attracted more participants (approximately 4,000) compared to 2018. Survey results suggested that, although this festival has been held for more than 10 years, our festival still not only keeps return visitors but also attracts new visitors.

Approximately 53% of the respondents were first time visitors and 47% were return visitors. As a regional festival, MCRF starts to attract visitors from other states including Iowa, Arizona, and Oregon. Most of our respondents indicated they liked sampling value-added chestnut products, however, only a quarter of our respondents had bought value added chestnut products before. This indicates the great market potential for value-added chestnut products.

Respondents provided very positive feedback about the festival. Many of the festival offerings were liked by majority of our respondents. The festival has a significant educational impact on participants' knowledge on specialty crops and cultures of the festival region. The results also suggest that the festival may positively affect participants' future purchases of specialty products, and interests in growing chestnut trees and implementing agroforestry practices.

Missouri Consumer Preferences for Pawpaw & its Value-added Food Products

Author: Dr. Zhen Cai, Assistant Professor, Economics

The University of Missouri Center for Agroforestry (UMCA) organized pawpaw taste tests at the Columbia farmers market, the City Market in Kansas City, The Tower Grove Farmers' Market in St. Louis and the Farmers Market of the Ozarks in Springfield. At the farmers market, free fresh pawpaws and pawpaw muffins were provided. A follow up survey was conducted to explore consumers' preferences for pawpaw and its value added-food products. In totality, 367 responses were collected. Below are some highlights of our findings.

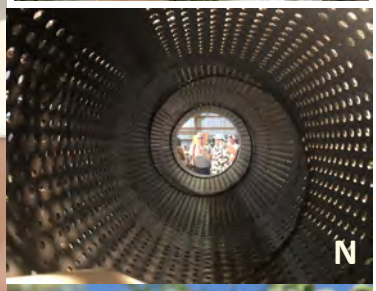
Of all the respondents,

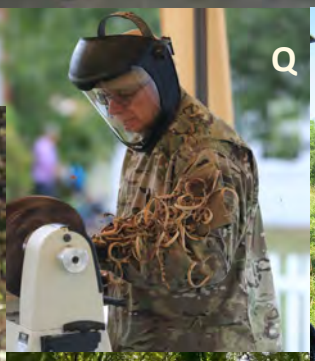
- 58% had heard about pawpaws before taking the survey, 31% had eaten pawpaws before, and 13% had eaten pawpaw value added food products before.
- 49% indicated that pawpaws have a banana flavor, 59% indicated a mango flavor, 30% indicated a papaya flavor, and 7% pineapple.
- 81% like eating fresh pawpaws (compared to 87% like eating mango)
- 65% like eating pawpaw muffins (compared to 87% like eating blueberry muffins)
- 87% indicated they will purchase fresh pawpaws in the future, and 75% indicated they will purchase pawpaw muffins in the future

In July at the Tower Grove Farmers Market in St. Louis, UMCA Fulbright grad student Olga Romanova surveys customers after they sample fresh pawpaw. Photo by Mike Gold, UMCA Associate Director.

2019 AT THE CENTER FOR AGROFORESTRY: A YEAR IN PHOTOS

A. Visitors at the LORC Grand Opening learn about elderberries; B. A lunch feast at the LORC Grand Opening; C. The LORC barn; D. Dr. Sarah Lovell, Director of the Center for Agroforestry, addresses the LORC Grand Opening visitors; E. Pawpaws nearing ripeness at HARC; F. Osage visitors at the LORC Grand Opening; G. Inaugural ceremonies at the LORC Grand Opening; H. This year marked the 200th anniversary of the Hickman House at HARC; I. Agroforestry Academy participants learn to grow mushrooms in mulch beds; J. Agroforestry Academy Case Study Farmers share their story at Covered L Farm;





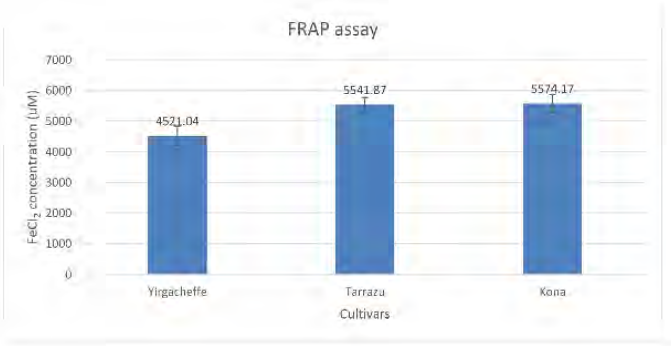
K. Helen Pohlemann demonstrates crocheting during the Chestnut Roast at HARC; L. Mushroom workshop participants learn to grow mushrooms on stacked logs; M. Graduates of the 2019 Agroforestry Academy; N. Inside a chestnut sorter at Cedar Hill Farms; O. Aidan Cornelison, 2019 summer agroforestry undergraduate intern; P. Andy Thomas presents at the Southwest Research Center Field Day; Q. Ernest Hildebrand demonstrates wood turning at the Chestnut Roast at HARC; R. Greg Judy shows the Agroforestry Academy group a healthy cow patty; S. Elderberry in flower at HARC; T. Graduate student Sam Sergent shares with a group about elderberry at HARC; U. Roasting chestnuts for sampling at the Chestnut Roast Festival at HARC in New Franklin, Mo.

Coffee Grounds Brewed into Economic Opportunity

Author: Phuc Vu, UMCA Research Technician

Coffee is a popular beverage consumed in most countries around the world. This has brought significant economic benefits for coffee exporting countries, but at the same time this industry also creates a large amount of waste materials. Annually, more than 6 million tons of spent coffee grounds (SCG) are generated worldwide. Whereas SCG has little commercial value and SCG has been treated as solid waste or used as home gardening, compost and landfills. Therefore, their reuse is an issue of current concern and opportunity.

The purpose of this study is to explore the economic opportunities and the niche applications of the SCG. The bioactive compounds with anti-aging, antioxidant, and anti-inflammatory activities in the SCG of three coffee cultivars (Ethiopia coffee (Yirgacheffe), Costa Rican coffee (Tarrazu), and Hawaiian coffee (Kona Blend) were extracted, identified and quantified with the modern metabolomic approach. Our innovative approach turns this renewable material into high-valued raw materials for organic cosmetic industry.

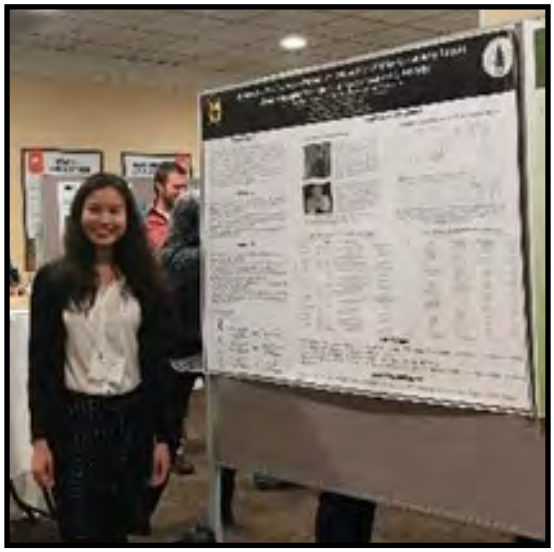


The antioxidant activities of the extracts from the spent coffee ground

In a first-of-its-kind study, using the global metabolomics approach, we have successfully annotated approximately 200 polyphenols in SCG, including several anti-oxidant, anti-inflammatory, skin brightening, and anti-aging agents, including 22 phenolic acids, 161 flavonoids, 2 coffee alkaloid,1 stilbenoid, and 3 anthraquinones, such as caffeic acid, gliricidol, delphinidin, anthocyanins, dihydrocurcumin, naringin, malvidin, eriodictyol, theaflavin, caffeoylquinic and quercetin.

During 2018-2019, we determined the contents of 35 identified bioactive compounds, such as strong antioxidant cafeoylquinic acid among the selected varieties.

We believe that our findings will create a new opportunity for SCG, and turn waste material into valuable products, including supplements and cosmetics with anti -inflammatory and antioxidant properties.



Phuc Vu, UMCA lab technician, presented "Quantification of bioactive phytochemicals in spent coffee grounds by liquid chromatography tandem-mass spectrometry (LC-MS/MS)" at the 2019 North American Agroforestry Conference.

From left to right: Elemental Enzymes employee; Shu Yu Hsu, Novianus Efrat, Phuc Vu, and Amanda Dwikarina, all from Dr. Chung-Ho Lin's UMCA Lab; on the right end is another Elemental Enzymes employee, delivering lab equipment from Elemental Enzymes in St. Louis, MO.

The Seed that Continues to Grow ~ MU alumni increase food production

Author: Brian Consiglio, MU News Bureau

According to the United Nations, the world's population is projected to exceed 9 billion people by 2050 and 11 billion by 2100. One of the biggest challenges this population growth creates is producing enough food to feed so many people.

Two University of Missouri graduates are working to solve this growing challenge. Brian and Katie Thompson are not only husband and wife, but also two of the three co-founders of Elemental Enzymes, a biotech company headquartered in St. Louis that makes agriculture products to help increase plant health, growth and overall food production. These products range from seed treatments to fertilizer enhancements.

Many of the products contain patented technology that Brian Thompson helped to discover while holding a post-doctoral research position at MU, where he also earned a master's degree. During his time on campus, Thompson worked with George Stewart, professor and chairman of the Department of Veterinary Pathobiology in the MU College of Veterinary Medicine and a primary investigator at the Christopher S. Bond Life Sciences Center, as well Chung-Ho Lin, an associate professor with the Center for Agroforestry in the MU College of Agriculture, Food and Natural Resources. Elemental Enzymes' products, which range from seed treatments to fertilizer enhancements, help increase plant health, growth and overall food production.

"Brian co-founded a company that utilizes the technology developed at MU to make products that are beneficial to the agriculture industry," Stewart said. "It is not only a good story of MU student success, but one that benefits the state of Missouri and Midwest region as well."

Thompson's research began in Stewart's lab at the Christopher S. Bond Life Sciences Center, where the original innovations that eventually launched Elemental Enzymes were first developed. Thompson also developed the company's business plan at the MU Life Science Business Incubator at Monsanto Place.

"Brian Thompson was a co-inventor, along with Drs. Stewart and Lin, on the intellectual property that was patented by the university and licensed to Elemental Enzymes," said Sam Bish of the MU Technology Advancement Office. "MU provides individuals with the opportunities, infrastructure and interactions to do commercially attractive research that impacts various sectors of society, such as the agricultural industry, to help find solutions to important problems, such as feeding a growing world population."

Elemental Enzymes, founded in 2011 at MU, is now a self-sustaining company with offices in St. Louis, Columbia and Jacksonville, Florida. Its agriculture products are on more than 6 million acres of American farmland, contributing to more than 1 billion additional pounds of corn grown in the United States. Enzymes are biological catalysts that accelerate chemical reactions, and when applied to agricultural products, they improve plant health, performance and yield.

Enzymes are biological catalysts that accelerate chemical reactions, and when applied to agriculture products, allow seeds to absorb nutrients more efficiently.

"Enzymes are the next wave of great innovation for crop, fruit and vegetable production, and we are proud to be on the forefront of bringing enzyme technologies to improve food production both domestically and internationally," Brian Thompson said. "The patents from Mizzou support our product lines, current and future, and protect our inventions so that we can continue to develop protected products to bring to growers."

Katie Thompson, the company's chief operations officer, earned a doctoral degree at MU in molecular and cellular biology. She credits her education and experience at MU for helping her find solutions to some of agriculture's toughest challenges.

"My education at Mizzou set the foundation to being able to start and lead a biotech company," Katie Thompson said. "It taught me how to approach and solve complex problems, and gave me the core expertise to be able to develop technology from the concept stage and apply it to commercial products that make a real-world impact."

In addition to helping with disease prevention and animal health, Elemental Enzymes' products allow seeds to absorb nutrients more efficiently.
In Missouri and throughout the Midwest, farming products are not in climate-controlled settings and

"must endure extreme temperatures," Katie Thompson said. "Our stabilized enzymes allow our products to survive these harsh conditions and ultimately improve agricultural productivity."

Founded in 2011 at MU, Elemental Enzymes is now headquartered in St. Louis with offices in Columbia and Jacksonville, Florida.

Bayer, a major multinational company, has licensed several of Elemental Enzymes' products. Now with 36 employees, Elemental Enzymes offers competitive salaries, full benefits and opportunities for advancement due to their rapid growth.

"It feels good to create jobs that people enjoy, opportunities for advancement, and be at a company that myself and others are proud to be a part of," Katie Thompson said.

Elemental Enzymes headquarters in St. Louis, MO.

Uncovering the Economic Sense of Planting Cover Crops

Author: Mark Esser, CAFNR, Oct. 11, 2019

Proponents say that rotating cash crops such as soybeans, wheat and corn with cover crops such as legumes, grasses and forbs has many benefits. It replenishes the soil, reduces erosion, cuts down on runoff pollution and helps to control pests. However, many farmers don't use cover crops because they believe it cuts into their bottom line. There's the cost to plant the cover crops and the cost of removing them when it's time to switch back to cash crops, which to many seem to outweigh whatever benefits conferred by improved soil health.

Studies into the economic sense of planting cover crops have so far have been inconsistent. A crop cover survey of 2,000 farmers taken in 2015-16 revealed that only one-third saw an increase in profits during the year. Most reported that they lacked the data or that there was no change.

However, few studies have economically compared cover crops under controlled conditions where some fields were planted with cover crops of different varieties, some grass, and some left uncovered over a period of years.

To uncover what's going on with cover crops, University of Missouri College of Agriculture, Food and Natural Resources (CAFNR) researchers Zhen Cai and Ranjith Udawatta did such a study of the economic effects of cover crops on cash crop production. The four-year study took place at the Natural Resources Conservation Service (NRCS) Soil Health Farm in Chariton County, Missouri, in a 26.3-hectare (64.9-acre) area, which was divided into six fields and planted with soybeans, corn and wheat.

During the study, they measured the annual profitability of corn, wheat, and soybean production both with and without a cover crop in the rotation. As part of the study, they examined the cost of planting, maintaining, and terminating the cover crop, the cost of the cash crop, cash crop revenues, and the yields of the cash crop.

"We found that economic profitability of the cash crop is negatively affected by the cover crop during the first two years but were positive in the fourth year," says Cai. "In the short term, the cost associated with the cover crop has a negative economic impact on cash crop production. However, a positive impact may occur in subsequent years because of improved soil health and yields."

Udawatta says that cover crops impact the health of the soil in several ways. "Cover crops keep soils covered and thereby reduces the impact of rain drops, which reduces soil detachments and erosion," says Udawatta. "Live cover keeps all soil organisms active by providing food and buffering adverse conditions and thereby protecting soils, improving fertility, and carbon and water holding capacity."

Their work supported a recent case study conducted by the NRCS in 2015 in Missouri where it was found that adding a cover crop to a corn–soybean rotation was initially economically costly, it could potentially be profitable in the long term.

Cai and Udawatta stress that more data are needed on the economic impact of cover crops before any policy judgments concerning financial assistance for farmers using cover crops can be made. They say that payments are essential in the short term to encourage the use of cover crops. Long-term help may encourage the use of cover crops but may not be necessary if the benefits of cover crops markedly improve the profitability of cash crops through improved soil health.

Collaborators on the project include Clark Gantzer, professor emeritus, soil science; Shibu Jose, CAFNR's interim associate dean for research; Larry Godsey, associate professor, Missouri Valley College; and Lauren Cartwright, natural resource specialist/agricultural economist at NRCS.

Water Quality

Mississippi River Basin Healthy Watershed Initiative (MRBI)

Authors: Ranjith Udawatta, Steve Hefner, Shibu Jose, Karen Brinkman

The Gulf of Mexico, formed approximately 300 million years ago as a result of plate tectonics, is an ocean basin largely surrounded by the North American continent and the island of Cuba.

According to International Monetary Fund (IMF) (2007), this region ranks seventh in global economy in terms of combined gross domestic production of the five bordering states (FL, AL, MS, LA, and TX). Major productions in the region are fishing, shrimp, oyster, tourism, recreation, oil, and gas. Many of these industries depend on water quality of the Gulf. It is believed that productivity and health of the region contributes not only to the local and regional economy but also to national and global economy.

Hypoxia in the Gulf is the main factor affecting health, water quality, and gross production of the region. The development of a "dead zone" where dissolved oxygen concentration drops to a level that does not support aquatic life is called hypoxia. Increased algal growth and their subsequent death, sinking, and decomposing cause depletion of oxygen in the water. There is a strong consensus that the cause of the Gulf's hypoxic zone is attributed to nutrients coming from the Mississippi River watershed.

In 2000, USEPA Science Advisory Board developed an Action Plan to reduce both N and P loads by 45% aiming to reduce the hypoxic zone to 5,000 km2 by 2015 (U.S. EPA Mississippi River/ Gulf of Mexico Watershed Nutrient Task Force, 2008). To help solve these water quality problems, Natural Resources Conservation Service (NRCS) has developed the Mississippi River Basin Healthy Watershed Initiative (MRBI). On March 2, 2010 the Chief of the NRCS announced the availability of financial assistance (Federal Register Vol 75, No 40) for the MRBI. The focus of the program was to reduce N and P loadings to the Gulf from agricultural watersheds through adoption of multiple conservation practices in agricultural watersheds in the Mississippi-Missouri Watershed Basins. NRCS has approved a number of core and support conservation practices, which are recognized methods of avoiding, trapping, and controlling pollutants (www.nrcs.usda.gov/programs/mrbi/mrbi.html).

To study the effectiveness of these practices, thirteen northern Missouri farms were monitored using water samplers, flow meters, flumes, and burms. Water samples were collected and analyzed by runoff event for sediment (TSS), N, and P to evaluate the effects of crop production, residue types, and conservation land treatment on runoff. The presence of living vegetation in the winter, whether established as a cover crop or cash crop, significantly reduced the sediment loads ($p<0.0001$) and nutrient loads ($p\leq 0.0077$). Additional benefits occurred on sites that produced higher residues, like corn or corn with winter wheat (Triticum aestivum L.).

Significantly lower TSS losses occurred during soybean years with corn and winter wheat residues. Sites that implemented full land treatment, having conservation practices that serve to avoid, control, and trap a pollutant, were more effective than those with fewer treatments, especially with respect to phosphorus loading. The study findings support the conclusion that conservation structural and management practices are effective and can mitigate some negative impacts generated by agriculture.

UMCA research professor Ranjith Udawatta checks field equipment that transmits data to his lab on the MU campus. *Photo by: Sarah Lovell*

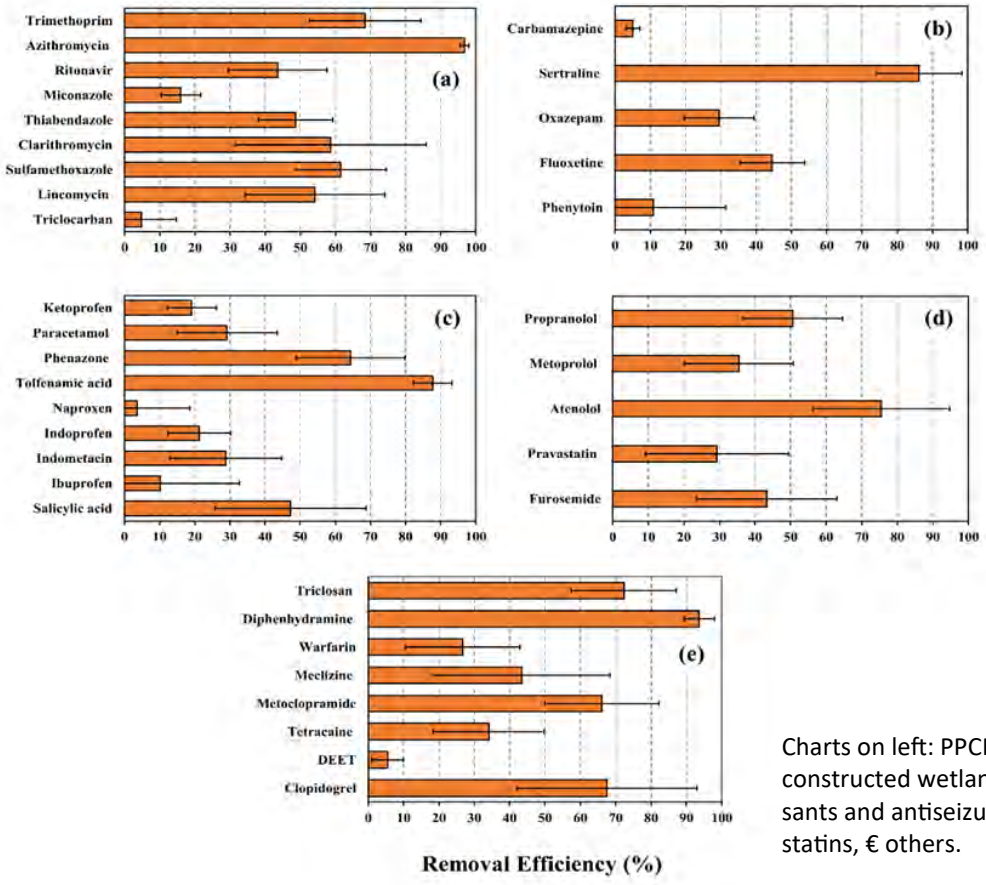
Efficiency of Columbia Constructed Wetlands in Removing Pharmaceuticals and Personal Care Products from Treated Municipal Wastewater

Author: Mohamed Bayati, MU Civil and Environmental Engineering Ph.D. Candidate in collaboration with Chung-Ho Lin, Thi Ho, Danh Vu, Fengzhen Wang, Craig Cuvellier, Steve Huebotter, Enos C. Inniss, Ranjith Udawatta, Shibu Jose

Pharmaceutical and personal care products (PPCPs) and halogenated disinfection byproducts (DBPs) as emerging environmental contaminants have drawn increasing concern over the last decade. These products originate from direct human disposal and other personal care use before discharge to the wastewater systems. Several classes of PPCPs that have endocrine disrupting activity are persistent and frequently found in effluents from municipal and hospital wastewater treatment facilities. Endocrine disruptive PPCPs can adversely affect normal reproductive, behavioral, immune system, and neurological functions of aquatic organisms. Several studies indicated that conventional wastewater treatment plants are not able to completely remove these kinds of micropollutants from wastewaters and they are consequently discharged into the aquatic environment. Constructed wetlands have been successfully used as tertiary treatment process for removal of biological oxygen demand (BOD), total suspended solids (TSS), organic matter, nitrogen, and phosphate from domestic wastewater. However, there are studies that show the effectiveness and efficiency of this low-cost, environmentally friendly tertiary treatment process in removal of the PPCPs.

In this project, we worked closely with Regional Wastewater Treatment Plant at the City of Columbia, Missouri. The City of Columbia is considered the medical center in the Central Missouri, and its wastewater treatment plant processes 25.2 million gallons of wastewater per day, including the effluents from the eight hospitals. The treatment plant consists of an activated sludge mechanical plant followed by a 4-unit, 23-cell constructed treatment wetlands. The goal of this study is to evaluate the effectiveness of the constructed wetlands in removing the selected persistent PPCPs in the municipal wastewater by the engineered wetlands. We conducted sampling sessions over a period of one year on Columbia wetlands and more than 36 PPCPs compounds in the inflow and outflow have been detected.

The removal of detected PPCPs was investigated in constructed wetlands and the results showed that the wetlands can be an effective solution for reducing environmental risk of PPCPs discharge from the wastewater treatment plant by removing them before reaching the surface water systems. The outcome from this study will allow us to optimize design criteria and develop alternative mitigation strategies and policy guidelines to reduce public exposures to PPCPs and support outreach efforts to improve water quality, thereby providing long-term health and environmental benefits.



Charts on left: PPCPs removal efficiency in Columbia constructed wetlands: (a) antibiotics, (b) antidepressants and antiseizure, (c) NSAIDs, (d) β-blockers and statins, € others.

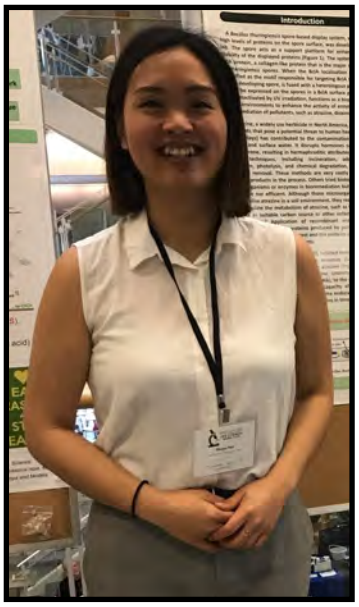
Bioremediation of Atrazine

Author: Shu Yu Hsu, Forestry Ph.D. candidate in collaboration with George Stewart, Hsin-Yeh Hsieh, Brian Thompson of Elemental Enzymes, Inc.

Increased use of herbicides in Missouri poses a threat to both public health and the environment. The herbicide, atrazine, has been proven to interrupt our hormone system and affect the reproduction. Because of atrazine's high mobility in soils and its relative persistence, it is often detected in surface and ground waters at concentrations well above the legal limits. To prevent Missourians from illness as well as to protect wildlife in the ecosystem, finding an innovative approach to remove atrazine is critical.

The spore expression system is used as a platform to deliver the enzyme which can degrade atrazine in this project. There are six enzymes in the atrazine degradation pathway. The goal of this project is to protect human health by constructing six enzyme-coated spores to completely degrade atrazine to carbon dioxide and ammonia. First, we have successfully proven that the spores with first enzyme, AtzA, is capable of degrading atrazine in both water and soil of the lab scale. In the three-month monitoring experiments, the AtzA-coated spores degraded 90% of the atrazine in three days. Furthermore, we mimicked the real environment and applied the washing steps after we applied the AtzA-coated spores. Surprisingly, the spores not only can stay in the soil but also degrade the atrazine.

The spore expression system can also be applied to remediate other organic pollutants, such as dioxins or TNT. Our research is to build the foundation of application and to eliminate all the obstacle before applying it to the real environment.



Shu Yu Hsu presenting research findings at the 2019 Agroforestry Symposium.

Phytotechnology

Great Lakes Restoration Initiative (GLRI)

Author: Liz Rogers, Forestry Ph.D. Candidate

Increasing human population, along with associated expansion of industrial and municipal activities, have led to widespread air, soil, and water pollution. Sustainable solutions are needed to address this issue; phytoremediation, the use of trees to clean up contaminated soils and water, is one such solution. Not only are phytoremediation systems cost-effective and aesthetically pleasing, but their efficacy to remediate pollution has been well-documented. My research strives to fill the knowledge gap for large-scale studies on poplars grown for phytotechnologies, specifically regarding water usage, productivity, and phytoremediation potential. I will collect data from poplar trees planted at landfill sites in Wisconsin. Trees were established as part of a Great Lakes Restoration Initiative (GLRI) project to reduce landfill runoff in the Lake Michigan watershed within the Great Lakes basin. The data I collect will help me determine which pollutants the poplars are taking up and the rate they are doing it. I will use this information to compare the remediation capabilities of different varieties of poplars, which will aid site managers in selecting superior varieties for future field establishment.

Liz Rogers pictured next to a hybrid poplar grown for a Great Lakes restoration Initiative (GLRI) Landfill Runoff Reduction project in Wisconsin.

The Effect of Agroforestry, Grass Buffer, Biomass Crop, and Row Cropping on Soil Biodiversity

Submitted by Ranjith Udawatta; written with Salah Alagele, Stephen Anderson, Kristen, Lalith Rankoth

Fig. 1. Agroforestry trees and hay bales at the study site.

Despite numerous benefits of biodiversity (BD), the global BD is changing at an unprecedented and alarming rate. Biodiversity loss has become a global concern and received significant attention worldwide due to its negative effects on soil and environmental quality as well as ecosystem sustainability. Domestication of crops from wild relative plants has reduced the number of plant species and varieties cultivated thus reducing BD worldwide. Planting one or two crops continuously on the same land further erodes agricultural BD and impacts food security, human nutrition, and other ecosystem services.

Although modern agriculture is largely blamed for declining BD, agricultural lands can support BD provided better management plans are implemented to support it. For example, in Europe ~50% of plant and animal species depend on agricultural habitats. Therefore, agricultural practices that favor BD can be used to conserve and improve BD. Agroforestry (AF) is recognized as a possible partial solution for BD conservation and improvement.

Researchers at the Center for Agroforestry conducted a study at the Paired watersheds at the Greenly Memorial Research Center, Novelty, Missouri to investigate the perennial buffers and cropping effects on soil BD. The design included treatments of grass waterways (GWW), grass buffers (GB), agroforestry buffers (AB), and biomass crops (BC), established in 1991, 1997, 1997, and 2012 (Fig. 1). These watersheds were on a corn-soybean rotation. Soil samples were collected from 0 - 10 cm depth for GB, BC, GWW, and RC treatments with three replicate positions. Soils were also sampled from 50 cm (AB50) and 150 cm (AB150) distances from the tree base. Soil microbial structures of bacteria gram (+), bacteria gram (-), actinomycetes, rhizobia, fungi, arbuscular mycorrhizal, saprophytes, protozoa, and total microbial biomass were determined using phospholipid fatty acid (PLFA) analysis. Significant differences ($P < 0.05$) were observed for all soil microbial biomass community structures consisting of bacteria gram (+), bacteria gram (-), actinomycetes, rhizobia, fungi, arbuscular mycorrhizal, saprophytes, and protozoa under perennial vegetation management practices (GB, BC, GWW, AB50, and AB150) as compared to the row crop treatment.

Total soil microbial biomass and soil organic carbon for GB, BC, GWW, AB50, and AB150 were consistently higher for total biomass and soil organic carbon (SOC) compared to row crop management (Fig. 2). Study findings imply that integration of tree/grass into cropland can help improving microbial biomass and community compositions.

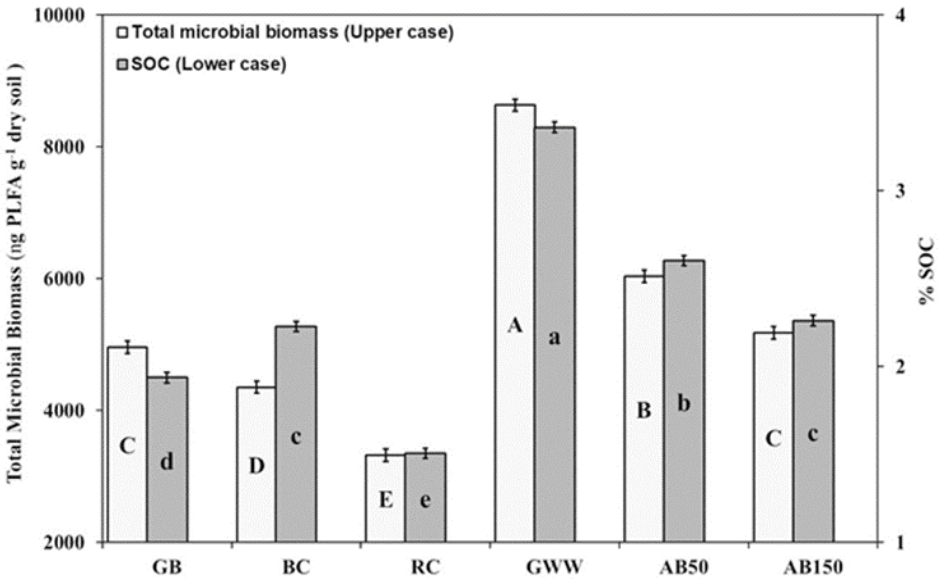


Fig. 2. Total microbial biomass and soil organic carbon (SOC) by treatments of GB-grass buffer, BC-biomass crop, RC-row crop, GWW-grass waterway, AB50-agroforestry buffer at 50 cm distance, and AB150-agroforestry buffer at 150 cm distance averaged across landscape positions (except for GWW treatment). Different letters (capital and small) represent significant differences among treatments at $p \leq 0.05$ based on Duncan LSD test. Bars denote standard error.

EDUCATION and OUTREACH

The Center for Agroforestry educates and trains producers, natural resource professionals and the public about advances and opportunities in agroforestry. We achieve this by hosting and participating in engaging events that translate the most up-to-date research and practice innovations, and highlight existing partnerships that extend our reach.

UMCA's comprehensive outreach approach is a multi-faced effort with a sustained commitment to advancing the knowledge infrastructure for agroforestry. Workshops, field days, technical guides, presence at engaging events, and widely accessible online programs each contribute to this framework. Altogether, the aim of these efforts is to achieve greater adoption of agroforestry practices and specialty crop value-added industries across Missouri and the region, and improved environmental and economic outcomes for all. Here are the highlights of UMCA education and outreach efforts in 2019.

Mushroom cultivation centerpiece of Missouri's agroforestry movement

Author & photos: Andrew Sheeley, the SalemNewsonline.com

Mushroom season has arrived in the Ozarks, and eager foragers are already scouring the countryside looking for the elusive morels. While nothing can replace the thrill of Missouri's mushroom hunting, a growing movement of landowners are using their forests to farm their own fungi. The practice is one element of forest farming which seeks to forested land to use for non-timber products.

"Forest farming is the intentional manipulation and management of forested land to improve forest stands and produce plants, parts of plants, fungi and other biological materials for edible, medicinal or other specialty uses," says Education Program Coordinator Hannah Hemmelgarn of the Center for Agroforestry at the University of Missouri in Columbia. "Products which can be forest farmed in Missouri include syrup from maple and black walnut trees, American ginseng, pine straw or cones and of course mushrooms like wine caps, oysters and shiitakes."

Hannah Hemmelgarn, UMCA Education Program Coordinator discussing oyster mushroom spawn.

On Thursday, MU Extension hosted Hemmelgarn to teach the fundamentals of mushroom cultivation during a workshop at Salem's Ozark Natural and Cultural Resource Center. Hemmelgarn said forest farming is particularly beneficial as its wild-simulated approach preserves wildlife habitat. This helps ensure there is game for hunting and also helps pull carbon dioxide out of the atmosphere. She added that mushroom cultivation also gives a unique view into one of earth's most interesting forms of life.

"Fungi is not an animal and not a plant, it is an other kingdom of life. There is still a lot of mystery involved, even for mycologists who study fungi," Hemmelgarn said. "Even today there are many mushrooms species not yet named by humans, and it is possible mushrooms you find aren't named."

Hemmelgarn later shared viable mushroom spores have even been discovered in outer space. When a mushroom releases its spores, they also don't fall out but actually shoot out faster that a bullet.

Three ways mushrooms can be grown at home, were described during the workshop. Depending on the mushrooms sought, Hemmelgarn said methods include cultivating them in a garden bed or growing them on logs with a totem or drill and fill approach. A common element required for all methods is spawn, which is a genetically identical mycelium mass used to grow mushrooms by introducing it to a growing medium.

Hemmelgarn demonstrated all three methods for the workshop's attendees. At the Salem Community Garden, she showed how oyster mushroom spawn and vertically-stacked oak logs can be used for the totem approach. She also demonstrated how winecap spawn and spread straw can be used in a garden bed to grow the fungi. At the Salem farmer's market pavilion, Hemmelgarn led attendees in inoculating oak logs with shiitake spawn using custom-designed equipment.

A few tips for mushroom growth Hemmelgarn shared are to avoid conifer logs or chips as a medium of growth and to watch out for slugs and snails.

Resources Hemmelgarn referenced for prospective mushroom growers include Mizzou's Center for Agroforestry, the Missouri Mycological Society and online retailers at fieldforest.net and fungi.com. She added to look for books authored by Peter McCoy and Paul Stamets.

Hemmelgarn concluded by saying the workshop was so popular that potential attendees had to be turned away for lack of space. She said another workshop will be organized to meet the local demand in the not too distant future.

Inoculating oak logs with shiitake mushroom spawn at the Salem Farmers' Market pavilion.

Salem Community Garden, learning how to grow winecap mushrooms in a garden bed.

Sarah Hultine-Massengale of Dent County's MU Extension Office added that once the mushrooms at the Salem Public Gardens are ready for harvest, a class will be hosted on how best to cook and serve them.

Water Quality Improvement & Watershed Restoration Courses in China

Authored and photos by: Ranjith Udawatta, UMCA Research Professor

Ranjith Udawatta was invited to conduct a 2-week lecture session on Conservation Practices for Water Quality Improvement and Watershed Restoration at the College of Resources and Environment of Southwest University, Chongqing, China. The invitation came through the Global Immersion program of the SWU through the International Center of MU. Eighty-one faculty from 40 countries joined the program to conduct lectures is numerous disciplines. Ranjith conducted a 40-credit lecture session for graduate and undergraduate students at the university from July 1 to July 12, 2019.

The University is located in the large satellite city of Chongqing in BeiBei District nearby the Jialing River. The landscape is green rolling hills at the foot of Jinyun Mountain. Southwest University is a comprehensive university in Chongqing, China. It is a Chinese Ministry of Education Double First Class Discipline University, with Double First Class status in certain disciplines. The university was found in July 2005 by merging Southwest Normal and Southwest Agricultural Universities, both are over 100 years old. The student population at the university is ~100,000 including ~45,000 online/distant education students and ~55,000 regular students. There are also international students pursuing BS, MS, and Doctoral degrees in various disciplines.

One of the eight gates at Southwest University, Chngquig, China.

Ranjith's course material included the following topics: current issues on water quality at global, continental, regional, and local scales to convince students of the importance of water quality and watershed restoration; watershed concepts, measurements, and instruments associated with water quality and watershed evaluation; conservation practices and bioengineering methods for water quality improvement and watershed restoration; development and implementation of a watershed restoration plan and evaluation of progress/success of watershed restoration plans.

Agroforestry Graduate Programs

The Center for Agroforestry currently offers three unique graduate degree options in agroforestry: a campus-based MS, an online MS, and an online graduate certificate. Due to the flexibility of the online degree programs, students include non-traditional students (e.g. farmers, working professionals and parents) who attend from all over the world. The Center also funds agroforestry PhD students, although a named agroforestry PhD emphasis area is still in the works. In 2019, ten of the 42 enrolled agroforestry graduate students completed their degree programs.

Agroforestry Academy

UMCA hosted its seventh annual Agroforestry Academy July 21st through 26th, 2019, at the Anheuser-Busch Natural Resources facility and at a number of nearby farms that demonstrate agroforestry practices, or who participated as case study farms.

A total of 26 new participants and 4 trainer participants, including farmers and natural resource professionals took part in the weeklong intensive training on agroforestry and sustainable land use practices. Interest in farm visits, forest farming, and marketing opportunities for agroforestry products were among the topics rated highest by attendees as their motivation to attend the Academy. Attendees, 13 of whom received financial assistance to participate, graduated from the program with the confident ability to create an agroforestry plan for their own farm or farmer clients.

Next year's Agroforestry Academy will be held July 26th through 31st; interested participants are encouraged to submit their registration information as soon as possible, as the program is quickly filling. More information is available at www.CenterforAgroforestry.org/Academy.

High School Agriculture Teacher Professional Development Programs

Now in its third year, this project has been supported by the USDA Sustainable Agriculture Research and Education's Professional Development Program since 2017. In 2019, the Center offered an additional two-day summer training for high school agriculture and science teachers throughout the state.

Those who attended (six educators total) each received the complete high school agroforestry curriculum materials, hands-on practice teaching the agroforestry content to their peers, and experiential learning opportunities for tree identification, elderberry and mushroom cultivation (two activities relevant to the student project and school year timeline), and soil health assessment toolkits. The agroforestry curriculum is also available online at www.CenterforAgroforestry.org, where 52 unique downloads of the materials have been documented in 2019.

Youth Education Partnerships

Several partnerships with regional environmental educators have contributed to the inclusion of agroforestry content for youth programs. As part of a Prairie Fork Conservation Area supported project, the Center for Agroforestry has collaborated with environmental educators again this year to include agroforestry in the Natural Resources Career Academy, a one-week program for high school upper classmen in Missouri to explore careers and content related to natural resources conservation, including hands-on field experiences. Additionally, UMCA continues to partner with Missouri River Relief, a local organization dedicated to stewardship and awareness of the Missouri River watershed. In addition to participation as a floodplain forest field guide in the Missouri River Days field trips for all Columbia Public Schools 4th graders, an agroforestry-focused film was included in the group's annual Wild & Scenic film festival. Also with Columbia Public Schools and supporting educators, the Center continues to advise and support the development of a Gentry Middle School habitat restoration garden, which will include perennial specialty crops. Partners in MU Extension throughout the state have also supported the inclusion of agroforestry materials in statewide 4H and science education fairs.

2019 Agroforestry Academy: hands-on learning in the elderberry planting at HARC.

Undergraduate Summer Internship

This year, in an attempt to engage with interested undergraduate students who are not yet eligible to enroll in the Center's graduate programs, a summer research center internship program was offered as an alternative hands-on agroforestry learning opportunity. Aidan Cornelison, entering her final year of an

Intern Aidan Cornelison demonstrating basket weaving .

undergraduate forestry degree, spent between 10 and 20 hours a week at the Horticulture and Agroforestry Research Center farm, assisting faculty and farm staff with summer research activities. Additionally, Aidan supported and participated in the 7th Annual Agroforestry Academy, where she had an opportunity to expand her understanding of temperate agroforestry practices. Her reflections on the internship experience can be found at https://agroforestry.home.blog/.

Based on this pilot internship experience, UMCA seeks to expand this offering to a greater number of undergraduate students who can work and learn together in the field, with direct faculty mentorship relevant to student interests.

The Agroforestry Podcast

New to the Center's menu of media, The Agroforestry Podcast capitalizes on this unique downloadable audio platform rapidly growing in popularity. While there are several podcasts on farming and food systems, none has featured agroforestry until now. With the strong network of growers, researchers, and educators in our midst, The Agroforestry Podcast is a place where we share diverse, knowledgeable voices on a wide array of topics. Season one includes episodes on forest farming with medicinal plants, establishing silvopasture with cattle, the ins and outs of alley cropping, pawpaw as a unique specialty crop, benefits of native plants as perennial crops, and much more. As listeners continue to spread the word and subscribe to the podcast, there have been at least 1000 unique downloads of each podcast episode this year, with 30-50 new listeners every day. The Agroforestry podcast is available on any podcast app, and on the Center for Agroforestry's website, free to stream or download.

Annual UMCA Agroforestry Symposium

Despite snow and ice on MU's campus, on January 30th, 2019, the 10th Annual Agroforestry Symposium, "Research to Entrepreneurship: Fostering a Culture of Research Translation" was attended in-person and via livestream by more than 250 viewers. The event highlighted examples of Center for Agroforestry and CAFNR collaborations with external partners that have brought innovations to successful commercial development. Keynote speakers included Dr. Kelly Sexton, Associate Vice President for Research – Technology Transfer and Innovation Partnerships for the University of Michigan, and Dr. Rodolphe Barrangou, Associate Professor of Food Science and the Todd R. Klaenhammer Distinguished Scholar in Probiotics Research at North Carolina State University.

Annual Missouri Chestnut Roast Festival

With beautiful weather in our favor, several thousand visitors attended this year's celebration of the fall tree nut harvest at the Horticulture and Agroforestry Research Center in New Franklin, Missouri.

This year marks the 200th anniversary of the historic Hickman House, restored to its original beauty and opened for the festival with guided audio interpretation in each room. In addition to local craft and native plant vendors including Forrest Keeling Nursery, Missouri Native Plant Society, Alpacas D'Auxvasse, and 3 Dandelion Seeds, educational exhibitors and demonstrations added an engaging element to the event.

Among many demonstration areas this year, our summer intern, Aidan Cornelison, taught basket weaving with willow harvested from the discontinued biomass area, and Ernest Hilderbrand once again displayed the wood turning process with tree species represented on the farm. Helen Poehlmann demonstrated and taught crocheting to many eager young learners.

Food is always a highlight of the event, with the roasted chestnuts and pawpaw ice cream from the research farm, elderberry cordials from River Hills Harvest, a beverage-tasting tent, and BeetBox back again to demonstrate cooking with perennial crops and to provide a nourishing lunch.

The Chestnut Roast is fun for the whole family, with farm tours, pumpkin picking, wagon rides, and yard games. We are proud to offer this event free and open

Every year local producers sell their harvest & added value products at the Chestnut Roast.

to the public as a highlight of agroforestry research and community at the Horticulture and Agroforestry Research Center, and look forward to next year's festival, on October 3, 2020.

Green Horizons & Agroforestry E-Newsletter

Each month, the Center for Agroforestry sends highlights about our work, upcoming events, new publications and innovations, and important news in the Agroforestry in Action E-Newsletter. Recipients of the newsletter are able to stay up to date with regional agroforestry media.

Additionally, three times per year, forestry and agroforestry professionals in Missouri share important information about all aspects of the field in the Green Horizons newsletter. This perennial online publication features critical updates on forest and tree health, urban and suburban trees, agroforestry and forestry industries. To sign up to receive Agroforestry in Action and/or Green Horizons, contact Mike Gold, at goldm@missouri.edu with your name, affiliation, and preferred email address. Past issues are available at http://www.centerforagroforestry.org/pubs/newsletters.php.

Agroforestry in Action Webinar Series

This monthly webinar series offers presentations by leading researchers and practitioners in the field of agroforestry that showcase recent and compelling work regionally and internationally. Among this year's presenters are Naresh Thevathasan on Food Security through Agroforestry Land-use Systems: A Case Study from Ghana; Jono Neiger and Russell Wallack on Chestnut Agroforestry in the Northeast: Implementation Strategies, Economics and Remaining Challenges; Eduardo Somarriba on the Analysis and Design of Coffee and Cocoa Shade Canopies; and Diane Mayerfeld on Silvopasture in Wisconsin: Goals, Challenges, and Fodder for Thought. Past webinars can be viewed at https://agroforestryinaction.wixsite.com/agroforestryinaction/recorded-webinars-

Agroforestry Training Workshops, Demonstrations, and Field Events

Based on farmer-landowner interests, the Center for Agroforestry has focused particular attention on silvopasture, forest farming, and integrated specialty perennial crops as promising land use practices and income generating strategies for small producers in Missouri. Workshops and demonstrations throughout the region help to build a network of knowledgeable agriculture and natural resource professionals and farmers. Workshop topics include: cultivation of mushrooms and medicinal herbs, getting started with Chinese chestnuts, pawpaw, and other alternative tree crops, and grazing considerations in silvopasture systems.

An example of one such field workshop is the "Pasture Walk and Producer Field Day" held on November 9, 2019 to showcase an in-process silvopasture establishment at the RRR ranch in Subiaco, Arkansas. Participants were introduced to how producer Rennie Reynolds is implementing a range of conservation practices under an NRCS cost-share arrangement while also working with a consulting forester. Attendees were able to observe first hand and hear from Mr. Reynolds about the process and approaches for establishing silvopasture and how one can use natural shade for improving economic returns, animal welfare, and production in a cow calf operation, while also improving environmental outcomes. The site is also one of the participating farms collaborating with Principal Investigator Christine Nieman of USDA-ARS in Booneville AR under a recently awarded SARE Grant.

Similar field events hosted on working farms and at MU research centers have contributed to the Center's 3-year capacity-building project "Agroforestry and Specialty Crop Development for Resource Stewardship, Livelihoods and Vibrant Communities across Missouri" made possible under a grant from the NRCS-CTA-EQIP program.

Participation in Agroforestry networks and Coordinating Bodies

UMCA outreach staff participate in a range of regional and national agroforestry coordinating bodies to advance agroforestry knowledge infrastructure, coordination and policy development. Among others, this participation includes Center for Agroforestry staff on the Board of Directors of the Association for Temperate Agroforestry and biennial North American Agroforestry Conference planning committee; and the Savanna Institute's advisory committee and Perennial Farm Gathering planning committee.

International Engagement:

UMCA faculty and staff regularly collaborate with international partners. The following are highlights of the Center's international engagement in 2019.

During winter break, 2018/2019, a short course on Sustainable Agriculture, in collaboration with agroecology faculty from UNIMINUTO, to students at UNIMINUTO students at the UNIMINUTO's Zipaquira Colombia, was provided as a follow up to

previous visits to UNIMINUTO as part of an MU delegation to foster collaboration between the two institutions.

During spring break 2019, the first cohort of 10 students participated in the newly created study abroad course in Belize titled "Protection and Management of Tropical Ecosystems". The initial proposal for the course was submitted by the Center for Agroforestry with support from CAFNR Study Abroad in finalizing the design and planning of the course, including the recruitment of faculty leaders Dr. Alba Argerich and Dr. Michael Byrne of CAFNR's School of Natural Resources. The course will be offered again in spring 2020.

Several of the Center's faculty attended the 4th World Agroforestry Conference held May 29-23, 2019 in Montpelier, France, and participated in the launch of the International Union for Agroforestry (IUAF) for which UMCA representatives Gregory Ormsby Mori and Dr Shibu Jose were part of the charter drafting committee.

Following a December 2018 visit to The Tropical Agricultural Research and Higher Education Center (CATIE) in Turrialba, Costa Rica, home to a major cocoa germplasm collection and long-term research plots on cocoa and coffee agroforestry systems, in 2019 the Center's outreach staff continued to serve as liaisons between CATIE and CAFNR researchers for the development of several collaborative initiatives, including a Global Agroforestry Business Incubator with MU Innovation Center and CAFNR Center for International Programs participation.

MU/UMCA OUTLYING FARMS & CENTERS

University of Missouri's Agricultural Research Centers are a network of sites across the state hosting state-of-the-art programs that bring Missouri agricultural land and forest owners' new information for reaching maximum income potential and environmental benefits on a variety of land types and eco-regions.

Horticulture and Agroforestry Research Center (HARC)

Located at New Franklin, Mo., and set in the beautiful, rolling Missouri River hills, HARC is the primary research site for the Center for Agroforestry. HARC sits at the interface of the loess hills and Missouri River bottom and provides a scenic, historic and scientific setting for development of horticultural- and agroforestry-related studies. This 665-acre farm includes several experimental fruit and nut orchards; forest farming, riparian buffer, silvopasture, alley cropping, and windbreak demonstrations as well as forage shade trials; flood tolerance trials; biofuel trials; pinestraw production trials; greenhouses; five lakes and ponds and one of Missouri's oldest brick homes, the fully restored 1819 Thomas Hickman House. Tours and educational events are hosted regularly including the annual Missouri Chestnut Roast.

HARC co-superintendent Barry Eschenbrenner, on right and Mark Abney with a HARC soil core.

Specialty crops featured include major germplasm collections of northern pecan, eastern black walnut, and Chinese chestnut, along with research on elderberry, pawpaw, pine straw, grapes, and gourmet mushrooms. In addition HARC features an innovative, outdoor 24-channel flood tolerance research laboratory and bioremediation, non-point source pollution and shade tolerance studies.

Southwest Research Center

Established in 1959 in Mt. Vernon, Mo., this Center addresses the main agricultural concerns of area industries including dairy, beef, forage and specialty crop production. Horticultural research, including black walnut, pecan, pawpaw, persimmon, chestnut, elderberries and grapes provides information on viable production alternatives for both commercial producers and home gardeners interested in small fruits and vegetables. Forage grass breeding conducted at the Southwest Center

focuses on variety testing and development, proper fertilization practices and harvest management alternatives. production are being implemented.

Greenley Research Center

Located in Novelty, Mo. the major objective of the Center is to evaluate efficient, profitable crop production in northern Missouri while emphasizing soil conservation, water quality and energy efficiency. Researchers study the benefits of reduced tillage, alternative cropping practices, the effects of new technology and products, variety testing, soil fertility and beef cattle backgrounding. Studies on water quality and the environmental impact of crop UMCA has maintained a long-term paired-watershed agroforestry research study located at Greenley that has generated a wealth of scientific information about the value of upland agroforestry buffers in claypan agricultural soils. Ongoing performance testing of corn, soybean, sunflowers, biomass and winter wheat yields results to aid Missouri producers.

Bradford Research Center

As a research laboratory and outdoor classroom in Columbia, Mo., Bradford's faculty and students investigate wastewater management, entomology, pest and weed control, specialty crops, organic transition techniques, agroforestry, permaculture and engage the community through workshops, field days, and partners with University organizations to improve MU's sustainability.

Land of the Osages Research Center

LORC contains 550 predominantly hilly and wooded acres in the Ozark region near Laurie, Mo., and contains many desirable tree species, including black and white oak, shagbark hickory, northern red oak, white ash, river birch and eastern red cedar. Approximately 83 acres of the site are bottomland fields and have been converted to warm season prairie grasses. Portions of the property feature soil well-suited to growing the Missouri native shortleaf pine - a species the Center has invested over fifteen years of research into as a potential source of short and long-term income for landowners.

Wurdack Research Center

Nestled along the Meramec River near Cook Station in the northeast Ozarks, the Hugo Wurdack Research Center conducts demonstrations and research in silvopasture and wildlife management practices that are economically viable, environmentally sound and sociologically acceptable for the region. Wurdack is operated using Best Management Practices that promote sustainable agricultureal production while protecting the natural environment. This provides educational information on a wide range of agricultural, natural resource and scientific topics to area beef and forage producers, soil and water district members, students from elementary and secondary schools, and other interested groups.

Pawpaw harvesting at Southwest Center in Mt. Vernon, Mo.

Miguel Salceda, Fulbright Ph.D. student from Panama, downloading rainfall data at the Missouri River Basin Initiative location in Livingston County, Missouri.

GRANTS & GIFTS 2019

Bardhan, S. (PI). HBCU Capacity Building Grant, USDA. 2018 – 2021. Variability of Soil Greenhouse Gas Emissions and Soil Microbial Diversity and Function in Conventional and Alternate Land Use Systems in Floodplain Soils. $293,500

Bardhan, S. (PI). MU CAFNR International Program. 2018 – 2019. Approaching Microbial Community Divergence as Diagnostic Tool for Early Warning of Climate Change. $,2500.

Cai, Z. (PI). MDA Specialty Crop Block Grant Program (SCBG). 2020-2021. Explore the Economic Opportunities and Health Benefits of the Pawpaw in Missouri. $46,689.

Gold, M./Lovell, S.T.(PI), USDA-Agricultural Research Services. 2016-2021. Integrating agroforestry into small farm production systems. $3,928,295 (to date).

Gold, M.A. (PI), Co-PIs: Cai., Hemmelgarn, Ormsby-Mori. MO NRCS. 2018-2021. Agroforestry and Specialty Crop Development for Resource Stewardship, Livelihoods and Vibrant Communities across Missouri. $102,318.

Gold, M.A. (PI). Co-PIs: Ball, Stelzer, Hemmelgarn. USDA NCR SARE PDP. 2017-2020. Missouri Agroforestry Summer Institutes: High School Educator Training for Curriculum Delivery. $70,335

Gold, M.A. (PI). MDC. 2019. Tree improvement program. $16,500.

Jose, S. (Co-PI), USDA-AFRI. 2015-2020. Armed to Farm: Veteran Labeled Marketing, Education and Research Strategies to Soldier Success for Military Veteran Farmers. $499,978.

Hemmelgarn, H.L. (PI). University of Missouri Division of Inclusion, Diversity & Equity. 2018-2019. Laying the Groundwork for Decolonized Education in CAFNR. $4,630.

Hemmelgarn, H.L (Co-PI). Prairie Fork Conservation Area. 2018-2019. Engaging and Empowering Urban Youth through Schoolyard Habitat Restoration and Conservation Education- An Innovative Middle School Program. $9,800.

Hemmelgarn, H.L (Co-PI). Prairie Fork Conservation Area. 2018 – 2019. Natural Resources Career Academy: A Summer Residential and Experiential Course for Missouri High School Stu- dents. $14,500.

Lin, C.H. (Co-PI). EPA Region 7. 2016-2019. Pesticide Sensor Development and Landscape-Based Sampling Strategy Supporting Implementation of Wetland Water Quality Standards. $406,661.

Lin, C.H. (PI). MDA SCBG. 2017-2019. Explore the economic opportunities and health benefits of the black walnut in Missouri. $29,500.

Lin, C.H. (PI). MDA SCBG. 2019-2021. Explore the economic opportunities and health benefits of the pawpaw in Missouri. $46,500.

Lin, C.H. (PI). MDA SCBG. 2018-2020. Explore the economic opportunities and health benefits of the elderberry in Missouri. $29,500.

Lin, C.H. (PI). MU Office of Academic Affairs, Research and Economic Development, FastTrack Pitch Competition Award. 2018-2019. A novel Continuous Flow System for Blood Type Conversion. $50,000.

Lin, C.H. (PI). SNR Mini-Grant. 2019-2020. Identify novel uses of elderberry and its byproducts through global metabolomics profiling and high-throughput screening. $5,000.

Lin, C.H. (PI). SNR Mini-Grant. 2018-2019. Identify novel uses of black walnut and its byproducts through global metabolomics profiling and high-throughput screening. $5,000.

Lin, C.H. (PI). Cummings, Cummings & Dudenhefer Law Firm. 2019-2020 Analysis of chloroprene, toluene, and their metabolites in urine samples collected from communities around Denka/Dupont plant in St John the Baptist Parish in Louisiana. $4,500.

Lin, C.H. (PI). Tiger Energy. 2016-2019. Development of Continuous-flow Enzymatic Bioreactor for Industrial Applications $200,000

Lin, C.H. (Co-PI). Pilot Grant Supporting Research and Scholarly Works MU School of Medicine. 2019-2020. Paternal residential exposure to unconventional oil and natural gas extraction (UOG) $25,000.

Lin, C.H. (Co-PI). MO DNR. 2018-2020. Technology Assistance to Missouri Utilities to Meet DBPs Standards. $44,081.

Lin, C.H. (PI). MU Internal Service. 2019 The Analysis of the Dicamba by LC-MS/MS. $10,000.

Lin, C.H. (Co-PI). Foreign Agricultural Service. 2019-2021. Enhance the value of sorghum grains by creating fermented germinated grains by Aspergillus oryzae. $49,988.

Lin, C.H. (PI). Environmental Health News.2019-2020 Assessment of health risk of the public exposure to fracking chemicals. $33,184.

Lin, C.H. (PI). Elemental Enzymes. 2019 Gift $10,000.

Lin, C.H. (Co-PI). NIH R21 (award pending). 2020-2022. Paternal Residential Exposure to Unconventional Oil and Gas Drilling (UOG). $450,000.

Lovell, S. (PI). USDA – NIFA Competitive Grants Program, Foundational Program. 2018-2021. Multifunctional woody polyculture for integrating conservation and production. $460,000.

Lovell, S. (PI). NIFA Competitive Grants Program, Foundational Program. 2014-2019. Multifunctional perennial cropping systems (MPCs) for introducing local food and biomass production for small farmers in the Upper Sangamon River Watershed. $499,866.

Thomas, A.L. (PI). USDA National Laboratory for Agriculture and the Environment. 2015 – 2019. Carbon and Nutrient Dynamics of a Bioenergy Agroforestry System. $32,570.

Thomas, A.L. (Co-PI). USDA- NIFA-Capacity Building Grants for Non-Land Grant Colleges of Agriculture. 2018-2021. Building Research and Education Capacities to Strengthen the Black Walnut Breeding Program. $297,847.

Udawatta, R.P. (Co-PI). Missouri Fertilizer and Ag Lime Board. 2016-2019. Impact of Cover Crops on Nutrient Loss in a Terraced Fields. $87,000.

Udawatta, R.P. (PI). USDA NRCS. 2015-2022. Mississippi River Basin Healthy Watershed Initiative (MRBI) Edge of Field Monitoring-Ora Morris, Livingston County. $147,298.

Udawatta, R.P. (PI). USDA NRCS. 2016-2019. Monitoring and Modelling of Mississippi River Basin Healthy Watershed Initiative (MRBI) Edge of Field Monitoring and Environ mental benefit evaluation. $169,846.

Udawatta, R.P. (PI). USDA NRCS & MDNR. 2017-2022. Mississippi River Basin Healthy Watershed Initiative Edge of Field Monitoring-Alita Johnson Revocable Trust, Audrain County. $119,615.

Udawatta, R.P. (PI); Bardhan, Cai, Cartwright (Co-PIs) NRCS, MO-CIG. 2018 – 2021. Ecosystem Services of Cover Crops, Riparian Buffers, and Crop Rotation with Biochar on Eroded Midwest Corn/Soybean Landscapes, $75,000.

PUBLICATIONS 2019

Books and Book Chapters

Anderson, S.H., Udawatta, R.P. 2019. *Agroforestry: A System for Improving Soil Health*. In: M.R. Mosquera-Losada and R. Prabhu (eds.) Agroforestry for Sustainable Agriculture. Burleigh Dodds Science Publishing, Cambridge, UK. p. 317-334.

Bonnot, T.W., Millspaugh, J.J., Schulz, J.H., Burhans, D., Dey, D.C., Walter, W.D. In press. Managing for wildlife in agroforestry. Chapter 13. In: Garrett, H.E., Jose, S. and Gold, M.A. (eds). North American Agroforestry. 3rd Edition. Agronomy Society of America, Madison, WI

Cai, Z., Gold, M.A., Cernusca, M.M., Godsey, L.D. In press. Agroforestry product markets and marketing. Chapter 15. In: Garrett, H.E., Jose, S. and Gold, M.A. (eds). North American Agroforestry. 3rd Edition. Agronomy Society of America, Madison, WI

Cai, Z., Godsey, L.D., Mercer, D.E., Grala, R.K., Grado, S.C., Alavalapati, J.R.R. In press. Agroforestry economics and policy. Chapter 16. In: Garrett, H.E., Jose, S. and Gold, M.A. (eds). North American Agroforestry. 3rd Edition. Agronomy Society of America, Madison, WI

Garrett, H.E., Jose, S. Gold, M.A. eds. In press. North American Agroforestry. 3rd Edition. Agronomy Society of America, Madison, WI.

Garrett, H.E., Wolz, K.J., Walter, W.D., Godsey, L.D., McGraw, R.L. In press. Alley Cropping Practices. Chapter 7. In: Garrett, H.E., Jose, S. and Gold, M.A. (eds). North American Agroforestry. 3rd Edition. Agronomy Society of America, Madison, WI

Gold, M.A., Garrett, H.E. In press. Agroforestry nomenclature, concepts and practices. Chapter 2. In: Garrett, H.E., Jose, S. and Gold, M.A. (eds). North American Agroforestry. 3rd Edition. Agronomy Society of America, Madison, WI

Gold, M.A., Hemmelgarn, H.L. In press. Agroforestry education and training. Chapter 19. In: Garrett, H.E., Jose, S. and Gold, M.A. (eds). North American Agroforestry. 3rd Edition. Agronomy Society of America, Madison, WI

Gold, M. 2019. Agroforestry for the cultivation of nuts. Chapter 17. In: M.R. Mosquera-Losada and R. Prabhu (eds.) Agroforestry for Sustainable Agriculture. Burleigh Dodds Science Publishing, Cambridge, UK.

Jose, S., Holzmueller, E.J. In press. Tree-crop interactions in temperate agroforestry. Chapter 4. In: In: Garrett, H.E., Jose, S. and Gold, M.A. (eds). North American Agroforestry. 3rd Edition. Agronomy Society of America, Madison, WI

Jose, S., Garrett, H.E., Gold, M.A., Lassoie, J.P., Buck, L.E., Current, D. In press. The development of agroforestry as an integrated land use management strategy. Chapter 1. In: Garrett, H.E., Jose, S. and Gold, M.A. (eds). North American Agroforestry. 3rd Edition. Agronomy Society of America, Madison, WI

Lin, C.H., Weber, E.E., Walter, W.D., Lim, T., Garrett, H.E. In press. Vegetative Environmental Buffers for Air Quality Benefits. Chapter 11. In: Garrett, H.E., Jose, S. and Gold, M.A. (eds). North American Agroforestry. 3rd Edition. Agronomy Society of America, Madison, WI

Lovell, S.T., Bentrup, G., Stanek, E. In press. Agroforestry at the Landscape Level. Chapter 14. In: Garrett, H.E., Jose, S. and Gold, M.A. (eds). North American Agroforestry. 3rd Edition. Agronomy Society of America, Madison, WI.

Lovell, S.T., Revord, R.S., Stanek, E. In press. Agroforestry integration and multifunctional landscape planning for enhanced ecosystem services from treed habitats. In: Udawatta, R.P., Jose, S. (eds). Ecosystem Services of Agroforestry. Springer.

Page-Dumroese, D.S., Sanchez, F.G.., Udawatta, R.P., Perry, C., González, G., Berryman. E.M. In Press. Soil Health Assessment Examples – Forest Soils. In: D. Karlen (ed.) Approaches to Soil Health Analysis. American Society of Agronomy-Crop Science Society of America-Soil Science Society of America (ASA-CSSA-SSSA). Madison, WI, USA.

Udawatta, R.P., Perry, C., González, G., Berryman. E.M. In Press. Soil Health Assessment Examples – Forest Soils. In: D. Karlen (ed.) Approaches to Soil Health Analysis. American Society of Agronomy-Crop Science Society of America-Soil Science Society of America (ASA-CSSA-SSSA). Madison, WI, USA.

Schultz, R.C., Isenhart, T.M., Colletti, J.P., Simpkins, W.W., Udawatta, R.P., Schultz, P.L. In press. Riparian and upland buffer practices. Chapter 8. In: Garrett, H.E., Jose, S. and Gold, M.A. (eds). North American Agroforestry. 3rd Edition. Agronomy Society of America, Madison, WI

Udawatta, R.P., Anderson, S.H, Kremer, R.J. In press. Agroforestry for soil health. Chapter 12. In: Garrett, H.E., Jose, S. and Gold, M.A. (eds). North American Agroforestry. 3rd Edition. Agronomy Society of America, Madison, WI

Valdivia, C., Gold, M.A., Barbieri, C., Flora, C., Zabek, L., Arbuckle, J. In press. Human and institutional dimensions of agroforestry. Chapter 17. In: Garrett, H.E., Jose, S. and Gold, M.A. (eds). North American Agroforestry. 3rd Edition. Agronomy Society of America, Madison, WI

Journal Articles

Alagele, S.M., Anderson, S.H., Udawatta, R.P., Veum, K.S., Rankoth, L.M. 2019. Effects of conservation practices on soil quality compared to a corn/soybean rotation on a claypan soil. *Journal of Environmental Quality*. 48 (6):1694-1702. doi:10.2134/jeq2019.03.0121

Alagele, S.M., Anderson, S.H., Udawatta, R.P. 2019. Biomass and buffer management practice effects on soil hydraulic properties compared to grain crops for claypan landscapes. Agroforestry Systems. 93:1609-1625. Doi.org/10.1007/s10457-018-0255-1

Alagele, S.M., Anderson, S.H., Udawatta, R.P. 2019. Agroforestry, grass, biofuel crop, and row-crop management effects on soil water dynamics for claypan landscapes. Soil Science Society of America Journal. doi:10.2136/sssaj2019.07.0209

Ayoub, N., Costello, C., Jose, S. 2019. Systematic application of a quantitative definition of marginal lands in estimating biomass energy potential in the Missouri/Mississippi River Corridor. *Biofuels.* DOI: 10.1080/17597269.2018.1554945

Bennett, A.B., Lovell, S.T. 2019. Landscape and local site variables differentially influence pollinators and pollination services in urban agricultural sites. *PLOS ONE*: https://doi.org/10.1371/journal.pone.0212034

Body, M.J.A., Neer, W.C., Vore, C., Lin, C.L., Vu, D.C., Schultz, J.C., Cocroft, R.B., Appel, H.M. 2019. Caterpillar chewing vibrations cause changes in plant hormones and volatile emissions in *Arabidopsis thaliana. Frontiers in Plant Science* (editor's pick). doi: 10.3389/fpls.2019.00810.

Body, M.J.A., Zinkgraf, M.S., Whitham, T.G., Lin, C.H., Richardson,

R.A., Appel, H.M., Schultz, J.C. 2019. Heritable Phytohormone Profiles of Poplar Genotypes Vary in Resistance to a Galling Aphid. *.Mol Plant Microbe Interact* (Featured cover article). 32(6):654-672. https://doi.org/10.1094/MPMI-11-18-0301-R

Bolster, C.H., Baffaut, C., Nelson, N.O., Osmond, D.L., Cabrera, M.L., Ramirez-Avila, J.J., Sharpley, A.N., Veith, T.L., McFarland, A.M.S., Senaviratne, A.G.M.M.M., Pierzynski, G.M., Udawatta, R.P. 2019. Development of PLEAD: a database containing event-based runoff phosphorus loadings from agricultural fields. *Journal of Environmental Quality*. Doi:10.2134/jeq2018.09.0337

Borucke, M., Howard, D., Jose, S. 2019. A spatially explicit tree search application for agroforestry in the United States. *Agroforestry Systems*, 12 p. https://doi.org/10.1007/s10457-019-00462-9

Braun, E.A., Lovell, S.T., Babadoost, M., Forcella, F., Clay, S., Humburg, D., Wortman, S. 2019. Abrasive grit application in organic red pepper: An opportunity for integrating nitrogen and weed management. *HortScience* 54(9):1509-1516.

Burli, P., Lal, P., Wolde, B., Jose, S., Barhan, S. 2019. Factors affecting willingness to cultivate switchgrass: Evidence from a farmer survey in Missouri. *Energy Economics*. 80:20-29. https://doi.org/10.1016/j.eneco.2018.12.009

Byers, P.L., Thomas, A.L., Nichols, E. 2019. Blackberries: a model for integrating research with outreach and education to farmers and the public. *Acta Hortic*. 1265. ISHS 2019. DOI 10.17660/ActaHortic.2019.1265.8.

Cai, Z., Udawatta, R.P., Gantzer, C., Jose, S., Godsey, L., Cartwright, L. 2019. Economic impacts of cover crops for a Missouri Wheat-Corn-Soybean rotation. *Agriculture*. 9:83 doi:10.3390/agriculture9040083

Çerçioğlu, M., Anderson, S.H., Udawatta, R.P., Alagele, S. 2019. Effect of cover crop management on soil hydraulic properties. *Geoderma.* 343:247-253.

Chowdhary, G., Gazzola, M. Krishnan, G., Soman, S., Lovell, S. 2019. Soft robotics as an enabling technology for agroforestry practice and research. *Sustainability*. 11:6751. doi:10.3390/su11236751

Davis, A.N., Carlo, G., Gulseven, Z., Palermo, F., Lin, C.H., Nagel, S.C., Vu, D.C., Vo, P.H., Ho, T.L., McElroy, J.A. 2019. Exposure to Environmental Toxicants and Young Children's Cognitive and Social Development. *Reviews on Environmental Health.* 26:34(1):35-56. doi: 10.1515/reveh-2018-0045.

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Ferguson, R.S., Lovell, S.T. 2019. Diversification and labor productivity on U.S. permaculture farms. *Renewable Agriculture & Food Systems* 34(4):326-337.

Holmes, A.A., Thompson, A.A., Lovell, S.T., Villamil, M.B., Yannarell, A.C., Dawson, J.O., Wortman, S.E. In press. Nitrogen provisioned and recycled by cover crops in monoculture and mixture across two organic farms. Accepted for publication in: *Nutrient Cycling in Agroecosystems*. 115: 441–453. https://doi.org/10.1007/s10705-019-10024-1

Ho, K-V., Schreiber, K.L., Vu, D.C., Rottinghaus, S.M., Jackson, D.E., Brown, C.R., Lei, Z., Sumner, L.W., Coggeshall, M.V., Lin, C.H. 2019. Black walnut (*Juglans nigra*) extracts inhibit proinflammatory cytokine production from lipopolysaccharide-stimulated human promonocytic cell line U-937. *Frontiers in Pharmacology*. 19 Sept. 2019. https://doi.org/10.3389/fphar.2019.01059

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Jose, S. 2019. Environmental impacts and benefits of agroforestry. *Agriculture and Environment*. DOI: 10.1093/acrefore/9780199389414.013.195

Jose, S., Dollinger, J. 2019. Silvopasture: A sustainable livestock production systems. *Agroforestry Systems.* 93(1):1-9. https://doi.org/10.1007/s10457-019-00366-8

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AGROFORESTRY ACADEMY

July 26 - 31, 2020 | Columbia, Missouri

What is the Agroforestry Academy?

A week-long training that includes integrated classroom workshops, multiple on-farm visits, hands-on demonstrations and content integration into practical on-farm agroforestry planning and design to advance adoption of agroforestry as a cornerstone of productive land use.

Tell me more

Agroforestry is a **land management approach** that provides opportunities to combine **productivity and profitability** with environmental stewardship, resulting in healthy and sustainable agricultural systems that can be passed on to future generations.

Who will Benefit?

- **Educators** (natural resource professionals, extension agents…)
- **Farmers**, including beginning and military veteran farmers.

Advanced training will be provided on the main temperate zone agroforestry practices integrated with options for bioenergy, marketing, economic, social dimensions, and environmental services.

Trainers

Experienced trainers will be drawn from the MU Center for Agroforestry, USDA National Agroforestry Center, Extension and NRCS agroforestry specialists, other selected experts from the US and Canada, farmer educators and agroforestry practitioners.

Resources

The Agroforestry Academy link on the Center's website contains the 2019 edition of the UMCA Training Manual and the Handbook for Agroforestry Planning and Design which will serve as the foundational tools for the Academy.

In addition, the Academy web pages (www.centerforagroforestry.org/academy/) contain a wealth of additional information and resources from past academies.

REGISTRATION

FULL REGISTRATION:

$1,000/person (includes lodging, food, local travel and all training materials)

Scholarships available for Veteran farmers

Please register by **May 29, 2020**

HOW TO REGISTER? Please submit application:

- Registration (name, organization, address, phone number and email), and
- Payment (total attending number, total payment) ***make checks payable to the University of Missouri***

to **Caroline Todd**
Center for Agroforestry
203 ABNR - University of Missouri Columbia, MO 65211
Phone: 573-884-2874
Email: ToddCS@missouri.edu

Contact

For more information about scholarships and other details, contact:

Mike Gold: GoldM@missouri.edu

Hannah Hemmelgarn
HemmelgarnH@missouri.edu

Center for Agroforestry (UMCA)
www.centerforagroforestry.org/academy/