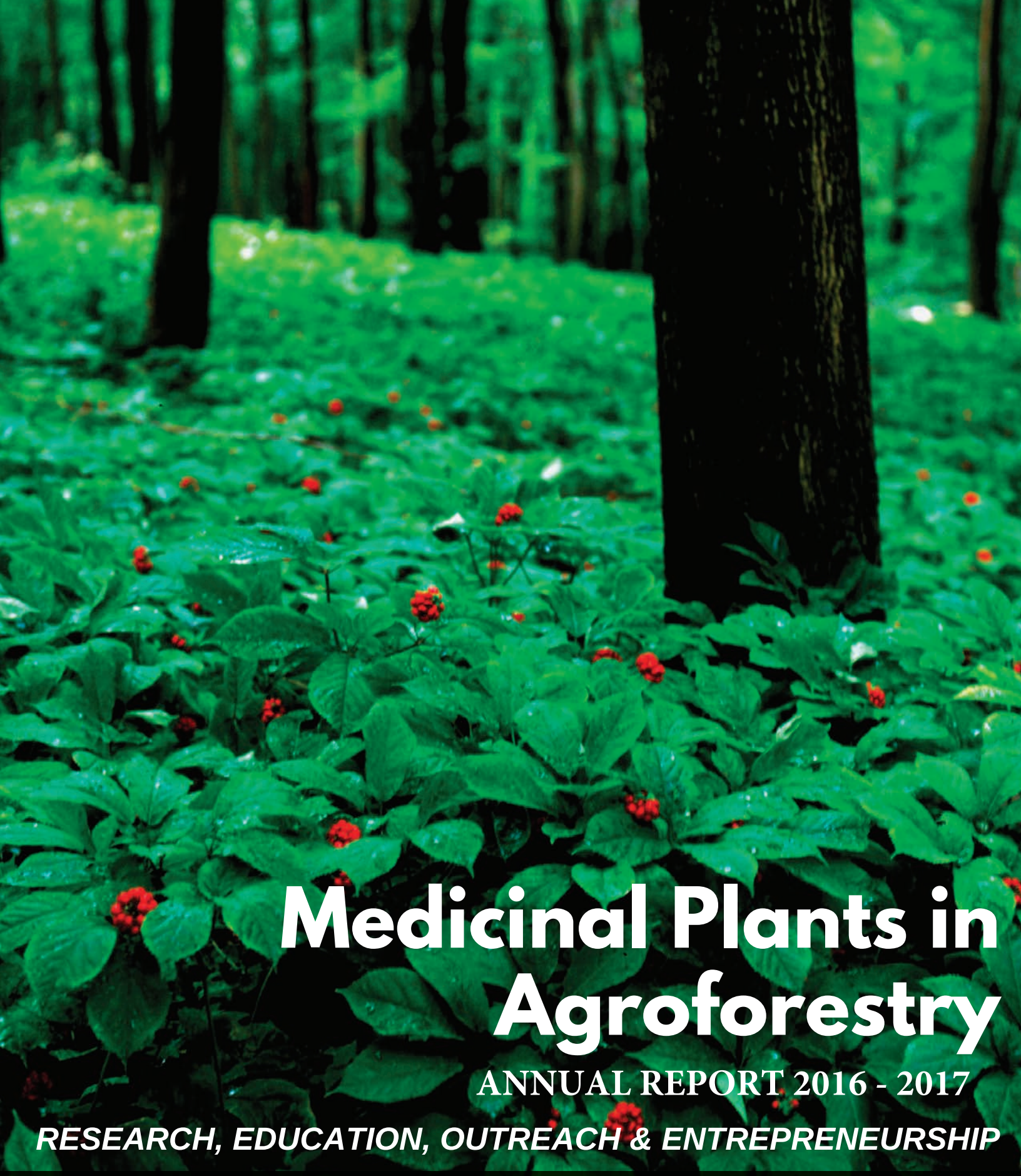

Medicinal Plants in Agroforestry

ANNUAL REPORT 2016 - 2017

RESEARCH, EDUCATION, OUTREACH & ENTREPRENEURSHIP

Center for Agroforestry
University of Missouri

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. 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 Michael A. Gold, Carol Williams
Design and Layout by Caroline S. Todd

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MESSAGE FROM THE INTERIM DIRECTOR

Greetings from the Center for Agroforestry at the University of Missouri on our 20th Anniversary! Our Center was established in 1998 as a big "C" Center here at MU. In March of 2017, the Center went through its second leadership change (of a sort). Dr. Shibu Jose, UMCA Director from 2009 – 2017, took a new position as Director of the MU School of Natural Resources (SNR). In that new role Dr. Jose is already making a strong and positive impact on SNR and remains a genuine supporter of our Center. I served as the Associate Director for our Center from 2002 to 2017 and worked closely with both Dr. Jose while he was Center Director and Dr. Garrett the founder and former Director of our Center. As Interim Director, I am honored to continue the great work of both previous Directors, Gene Garrett and Shibu Jose.

The University of Missouri Center for Agroforestry is one of the premier centers of its kind in the world dedicated to agroforestry research, education, outreach and economic development. Our strength lies in the success of our dedicated and productive core Center faculty and staff, our active collaborative efforts, over 50 associated faculty, staff and external collaborators, and our graduate students and postdoctoral research associates who define, design and carry out dozens of research and outreach projects (http://www.centerforagroforestry.org/personnel). We also find strength in the diversity of our stakeholders and friends who believe in agroforestry as a major form of global land use in the coming decades.

Our Center has been unusually blessed with long-term continuity in all of our endeavors. These long-term efforts are now "bearing fruit" on multiple fronts (research, education, outreach, economic development). The impacts of our research, education, outreach and economic developments activities are profound and positively impact landowners in Missouri, regionally, nationally and also have a global impact.

As we head into our 20th Anniversary year, 2018, I want to provide you with a status update on our Center and **highlight** a few outstanding accomplishments:

A three year USDA SARE PDP grant was awarded (2017-2019). This grant will enable the Center to create and offer six Agroforestry Summer Institutes and over three years, train 90 High School educators (20% of the total High School Agriculture Science teachers in Missouri), providing the necessary tools and materials to teach the agroforestry unit in their high school Agriculture Science II classes.

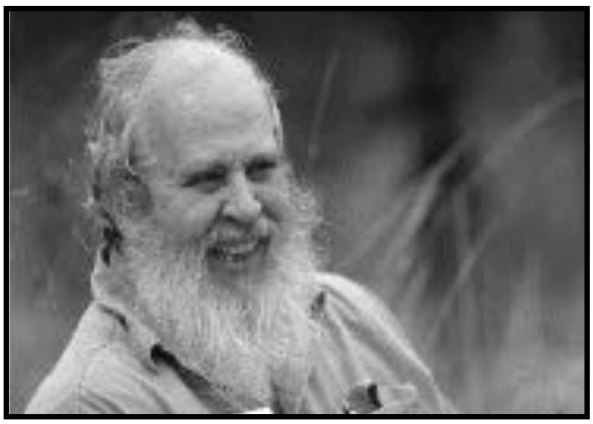
In 2017, the Center offered its' 5th Annual Agroforestry Academy as a crash course to train educators and landowners in agroforestry. Over 5 years, the weeklong Agroforestry Academy has trained 125 future agroforesters from 25 states, Washington, D.C., as well as hosting international participants from Canada, Taiwan and China.

Over the past two years, 9 MS thesis students from Indonesia initiated agroforestry graduate programs at MU, funded via Fulbright-CIFOR-USAID-PRESTASI.

Going forward, we will continue to focus on our mission to support the long-term future of rural and urban working farms and forests by achieving economic, environmental and social sustainability. The knowledge that agroforestry offers concrete solutions to many of the environmental and economic challenges that we face today is helping to spur adoption. Working closely with our many partners, our collective efforts are and will continue to help to realize agroforestry's potential. On behalf of UMCA, we look forward to an exciting and productive year in 2018.

Michael A Gold, Ph.D.
Research Professor and Interim Director
The Center for Agroforestry at the University of Missouri

In Memoriam



Douglas T. Allen, age 70, passed away November 6, 2017. He is survived by two brothers, Greg Allen and Steve (wife Beverly) Allen, and their families.

Mr. Allen endowed 521 acres of forested land near Laurie, Mo to the Center for Agroforestry. His interest in natural resources conservation, timber management and production of niche agroforestry crops will be realized on multiple levels at the site. His vision for the property is that it becomes a showplace to demonstrate that "man can live in harmony with his environment while successfully providing for his family". He wants rural Missourians to learn how to make extra money off their land and practice good stewardship. A corresponding Allen Endowment Fund will maintain and support the property for agroforestry research.

Awards

Dr. Michael A. Gold, 2017 Association of Temperate Agroforestry Outreach and Education Award.

Dr. Chung-Ho Lin, 2017 Outstanding Research Faculty Award, MU School of Natural Resources.

Jihyun Park, 1st place NAAC 2017 poster presentation award, 15th annual competition.

Danh C. Vu, 2017, Ozark-Prairie Regional Chapter of the Society of Environmental Toxicology & Chemistry Poster Presentation Competition, 2nd place.

Drs. Anna Ball, Michael Gold, Hank Stelzer; Hannah Hemmelgarn 2016 Paula Ford Professional Development Program Proposal of the Year.

Dr. Sagar Gupta, 2016, Outstanding Business Generalist Award, MU Crosby MBA Program.

Dr. Sagar Gupta, 2016, The Best & Brightest MBAs, Poets and Quants Class of 2016.

Dr. Michael Gold receives Outreach and Education Award at the annual Association of Temperate Agroforestry conference in Blacksburg, Virginia

Dr. Chung-Ho receiving Outstanding Research Faculty Award from SNR Director, Dr. Shibu Jose and Dr. Anthony Lupo, Chair of the Director's Faculty Council.

THE MAIN PRACTICES OF

Agroforestry

Windbreaks

Windbreaks are planned and managed as part of a crop and/or livestock operation. Field windbreaks protect a variety of wind-sensitive crops; enhance production and conservation; control wind erosion; and increase bee pollination and limit spray drift of pesticides. Livestock windbreaks help reduce animal stress and mortality; reduce feed consumption; and help reduce visual impacts and odors. Windbreaks also may provide excellent wildlife habitat.

Forest Farming and Urban Food Forests

In forest farming, high-value specialty crops are grown under the protection of a forest canopy modified to provide the correct shade level. Crops such as ginseng, truffles, shiitake mushrooms and decorative plants are sold for medicinal, culinary and ornamental uses. Forest farming provides short-term income while high quality trees are grown for timber or wood products will provide more long-term income. An urban food forest integrates perennial nut and fruit-producing trees and shrubs with herbs, vines and ground flora that produce fruits, vegetables, and edible greens and roots, to achieve a self-sustaining, food-producing ecosystem. Urban communities are increasingly taking up the practice as a way to put underutilized city land to work and combine urban agriculture goals with goals for open space, recreation, and community development.

Silvopasture

Silvopasture is the intentional combination of trees, forage and livestock managed as a single integrated practice. In a typical silvopasture practice, perennial grasses and/or grass/legume mixes are planted between rows of widely spaced trees for livestock pasture. The trees not only provide a long-term investment with nut crops or a timber harvest, but also provide animals shade in the summer and a windbreak in the winter. In turn, the forage base provides feed for cattle, and other livestock. A silvopasture practice diversifies farm income; can minimize the need for vegetation control; and can reduce hay and feeding costs for livestock and improve animal health.

Alley Cropping

Alley cropping is planting rows of trees at wide spacings while a companion crop grows in the alleyways between the rows. Alley cropping can diversify farm income, improve crop production, and provide protection and conservation benefits to crops. Common examples of alley cropping plantings include pumpkins, hay, berry bushes, wheat, corn, or soybeans planted in between rows of chestnuts, black walnut or pecan trees. Trees selected for alley cropping may include valuable hardwood species, such as nut or fruit trees, or trees desirable for wood products.

Riparian Forest & Upland Buffers

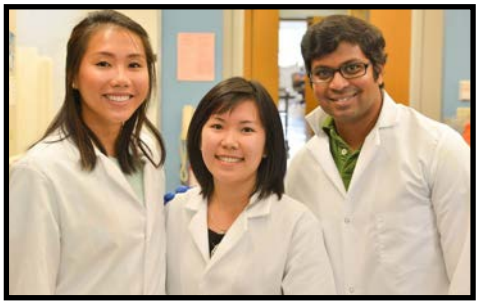
Riparian forest and upland buffers are living filters comprising trees, shrubs, forb and grasses, including native plants. They enhance filtration of nutrients from surface runoff and shallow groundwater. These excess nutrients are utilized for plant growth. Riparian forest and upland buffers protect the water quality of streams and lakes and are an effective tool for controlling erosion and providing food and cover for wildlife. Decorative woody florals, nuts and berries planted in the shrub zone can provide additional income.

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/Phyto remediation

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.



Minh Ma, Hien Huynh, Sagar Gupta, decode science page 36. Photo~Phillip Sitter, MU Journalism graduate.

Socio-economic-marketing

The cluster's integrated approach works to understand the social and economic dimensions of a given enterprise, including institutions, networks, market 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 all researchers involved in pecan, black walnut and chestnut research (with consideration to additional nut species in the future). Foci for all nut species include field studies, market 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 #1 best value online EnviroScience MS program.

Outreach

The outreach program is focused on five diverse areas of Missouri 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. Includes an annual week-long Agroforestry Academy targeted to natural resource professionals, landowners and military veterans; annual Agroforestry High School Institute educators to teach agroforestry in the agriculture science curriculum; the annual Missouri Chestnut Roast, the Center's premier annual outreach event; numerous short-term trainings on all facets of agroforestry and specialty crops throughout the year. Socio-economic-market research is designed to mesh closely with outreach programming.

Phytochemistry/Medicinal

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. Additionally bioremediation studies are conducted on a wide range of agricultural chemicals, pharmaceuticals and personal care products.

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).

PARTNERSHIPS

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. We are a Center for both entrepreneurship and the environment through the practices of agroforestry.

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
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 Devlpmnt & 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; University of Missouri Extension

External University Collaborations

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 Minnesota, University of Notre Dame, University of Tennessee

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 Forestry Research Advisory Council
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.
Etimine USA
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
Monarch Media
MS-Omics
National Aviary
Nutrapetsystems, LLC
Roeslein Alternative Energy, St. Louis
Savanna Institute
Thar, Inc.
Tiger Energy Solutions, LLC

Donors and Friends

AgriGro
Caribbean Probiotics, LLC
Doug Allen
Barnes & Associates
Bartimus Frickleton Robertson & Goza
Kelly Foods Corp.
NutraPet Systems, LLC
Proviera Biotech
SCD Probiotics

Landowner Collaborations

Penny Clark, Goods from the Woods
Terry Durham, Eridu Farm
Greg and Jan Judy, Green Pastures Farm
Nicole McPherson, Ozark Forrest Mushrooms
Josh and Larin Payne, Payne Farms, Inc.
Dan and Jan Shepherd, Shepherd Farms
Shryocks Callaway Farms
Bill and Sue Ellen Stouffer, Cedar Hill Farm

International Collaborations

Abdul Wali Khan University, Pakistan
Center for International Forestry Research
Gadja Mada University, Yogyakarka, Indonesia
Inner Mongolia Agriculture University, China
Institute Pertanian Bogor, Indonesia
International Crops Research Institute for the Semi-Arid Tropics, India (ICRISAT)
French National Institute for Agricultural Research-France
Institute of Technology of Buenos Aires, Argentina
Moscow State University, Russia
NATO – Science for Peace and Security Program
National Biodiversity Institute (INBio) Costa Rica
Quad-i-Azam University, Pakistan
University of Abomey Calavi, Benin
University of Costa Rica
University of Pretoria, South Africa
World Agroforestry Centre, Nairobi, Kenya
National Sun Yat-sen University, Kaohsiung, Taiwan

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Kevin Whetstone
Bennett E. Wickenhauser
Niranga Wickramarathne, Graduate Thesis
Donald Whittaker, Graduate Certificate

Agroforestry: Online master's degree

- Master of science in natural resources with an emphasis in agroforestry (MS).
- Online master's in agroforestry is 100 percent online: no campus visits required.
- Students with full time jobs typically take one class each semester and finish the program in about three years. Students who take two classes each semester typically finish the program in two years.
- Course work covers
  - Principles of agroforestry
  - Agroforestry economics and policy
  - Watershed restoration
  - Soil fertility and plant nutrition
  - Natural resource policy & administration
- In-state tuition rates: as a distance learner in a University of Missouri graduate program, you qualify for in-state tuition rates, regardless of where you live.
- For more information:
  MizzouOnline@missouri.edu
  1-800-609-3727

Medicinal Plants in Agroforestry
Forest farming with non-timber forest products

In the US, the term "forest farming" describes the cultivation of crop species beneath a sustainably managed forest overstory. Many non-timber forest product (NTFP) species are medicinal plants with high market values (e.g., ginseng-*Panax quinquefolius*). Due to over-harvest in the wild, region-specific techniques for efficiently cultivating these species to meet market demand may aid in these species' conservation, as well as profitability to the harvester.

Proper conditions of light and soil fertility are key for successful NTFP forest farming in Missouri. In 2016 and 2017, Badger Johnson, agroforestry MS (2017), studied the effects of several aspects of site quality and treatments on growth of important medicinal and culinary NTFPs for forest farming applications in Missouri. Forest farming trials of four species of economic interest: wild ramps (*Allium tricoccum)*, black cohosh (*Actaea racemose)*, goldenseal (*Hydrastis canadensis*) and stone root (*Colinsonia canadensis*) were established at HARC in New Franklin, MO and the Doug Allen Project Site (DAPS) in Laurie, MO. A total of 16 plots were established, four in small canopy gaps and four under the natural forest canopy at each site.

Ginseng is a profitable plant for forest farming. Here Badger Johnson shows the size of a healthy plant.

Small canopy gaps created by uneven-age management silviculture are common in hardwood forests of Missouri. The relationships between canopy gaps and commercially-harvested forest herbs are not well understood. A total of 1,280 rootstocks of 4 medicinally important species (*Actaea racemosa* L., *Allium tricoccum* Aiton, *Collinsonia canadensis* L. and *Hydrastis canadensis* L.) were planted in small canopy gaps and under closed canopy (as a control), and replicated at two sites. **Results**: Positive correlations were found between canopy gap treatment and mean mature height of *A. racemosa, A. tricoccum* and *C. canadensis*, with flowering of *A. racemosa*, as well as with mortality of all species.

Integrating silvicultural systems with forest farming could result in profitable over-yielding. Relationships were explored between percent cover and plot occupancy of native non-timber forest product (NTFP) herbs with timber harvest type and ecosystem site description. Study species were *Actaea racemosa* L., *Apocynum cannabinum* L., *Aristolochia serpentaria* L., *Dioscorea quaternata* J.F. Gmel., *Echinacea simulata* R.L. McGregor, *Geranium maculatum* L., *Hydrastis canadensis* L., *Parthenium integrifolium* L., *Podophyllum peltatum* L., *Sanguinaria canadensis* L. or *Tephrosia virginiana* (L.) Pers. **Results**: Percent cover of the specified species and plot occupancy had significant relationships with certain ecological site descriptions. Results indicate that ecological site descriptions can be used in conjunction with silvicultural management to select and manage sites for forest farming.

Prescribed fire may lead to increases in size and abundance of woodland perennial herbs. This aspect of the study evaluated relationships between landscape-scale prescribed fire with percent cover and plot occupancy of eight herbaceous, non-timber forest product species: *Actaea racemosa* L., *Apocynum cannabinum* L. , *Aristolochia serpentaria* L., *Dioscorea quaternata* J. F. Gmel., *Geranium maculatum* L., *Parthenium integrifolium* L., *Sanguinaria canadensis* L. and *Tephrosia virginiana* (L.) Pers. **Results**: Percent cover and plot occupancy of some herb species were significantly related to the number of fires and/or time since beginning the experiment, as well as to particular ecological site types. For instance, a generalized positive trend in *Parthenium integrifolium* size was observed, a trend that was significantly pronounced on the "Chert Dolomite Exposed Backslope Woodland" site type, despite the negative relationship between this species' size and the number of fires, overall. These results may be used to identify forest farming sites and to tailor burn plans to stimulate growth of these species.

Establishing a forest food plot.

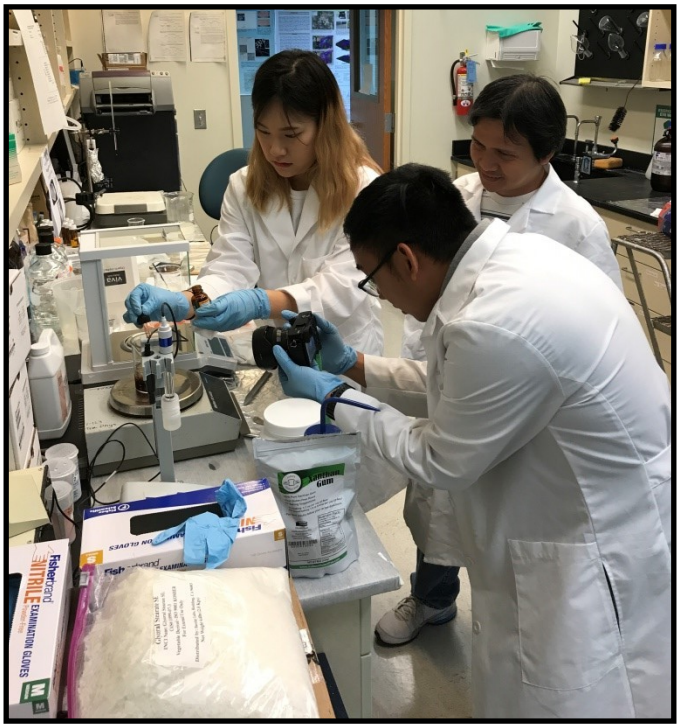
Bioremediation and Phytochemistry in Agroforestry

Under the direction of Dr. Chung Ho Lin, UMCA has developed a comprehensive Bioremediation and Phytochemistry Research Program. Dr. Lin leads a team of 18 staff, graduate students and post-doctoral scientists, working with over 25 collaborating faculty from a range of disciplines across the MU campus and multiple external public and private sector partners from across the USA and internationally. During 2016-2017, efforts were focused on reprioritizing research projects in the areas of analytical chemistry, molecular biology, metabolomics, proteomics and bioinformatics. The program has three major components: 1) advancing biological techniques for remediation of environmental contamination; 2) exploration and discovery of useful plant based compounds with potential for use in natural products in the pharmaceutical, cosmetic and other industries; and, 3) translating benchtop discoveries into commercial applications.

Bioremediation

Ongoing projects are exploring the removal of pharmaceuticals and personal care products (PPCPs) in municipal wastewater through engineered constructed wetlands and developing bio-remediation technologies using pollutant degraders (e.g., Pseudomonas putida and poplar trees) for restoring sites contaminated with hydraulic fracturing chemicals used in natural gas and oil extraction. The team has also developed novel spore-based biocatalyst systems for bioremediation and other agricultural and industrial applications. Results suggest that engineered constructed wetlands could successfully remove up to 95% of the 56 PPCPs found in the municipal wastewater, while novel spore -based biocatalyst systems could remove >90% of herbicide atrazine and explosive TNT in contaminated soils and water within 72 hours.

Working with scientists from MU Civil and Environmental Engineering and the Instituto Tecnológico de Buenos Aires in Argentina, Dr. Lin's team has made advances in elucidating the degradation pathway and kinetics for treatment of water contaminated with 2,4-D using solar photolysis and solar photo-Fenton-like treatment process, successfully identifying the degradation intermediates and degradation products.
Dr. Lin's team are also examining the relationship between chemical exposure and children's health and learning, by assessing environmental toxins in indoor air samples collected at several children's centers in Kansas City. Data collection is ongoing and also includes collection of samples at children's residences and information on use of use of personal products from participating parents. Among the 150 monitored volatile organic compounds (VOCs), the team has detected and quantified 66 VOCs in samples from the selected classrooms. Preliminary correlation analyses demonstrated significant negative links between personal care products and social behaviors and between home products and aggressive behavior.



From left to right, Dr. Chung-Ho Lin's students: Jihyun Park, Dahn C. Vu, Novianus Efrat at work in the agroforestry lab.

Natural products

Dr. Lin's team is exploring the utilization of plants and bacteria for the development of the bio-economy, seeking to identify bioactive compounds in low-value plant materials and their immediate applications for cosmetic, personal care products, and nutraceutical industries (e.g., anti-oxidant, anti-inflammatory, skin-whiting, and anti-aging). The findings from these projects will provide opportunities to turn abundant, low-value, renewable materials into a lucrative industry, helping to foster new economic development for the citizens of Missouri.

Work is ongoing to isolate and characterize a number of health promoting compounds (bioactive phytosterols, phytophenolics, and other secondary metabolites) from black walnuts (*Juglans nigra*) using targeted and untargeted global metabolomics approach (XCMS) and performing an array of bioassays (e.g., anti-inflammatory and antioxidant). Numerous health pro-

moting compounds were isolated from black walnut, and with significant differences in profiles between the 11 different cultivars studied. Another study on the chemical profiles of spent coffee grounds successfully isolated ~200 polyphenols, indicating that spent coffee grounds could be an excellent source of high value phytochemicals for use as raw materials in the cosmetics industry. Altogether, from these research efforts using the modern metabolomics and high throughput screening approaches, more than 250 health-promoting compounds (e.g. antimicrobial, anti -oxidant, anti-inflammatory, skin-whiting, and anti-aging) were identified in black walnuts, spent coffee grounds, Osage orange, switchgrass biofuel feedstock byproducts and other low value or waste plant materials.

Commercialization

The goal is to translate laboratory benchtop discoveries into real world commercial applications that could benefit the wellbeing of the general public. Dr. Lin and his team have successfully translated many of their inventions to industry, including start-ups like Tiger Energy Solutions LLC and Elemental Enzymes LLC., and established industrial players like Bayer. During 2015-2017, four patents were granted by the United States Patent and Trademark Office and 5 invention disclosures have been submitted. Spin-off start-ups from these translational research projects have created more than 30 full-time positions for scientists and professionals and have generated significant future revenue for MU through technology licensing. Elemental Enzymes Inc., originating in the MU Business Incubator, established its headquarters in St. Louis in 2015, including a 26,000 ft2 building and currently has more than 2,500 ongoing field trials in the US and worldwide.

Of special note: the team has developed a novel continuous-flow enzymatic bioreactor system for production of advanced biofuels (converting cellulose into fermentable sugars in the saccharification process), specialty chemicals and for blood type conversion (type A blood cells to type O universal blood cells). For the latter application, the invention received the FastTrack Pitch Competition Award ($50,000), sponsored by the UM Office of Academic Affairs, Research and Economic Development.

MU scientists are currently working with international collaborators on transferring the developed spore-based biocatalyst technologies to a pilot remediation project at the An-Shun sites (Taiwan), heavily contaminated with dioxins (570,000 tons of contaminated soils). Adoption of this novel remediation technology at other polluted sites along the Asian-Pacific Rim is anticipated.

By integrating research strengths and resources in some of the key technical areas mentioned above, UMCA has successfully developed relationships with a number of industry partners and is able to provide a range of services across the bioenergy, biomedical, and environmental research domains. Some of the major services provided include 1) reverse engineering and deformulation, 2) determination of hydrophilic-lipophilic balance values for biosurfactant and biodetergents, 3) establishment of a tanning laboratory at CAFNR to provide service for the industry, 4) development of an environmentally friendly production process to recover value-added byproducts in-process, 5) analytical services and consulting for public and private sectors, 6) analysis of high value natural products, 7) analysis of plant regulating hormones, 8) development of the biocatalysts for biofuel industry, and 9) assessment of persistence / composition of probiotic products in gastrointestinal tract/intestines using a next-generation sequencing approach. The overall aim of the effort is to transform the program into a self-sustaining and integrated program that offers research, training and service for agricultural, bioenergy, biomedical, and environmental research for both the public and private sectors.

Patents & Trademarks

Multi-Enzyme Platform Production of Specialty Chemicals, Biofuels, and Blood Type Conversion. Chung-Ho Lin, Hsin-Yeh Hsieh, George Stewart, Mason Schellenberg, Sagar Gupta, Shibu Jose, Ronald Wood and Kattesh V. Katti 2017 (Patent Submitted 2017)

A novel computer implemented 3D printing method for platforms for enzyme immobilization. Mason Schellenberg, Hsin-Yeh Hsieh, Chung-Ho Lin, Shibu Jose, Ronald Wood 2017 (Invention Disclosure Submitted 2017)

Watershed study shows that cover crops improve soil health, environmental quality and farm productivity in Missouri; demonstration site encourages cover crop adoption.

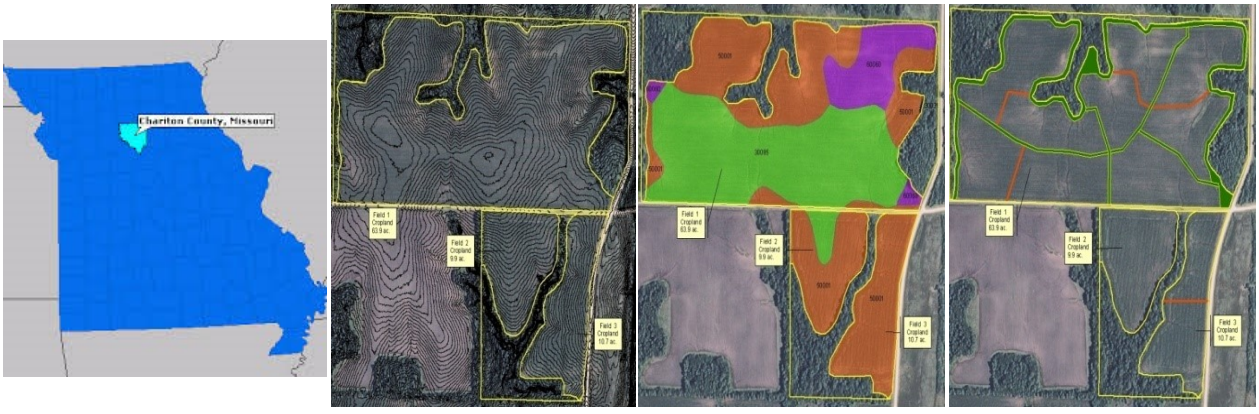
Cover crops in commodity row-crop rotations have been shown to improve water quality, soil quality, land productivity and farm economics. There is evidence that cover crops can reduce the amount of agricultural nutrients leaving farm fields and it is believed that more widespread use of cover crops would support reduction of hypoxia in the Gulf of Mexico. Despite these benefits more widespread adoption of cover crops is needed including among Missouri farmers. This may be due to lack of cover crop research and demonstrations in Missouri. Dr. Ranjith Udawatta is leading an effort to quantify water and soil quality benefits of cover crops in corn-soybean rotations in Missouri. The Missouri Department of Natural Resources is providing financial support for the project.

The project involves eight small watersheds where water, soil, land productivity, and economic benefits of cover crops are being monitored and quantified (Fig. 1). The research team consists of farmers, university faculty, and federal and state agency personnel who have worked together to ensure the success of the project.

Monitoring results indicate significant reductions in runoff volume, sediment, and nutrient losses from corn-soybean watersheds in northern Missouri compared to watersheds without cover crops. Cover crops increased soil organic matter in the top 15 cm of soil from 2013 to 2016 (Fig. 2). Phospholipid fatty acid (PLFA) concentrations were significantly greater with continuous ground cover as compared to exposed soils. Greater PLFA is an indication of diverse soil microbial communities that help promote efficient nutrient cycling, degradation of chemicals, and carbon sequestration. Land productivity increased on watershed with cover crops.

The study also showed improvements in crop yields in 2014 following a cover crop. However, weather conditions in Missouri are variable and both droughts and floods were observed during the study. In 2012 because of drought and in 2015 because of excess soil moisture planting was limited and where planting was done, plants were severely stressed. Thus, the study had only one year out of three where plant growth and development could be compared. This highlights the need for additional studies to acquire more years of information to better quantify the benefits of cover crops on crop yields.

Economic analyses indicate that cover crops can increase land productivity and farm economics of lands under wheat-corn-soybean rotation. Net income was shown to increase after three years of cover crop management on wheat-corn-soybean rotations. Yields were increased by 10% on the fields with cover crops compared to those without cover crops. While the use of cover crops added about



(a) (b) (c) (d)

Fig. 1. Maps showing: (a) Approximate location of the Chariton County Soil Health Conservation Farm in Chariton County, Missouri, (b) One-ft. interval contour lines of the farm, (c) Major soil distribution (Armstrong loam, Grundy silt loam, and Bevier silty clay loam) and (d) 8 demonstration watersheds to evaluate soil health, water quality, and production benefits.

Soil Health

Figure 2. Changes in soil organic matter (OM) percentage for 0-15 cm soil depth from 2013 to 2016 at the Cover Crop Soil Health Farm Chariton County. (left, no cover crop; right, with cover crop) The north section (rectangular) received cover crop treatments from 2012 and south (triangular) section was the control (no cover crop corn soybean rotation).

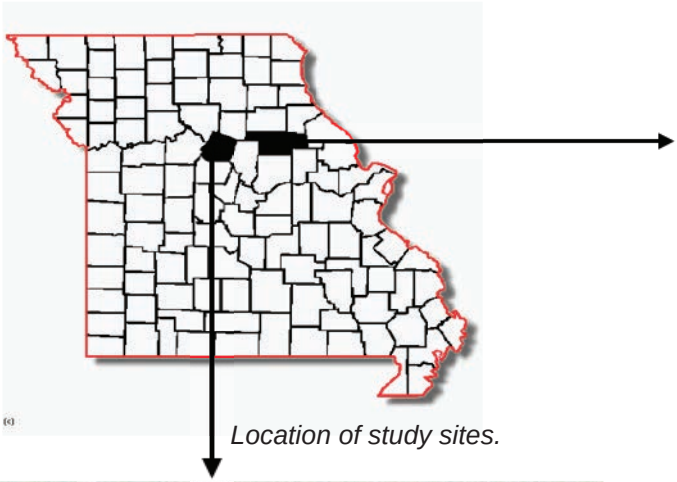
$100 per acre additional cost, the additional yield from cover crops offset this additional cost. Cover crop costs decreased in 2015 by 6% while the yields on the fields with cover crops were ~10% higher than the fields without the cover crops.

The second major goal of the project is increased adoption of cover crops. A demonstration was established at the Chariton County Soil Health Conservation Farm in Chariton County, Missouri to exhibit ecosystem benefits of cover crops. Results of the watershed study have been disseminated at field days at the demonstration farm and through peer-reviewed journal publications, conference abstracts, poster presentations, a graduate thesis, workshops, seminars, websites, and popular magazine articles. As a result of outreach efforts, 50 farmers in Chariton County have adopted cover crops in theirs farms, comprising 1584 acres in cover crops.

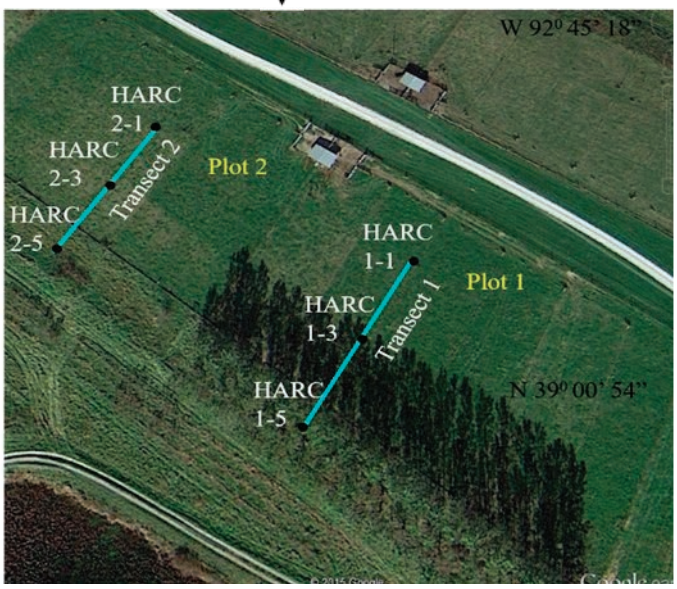
Understanding the difference between claypan and loess watersheds; Hydrologic regime and nitrogen cycling

Groundwater is an important resource for public drinking water supply in the U.S. Nitrogen (N) and phosphorus (P) pollution of water resources has been a major problem for years, causing contamination of drinking water supplies, harmful effects on aquatic life, and contributing to formation of the hypoxic zone in the Gulf of Mexico. Contamination of groundwater by nitrate (NO_3^--N) is of particular concern because elevated concentrations can affect human health. Agricultural runoff containing these nutrients has been shown to contribute to these water quality challenges.

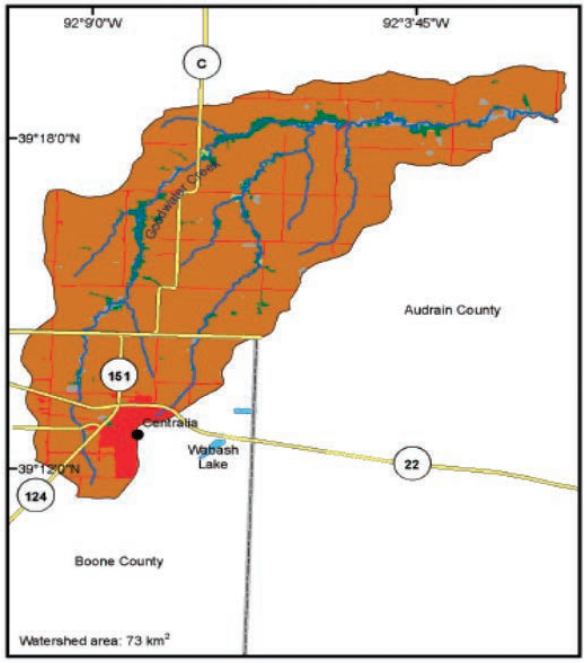
Best management practices aimed at reducing agricultural runoff and the amount of nutrients in runoff may improve water quality and reduce the negative impacts of agrochemical contamination. It is thought, though, that hydrologic regimes and contaminant sources may affect the success of proposed management strategies. However, knowledge of interactions between best management practices and specific hydrologic regimes at watershed scales in lacking. A study by UMCA researchers aim to understand how the hydrologic regime effects the fate and transport of agricultural nutrients and other chemicals. It is imperative to identify specific sources and transport mechanisms in various water bodies and soil types. The study focuses on interactions between hydrologic regime with N and P cycling in two contrasting soils in Missouri, specifically claypan and deep loess soils, and in two contrasting agricultural land uses, specifically row crop and pasture. Additionally, the study is examining the effect of slope and buffer zones on nu-



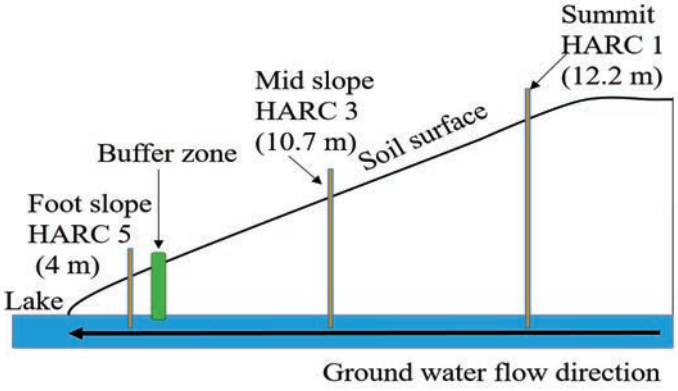
Location of study sites.



HARC study site with loess soils and livestock.



GCEW study site with claypan soils and annual row crops.



Groundwater monitoring wells at HARC.

trient concentrations in groundwater.

Two study sites were selected for the experiment representing claypan soils developed in glacial till and Loess soils. The deep loess soil site is located at MU's Horticulture and Agroforestry Research Center (HARC) within the Sulfur Creek watershed. The claypan soil site is located within the Goodwater Creek Experimental Watershed (GCEW). Cattle grazing/pasture is the land use/land cover at the HARC site, while annual row crop is the land use/land cover at the GCEW site. Groundwater samples are being collected weekly at both study sites to characterize interflow and groundwater chemistry under agricultural land use. Soil samples were extracted at HARC during drilling of the groundwater monitoring wells. These samples will be analyzed for various metrics of soil chemistry and physical properties. Soil samples from the GCEW site have been already analyzed.

Time series analysis of nutrient concentrations and precipitation data at the two watershed sites have been completed. Results indicate there is a considerable amount of NO_3^-–N in all monitoring wells. However, the concentration of NO_3^-–N in the wells at the summit and the mid slope at HARC are comparatively higher than the other two wells located beyond a riparian buffer at the foot of the slope. Total nitrogen concentration also shows the same pattern within the HARC wells. The concentration of NO_3^-–N and total nitrogen at the GCEW is comparatively higher than the concentration found in HARC site, demonstrating that the concentration of these nutrients is greater within groundwater of claypan crop land compared to deep loess cattle grazed land with a buffer zone.

Can manure improve soil health?

Is there a correlation between soil health (or soil productivity) and manure? A University of Missouri team involving Teng Lim and Allen Haipeng Wang from Food Systems and Bioengineering; Donna Brandt, Saranya Norkaew, and Randy Miles from Soil Health Assessment Center, analyzed many soil health related variables and manure land application details, based on data collected under the Missouri Cover Crop Cost-Share Program and experimental plots. On a state-level, no significant difference was found between the fields with and without manure application for most of the variables collected, except for phosphorus. The lack of correlation is mostly likely because only a small portion of the statewide samples were associated with manure land application, and the samples were highly variable in tillage, soil type or series, crop, and manure type, application rate and methods, and lack of consistent, multi-year data from similar fields.

However, narrowing down to county level, manure applications increased active carbon contents for two of the top three counties where manure application data was collected. The manure application significantly increased organic carbon, phosphorus, potentially mineralizable nitrogen, and water stable aggregate values for the third county. In order to better examine the effects of manure land application, data collected from experimental field plots with consistent tillage, and repeated crop and fertilizer treatments was analyzed. The manure application has clearly resulted in higher soil organic carbon, active carbon, phosphorus, and water stable aggregates, and lower bulk density.

Why Are These Important?

These findings confirm that the benefits of manure application to soil health, but also increase the phosphorus level. The findings regarding manure use and

Manure applied in a corn field using a drag-hose system.

important soil health indicators provide important information for stakeholders. Considering measurable economic and environmental impacts, especially for increasing the carbon content in the crop fields, manure land application can be a recommended practice.

The more uniform soil series and repeated experimental field plots provide a more controlled and homogenous comparison for the research of manure land application. The experimental field plot data agreed with the within-county comparisons, that the manure application was able to affect many of the soil health indicators, such as organic carbon contents. Manure application has shown to reduce the overall soil bulk density, which is important for the soil aeration, and ability to provide water to plants.

What are the soil health indicators?

Variables	What they mean and importance
Total organic carbon and active carbon	Organic contents has been shown to affect biological, chemical, and physical soil properties.
Bray 1 phosphorus	An estimate of available P levels for plants. Too much phosphorus can cause plant nutrient imbalances, and more importantly, contribute to high nutrient loss and potential environmental issues.
Potentially mineralizable nitrogen	A measure of soil biological activity and efficiency. Too much nitrogen in the soil can also mean high losses.
Bulk density	Indicator of soil compaction and the soil functions of regulating water, producing biomass, and providing support for plants and structures.
Water stable aggregate	Indicator of how soil particles bound together that resist breaking apart, even during wet soil conditions. It may be an indicator of soil water functions such as infiltration.

Water Quality

Recent data indicates that Missouri ranks 6th and 7th in cow-calf and hog operations respectively. Missouri is the 6th largest soybean and the 9th largest corn producer in the US (Missouri Agricultural Statistics 2016 Annual Bulletin). The large number of farms and agriculture activities are important for Missouri's economy, and the sustainability of large numbers of rural farms depends on best management practices that meet production goals, economic returns, and environmental services.

Center for Agroforestry research addresses landowners and agency personnel information needs on how to improve water quality and soil quality while protecting the environment and improving land productivity.

Corn-soybean watersheds located in five counties are monitored and water samples are collected after each runoff event. These watersheds represent multiple conservation practices including riparian buffers, grass waterways, cover crops, terraces, crop rotation, and nutrient management. Preliminary results show that conservation practices were effective in reducing non-point source pollution, and significantly influence soil water use compared to row crop areas, particularly for eroded claypan landscapes within these watersheds.

Biomass production systems as well as agroforestry and grass buffers have also been found to improve soil hydraulic properties and water quality relative to row crop management for temperate regions. Although claypan soil is dominant in northeastern Missouri, this study showed that biomass crops as well as agroforestry and grass buffer practices improve soil hydraulic properties relative to row crop management; they also have valuable economic and environmental benefits.

The research projects highlighted above attempt to address water quality issues by quantifying beneficial effects of agroforestry, other conservation practices including cover crops, land management, and crop management on the environment and land productivity. These studies also explain processes for integration of these practices into farming practices.

These projects were developed to quantify conservation effects on soil quality, water quality, and land productivity. The results can be used to develop management plans that can improve the environment, land productivity, and economic returns. Results can also be used to improve funding opportunities and policy development.

Dr. Ranjith Udawatta at the field day

Water monitoring system (by trees on the left, to evaluate water quality benefits of riparian buffers in an upland cattle grazing system.

Water sampling system used to collect water from run-off.

Biomass/biofuels

Experiment investigates effects of plant diversity, harvest and manure application on native prairie feedstock for biogas production.

Interest in production of non-woody native perennial plants as feedstock for bioenergy stems from potential profits and sustainability advantages compared to annual row crop production on marginal lands. Growing diverse mixtures of native prairie plants has the potential to prevent soil erosion, retain soil nutrients, improve water quality, sequester atmospheric carbon, provide critical wildlife habitat, and provide farm income. Individual prairie species, such as switchgrass (*Panicum virgatum*), and combinations of native grasses, forbs and legumes are already being used as commercial-scale feedstock for combustion to produce heat, power and steam. Anaerobic digestion (AD) is also a commercially feasible conversion method for turning prairie plants into renewable energy and biochemicals.

Biogas refining processes are supported by robust science. However, little is known about use of native prairie plants as managed cropping systems for maximizing biogas potential and ecosystem services at the same time. If commercial AD and biogas are to make significant contributions to national renewable energy goals, land owner productivity goals, rural economic development and agricultural sustainability goals, it is essential to understand how prairie plant mixtures and their management may effect biomass yields, biogas potential, and ecosystem services. Therefore, UMCA researchers have initiated an experiment as a first step towards this understanding.

In 2016, Dr. Carol Williams installed 108 biomass plots at the Bradford Research Center near Columbia, MO, using more than 12,000 plant seedlings. The experiment consists of six plant treatments: fescue monoculture (the experimental "control"), switchgrass monoculture, a "low-diversity" prairie mix (9 species; two grasses, six forbs, one legume), a "high-diversity" prairie mix (18 species; four grasses, 12 forbs and two legumes), a "moderate" mix (12 species; three grasses, seven forbs and two legumes), and fallow. The low- and high-diversity mixes contain switchgrass and other native grass species that are known to be aggressive growers that provide a large proportion of biomass but over time can displace native forbs and legumes. Therefore, the moderate-diversity mix contains less aggressive grasses to potentially reduce loss of forbs and legumes over time. The low-diversity mix is a modification of CRP CP2 mix, where the total number of species has been reduced from 12 to nine. The "feasible high diversity" mix was selected by a consortium of subject matter experts.

Grid used for plantings.

The experiment involves three harvest levels: no harvest, annual harvest (after senescence) and green harvest every third year (any time after July 15, according to grassland bird protection protocols). There will be two swine manure treatment levels: none and an average rate used by swine operations in the pork producing area of northern Missouri. Swine manure will be surface applied once annually, likely in spring.

~ continued on next page

Planting in grid formation.

~ *continued from page 17*

Observations will be made annually on plant species composition, above-ground biomass, below-ground biomass, soil carbon, soil moisture, soil microbial community, soil nutrient cycling, biogas potential, occurrence of invertebrates, and the fate of various compounds present in manure. Chemical and physical characteristics of each plant species and each plant mixture will be evaluated annually.

Findings from the experiment are expected to help Missouri landowners and industry make informed decisions regarding long-term agricultural productivity, energy productivity and sustainability performance (e.g., soil health and carbon balance) of biomass production systems involving native perennial herbaceous plant species. It is also anticipated that results will provide an understanding of nutrient cycling (N and P) and thus inform decision-making regarding nutrient management in dedicated biomass production systems.

Nitrogen and harvest impact on biomass yield and bioenergy quality of warm-season grasses

Perennial warm-season grasses including switchgrass (*Panicum virgatum L.*), big bluestem (*Andropogon geradii Vitman*), and Indiangrass (*Sorghastrum nutans L.*) have drawn interest as bioenergy feedstocks due to the high yielding capacity with minimal amounts of inputs under a wide range of geography, and the capability to produce multiple environmental benefits. Nitrogen (N) fertility and harvest timing are considered as critical management practices when optimizing the biomass yield and the feedstock quality of these grasses. The objective of this investigation was to quantify the impact of N fertilizer rate, N timing and harvest date on dry matter yield and bioenergy quality of warm season bioenergy grasses. Research was conducted in 2014 and 2015 in nine sites at four locations found in central and west-central Missouri.

Nitrogen fertility and harvest timing management strategies impacted warm season grass biomass yield and bioenergy quality parameters individually and in interactions. Dry matter yield of warm-season grasses

Collecting samples from the field.

increased with increasing N for eight of nine sites, and reached a plateau after 34 kg N ha-1 (30 lbs. N per acre) or 67 kg ha-1 (60 lbs. N per acre). Although higher N rates caused yield increases productivity and agronomic efficiency of applied N tended to decrease with increasing N supply. However, supplementation of N at 67 kg ha-1 (60 lbs. N per acre) per growing season provides an opportunity to maintain a balance between both yield and efficiency of N fertilizer inputs. Therefore, it is important to take both dry matter yield and N use metrics such as productivity and agronomic efficiency, in to account when producing these biomass grass species on a commercial scale in order to achieve economic and environmental sustainability of the system.

Single late harvest after a killing frost (November) resulted in better quality grass biomass under each N management and site conditions. In short, the biomass harvested late in the growing season had higher values of favorable quality characteristics including energy contents, cell wall constituents, and ethanol yield parameters. At the same time, late harvested biomass exhibited lower biomass N and ash contents which can negatively affect sustainability and longevity of biomass production and biomass energy conversion systems. Among harvest frequency practices, both single harvest (in November) and double harvests (first harvest in June and the second in November) per growing season, in combination with annual N inputs which are equal or greater than 67 kg ha-1 (60 lbs. per acre) gave higher energy yield and ethanol production per unit area of land.

Simultaneous consideration of N and harvest management practices and their impacts on both the quantity and quality of biomass in this research study helped in acquiring valuable data. Therefore, conducting similar studies in the long run while studying the effects of spatial and temporal variations in environmental, weather, and site conditions will provide an opportunity to generate data that can be used in life cycle accounting studies to determine the overall sustainability of feedstock production systems for future bioenergy economies.

Biomass research

Biomass research led by Dr. Sougata Bardhan and Dr. Shibu Jose addresses topics ranging from flood tolerance and cultivar success, to bioenergy and soil conservation. Bardhan and Dr. Shibu Jose, as part of a US -India Research Consortium, have been investigating three components of biomass feedstock production ecology, described below: Flood tolerance of sorghum cultivars developed as biomass feedstocks; 'Show-Me' switchgrass cultivar evaluation; establishing biomass alley cropping in a floodplain.

Flood tolerance of sorghum cultivars developed as biomass feedstocks

This project was developed to identify and develop flood tolerant sorghum cultivars for deployment in marginal land for biomass production systems. Based on the initial screening of 243 sorghum cultivars in 2014 and 2015, six flood tolerant and six flood sensitive cultivars were identified. The F1 progeny generated from crosses between flood-tolerant and flood-sensitive sorghum genotypes were self-pollinated in Puerto Rico and the resulting F2 seed were further developed at Florida. Ninety sorghum mapping population was tested for flood tolerance in the flood laboratory at HARC, New Franklin.

Flooding was imposed on 6 week old seedlings for 2 weeks and the biomass, plant height, and presence of air pockets in stem was quantified. The data is being analyzed.

'Show-Me' switchgrass cultivar evaluation

Switchgrass has shown promise as an economical and efficient source of cellulosic biofuel. The objective of this project was to develop a switchgrass cultivar which is locally adapted for use as a biomass production cultivar in a wide variety of landscapes. After initial screening, a multi-location cultivar evaluation trial at four locations in a latitudinal gradient from north to south Missouri was established. Observations indicated that the 'ShowMe' switchgrass cultivar performed better than 'Liberty' for the three northern latitudes. However, 'Alamo' and 'Kanlow' performed better than both of these cultivars. The findings suggest that the 'ShowMe' switchgrass cultivar may be better suited for biomass production compared to 'Liberty' for this region. A trademark/license was issued for the release of this cultivar, and Shibu Jose, Sougata Bardhan, and Steve Flick were recognized for their contribution.

Evaluation of sorghum hybrid cultivars developed for flood tolerance in the flood tolerance laboratory.

Establish Biomass Alley Cropping in a River Floodplain

Alley cropping systems consisting of perennial woody and herbaceous species has been suggested as an alternative biofuel production systems in river floodplains. Recent studies have reported that marginal lands in the Midwestern United States have the potential to produce up to 6 billion gallons of renewable biofuels each year. In this study, we evaluated the establishment of a large scale biomass alley cropping system in a river floodplain. Cottonwood cuttings that were harvested and stored in the cooler were soaked for 24 hrs. prior to planting. The tree saplings were started in early March in the greenhouse were ready for transplantation by May 1, 2017. We used a skid loader fitted with an auger to drill holes in the ground and planted the Harvey ground with help from a large planting crew.

Cottonwood cuttings for the floodplain started in a greenhouse at HARC. Bags are biodegradable.

Design and Study of Three-Tier Agriculture

International

Ph.D. graduate student Ryan Dibala is conducting research in Panama studying plant interactions in silvopastoral systems. Ryan is collecting data on two experiments: one containing three stratified layers of forage – trees, shrubs, and improved grasses – planted into pastures and another where grasses were seeded into the understory of established timber plantations. Over the past year, data have been collected for tree growth, grass production, grass nutritive content, volumetric soil moisture, and plant moisture stress. Preliminary findings suggest that grass biomass production increased in plots where shrubs are pruned and clippings are used as mulch, a technique commonly known as "chop and drop." When cattle are added to the system, they browse these shrubs, performing an active role in nutrient cycling. Future studies should examine whether grass production in treatments containing shrubs continues to respond positively to shrub alteration due to the effects of cattle browse. Additionally, Ryan is currently examining the biomass and nutritive content of grasses grown under different shade intensities. He hopes to demonstrate that intermediate shade intensities result in negligible losses in production while increasing overall forage quality for cattle.

UMCA Ph.D. graduate student, Ryan Dibala, measures tree height in a silvopasture created by seeding grasses into the understory of an existing plantation.

Collecting volumetric soil moisture data at the silvopasture in Los Asientos, Panama

Domestic

In 2018, Ryan will return to begin collecting data on Red Mulberry seedlings that have been planted in our Cherrybark Oak plantations at HARC. The understory has been seeded in two forage mixes: orchardgrass/crimson clover and orchardgrass/Illinois Bundleflower. Ryan will be examining the growth and production of Red Mulberry shrubs in a gradient of light intensities as a possible alternative forage source for livestock. He is also interested in investigating nitrogen flux dynamics using N15 stable isotope analysis. This research will help elucidate the nitrogen fixing abilities of Illinois Bundleflower, a native perennial legume, while assessing the feasibility of integrating shrubs into temperate silvopastoral systems. The common thread unifying Ryan's tropical and temperate research is the design and assessment of three-tier agriculture, a model that has potential to increase overall production in livestock systems.

SPECIALTY CROPS

Improved storage methods for Chinese chestnuts

Aaron Templemire and Darcy Gordon weigh chestnuts for storage research project.

Chestnut is a promising specialty crop with a growing market and is appropriate for agroforestry systems in Missouri and elsewhere in the Midwest. The native American chestnut (*Castanea dentata*) was devastated by a fungal blight in the first half of the 20th century and was nearly wiped out in the continental US. After many years without significant production of chestnut in America, the blight-resistant Asian chestnuts (*C. mollissima, C. crenata* and hybrids) are now being cultivated in the U.S. However, several generations of Americans have lived without chestnuts and chestnut trees. As a result, much scientific and cultural knowledge about chestnuts preparation and cultivation has been lost. Chinese chestnut varieties offer an important opportunity for a resurgence in chestnut cultivation and consumption in the U.S. For chestnuts to make the jump from a niche market crop back into the culinary mainstream, there is need for basic information and education for growers, distributors, retailers, chefs and consumers alike.

Researchers at UMCA are conducting Chinese chestnut post-harvest project to fill in some information gaps, specifically regarding chestnut storage. By evaluating storage life of some of the most promising and productive Chinese chestnut cultivars for mid-Missouri, and testing the effect of several pre-storage dip treatments on storage life of Chinese chestnuts, the researchers hope to provide producers with information on best practices that will improve their bottom lines.

In the first part of the project, eight Chinese chestnut cultivars are being evaluated for susceptibility to rot during a storage period at standard refrigerator temperature (4° C) and high (99%) humidity. The chestnuts' shell exterior and shell interior and the kernel exterior and kernel interior are being evaluated for rot in two week intervals. Researchers hypothesize that kernel moisture content is related to the incidence of kernel rot. Therefore, weight loss, as a measure of moisture loss, is being evaluated. The results of this experiment should help potential and actual chestnut growers assess which Chinese chestnut cultivars can best meet their storage goals, and should provide realistic storage life information for distributors, retailers, restaurants and consumers. The second part of the study focuses on several potential pre-storage disinfectant dips. The efficacy of high and low concentrations of bleach and StorOx® 2.0 on kernel and shell rot are being evaluated throughout the storage period. Bleach is commonly available and used, but ideal an concentration for Chinese chestnut has not been determined. StorOx® 2.0 is a commercially available product containing peracetic acid and hydrogen peroxide that is used prior to storage. It is currently used on European (C. sativa) chestnuts by a growers' cooperative in Michigan. It has not been used on Chinese chestnut. The results obtained will provide information to chestnut growers and consumers about best post-harvest practices involving disinfectants.

Ernest Hildebrand demonstrates his wood lathe at the annual Missouri Chestnut Roast Festival held at HARC.

Black walnut (Juglans nigra) research and breeding continues

The development of improved black walnuts (*Juglans nigra*) for use in agroforestry practices, such as alley-cropping, has been a component of the Specialty Crops Program within the University of Missouri Center for Agroforestry (UMCA) since 1996. Black walnut is an important native tree species in Missouri. It's prized both for its timber value, as well as being a source of edible nuts that are rich in antioxidants and other nutrients highly beneficial to human health. Significant levels of genetic variation for all nut quality and productivity traits have been observed in Black walnut. This means there is great potential to improve this species for both its nuts and timber through a traditional tree breeding program.

Such a program was initiated by Dr. Mark Coggeshall in 2001. The program focuses on three specific areas: 1) identification of the best adapted and most productive cultivars currently available to landowners in Missouri; 2) development of an applied breeding program that seeks to maximize future nut crop yields - both in terms of quality and quantity, and 3) development of multiple pedigreed populations for use in defining the genetic basis for resistance to emerging pests, especially Thousand Cankers Disease (TCD), a recently recognized disease with potentially significant economic and ecological impacts.

How the program benefits the people of Missouri, and scientific and natural resources communities.
The black walnut breeding program at UMCA is unique because it combines traditional plant breeding techniques, like controlled pollinations, with modern genomics tools to identify genes associated with commercially important traits. These methods are being used to develop new cultivated varieties of black walnut that possess improved nut quality and productivity characteristics. The new cultivars should lead to greater economic returns compared to currently available cultivars. The UMCA collection of black walnut nut cultivars is the largest of its kind and is an important for researchers nationally and internationally.

Dr. Coggeshall has produced two populations of genetically mapped walnut offspring as part of a multi-year research initiative sponsored by the National Science Foundation. Careful evaluation of the genetic variation patterns found within these populations will provide important information on the genetic basis for trait expression in the species. Such traits include those important to researchers interested not in only nut cultivation, but also timber improvement, as well as future threats posed by pests (such as TCD) and adaptations to the future effects of climate change. It is also expected that new investigations will help to document the beneficial effects of consuming black walnuts as part of healthy human diet.

Black walnut ready for harvest at HARC.

The long term goal of UMCA's black walnut genetics research program is to characterize all of the unique DNA sequences of the repository collections to allow for tracking of different versions of sequence records and associated sequence change over time. Another objective is to define the genetic basis for resistance to emerging pests such as TCD. Additionally, the research aims to identify specific cultivars to include as potential parents in an applied breeding program. The applied breeding portion of the program aims to intended to develop new cultivated varieties of black walnut that possess improved nut yield, nut and kernel quality characteristics, and disease resistance using traditional plant breeding techniques.

For the future.
A total of twelve elite nut selections have been derived from over 6,000 pedigreed trees. Grafted orchards of elite nut selections are being established in two locations in Missouri. These new orchards will represent the very "best" trees produced via control pollinations made in 2002, and will be planted along with a series of "standard" black walnut cultivars for comparison. Additional plantings will be established using the "best" selections by Hammons Products Company and Forrest-Keeling Nursery, both key UMCA partners who are committed to supporting the black walnut breeding program. These additional plantings, to be established in late 2017/early 2018, will enhance our understanding of the effect(s) of planting site on black walnut nut yield and productivity

SPECIALTY CROPS

Elderberry disease research

Interest in growing elderberry continues due to the potential for high economic returns for producers and increased consumer interest in health-promoting food products. As commercial growers expand their acreage and plantings mature, new production problems have been identified, including elderberry rust. This disease is caused by pathogenic fungi, *Puccinia sambuci* and was first described in 1861. This rust requires two living hosts to complete its life cycle, including elderberry and a sedge (*Carex*) species. The first symptoms of rust appear on rapidly expanding leaflets in early spring as pycnia which discharge pycniaspores. After fertilization of these spores, two more spore stages develop, resulting in foliar and stem pustules that cause tissue distortions on elderberry. During summer, uredinospores travel to the alternate host where they subsequently develop into teliospores and basidiospores. Since 1861, no additional research has been conducted on elderberry rust although it is common in Missouri. However, the level of at which a rust infection limits plant growth and reduces yield during the year of infection is unknown. Thus, the objective of this project was to determine the effect of *Puccinia* rust and other fungal diseases on vegetative growth, fruit yield, and juice quality of naturally-infected and inoculated elderberry plants.

Results from this study indicated that rust infection occurred at 9 to 18° C, ≥ 3 h leaf wetness, and ≥ 85% relative humidity on American elderberry plants. Also, a 31 % reduction in berry yield occurred when young 'Bob Gordon' elderberry plants had 6 or more rust pustules/plant during the growing season, which results in $440/ha estimated loss of income, using a typical plant spacing at 1.2 x 3.1 m (2,688 plants/ha). Even without rust re-infection, yield and plant growth was also reduced the subsequent growing season. For 'Wyldewood' plants with canes averaging 137 pustules/cane, yields were reduced by 47% equating to an estimated $2,295/ha loss of income due to rust infection. Rust infection also tended to reduce sugar content of juice expressed from elderberry fruit, which would increase the need for additional sweeteners to elderberry products. Based on these results, cultural, organic and chemical rust control recommendations were developed for producers when ≥ 6 rust pustules/plant occur on elderberry plants. A publication with key symptoms of elderberry rust and control recommendations for this disease can be found here: https://ipm.missouri.edu/pubs/ipm1036.pdf.

"Puccinia rust effecting elderberry plants. Ongoing research on elderberry plants, production, products for marketing is conducted at HARC and the Southwest Research Center in Mt. Vernon. ~ article submitted by Michele Warmund, Ph.D.; photos submitted by Andrew Thomas, Ph.D.

Nitrogen and harvest impact on biomass yield and bioenergy quality

'Bumpers' is a shade-adapted cultivar of eastern gama grass (*Tripsacum dactyloides)* cultivated in Arkansas and released by the US Department of Agriculture. Plants of a 'Bumpers' and of another cultivar were grown in the Alley Cropping Shade Laboratory (ACSL) at the Horticulture and Agroforestry Research Center. In fall 2016 and spring 2017, photosynthetic response curves to light *(i.e.,* PAR) were measured on top-canopy leaves of both 'Bumpers' and control plants grown in full sun (open field) or in dense shade under trees. The curves were used to calculate light-saturated photosynthetic rate (Amax), light compensation point, curvature factor and respiration in the dark , using the classic non-rectangular hyperbola fit. Curve parameters were then used to simulate daily net photosynthesis of top canopy leaves, when exposed to the actual incident light as measured at one-minute intervals in different positions in the alleys. The daily photosynthesis was then divided by the daily incident PAR to calculate the daily "radiation use efficiency" (RUE). The photosynthetic response curves to light differed between cultivars and growing conditions *(i.e.,* full sun vs. shade). Plants grown in full sunlight had greater Amax than plants grown in the tree shade. 'Bumpers', the shade-adapted cultivar, had lower Amax than the control cultivar. The cultivar effect was more important than the effect of growing light condition. At low irradiance photosynthesis was greater for the plants grown in the shade, in both cultivars. 'Bumpers' had higher photosynthesis than the control cultivar. The differences in the response curves to light allowed the modelled photosynthesis to reflect the light adaptation consequent to both the growing condition *(i.e.,* in full light or under tree shade) and the cultivar. In situations with high incident irradiance, RUE was lower for 'Bumpers' than for the other cultivar. Within each cultivar, RUE was lower for plants grown in

shade. At low irradiance (<10 mol m^{-2} day^{-1}) however, plants grown in shade outperformed plants grown in full light for both cultivars. At even lower irradiance (<5 mol m^{-2} day^{-1}) 'Bumpers' plants grown in shade outperformed all other plants, suggesting a greater ability of this cultivar to adapt to shade. Adaptation was related to reduced leaf respiration rate, thereby maintaining higher positive net photosynthesis at lower light levels than for other cultivars. Lower respiration was related to higher specific leaf area for 'Bumpers' when grown in the shade.

Researcher Dr. Adolfo Rosati checks Gama grass cultivar 'Bumpers' under shade.

MU Children's Learning Garden

Urban food forests and urban gardens have potential to serve as economical resources.

The original goal for developing the MU Children's Learning Garden was to create an outdoor space for children to learn about and engage in fruit/vegetable gardening and for researchers affiliated with the MU Child Development Laboratory (CDL) to explore the impact gardening has on children's healthy food choices. Through a collaboration of MOA with Gustave Carlo and Danielle Turley, we have expanded our efforts and have transformed our garden into an urban food forest with fruit-bearing trees and fruit-bearing perennial bushes. The transformation began in the Spring of 2016 and continues through the 2018 growing season. In the Spring of 2017, we reorganized the garden to highlight the benefits of perennials.

The primary goals of the current project are to explore the impact of fruit/vegetable gardening and development of an urban food forest on (a) preschool children's development, food choices, and healthy behaviors, (b) teachers' use of the garden to promote science, math, and other academic domains, (c) parents' use of gardening at home, inclusion of more fruits and vegetables in meals, and support of local farming, and (d) community involvement; support of gardening with children; and promotion of sustainable agricultural practices.

Over the past two years, we have collected survey data from parents of children participating in our garden program. The parent survey includes questions about children's reactions to their experiences in the garden, children's food choices at home, and parents' perception of how they believe garden experiences impact their children's behaviors and food choices.

Children playing under the pole beans.

The first two years of this project also involved teacher training. The confidence of teachers continues to be directly correlated with their knowledge of what is growing in the garden space and how they involve children in the garden. Trainings have been, and continue to be, developed and delivered to support teachers' personal knowledge and comfort working with the garden. For the 2017 growing season, we adjusted our approach. Each classroom was invited to join a garden team. This gave each classroom one designated person who had specific, weekly time allotted to learning about and planning for their garden time. We observed this new model to have the strongest impact on the individual classroom garden plots. This is the second year classrooms were assigned their own garden plot. In 2017 we expanded that model to include the toddler classroom. Teachers demonstrated the most initiative in 2017 in planning and executing their plots. The classrooms also reported more frequent trips to the garden this year than in years past. We believe the increased enthusiasm can be directly correlated with the trainings and establishment of a garden team. The increase in knowledge has increased teacher confidence, and teachers are now providing more enriching gardening opportunities for children and their families.

In efforts to understand how the garden program impacts children, their families, and our community, we were strategic in the design of our family

garden events and communication in 2017. Family events were rescheduled from Saturday events to weekday events with an "open house" format. Activities, shade, water, and garden-related children's books were provided for families during regular pick-up times throughout the summer. Garden staff (graduate students and faculty who work with the garden regularly) were present to talk with parents, answer questions, and encourage garden exploration. Additionally, we held family farmer's markets with food harvested by the children.

In 2017 we partnered with a research team on campus to pilot a new garden education program and examine the impact of the new curriculum on children's food choices. This pilot program has involved doubling the amount of time spent in the garden during weekly garden visits, and adding a systematic approach to the topics covered in the garden while remaining flexible to respond to children's interests. This project will continue throughout the winter of 2017 and spring of 2018. It is our hope that this project will equip teachers with knowledge and experience while continuing to engage children in gardening and agroforestry. Additionally, successful results from the piloted program will result in a curriculum, vetted by early childhood teachers and garden educators, available statewide.

Our teacher survey and observation data continues to indicate that garden training is a critical component of this project and likely any garden program. Access to educational resources for teachers who are new to gardening and growing plants is foundational to successful execution of a garden program. This may include brochures, pamphlets, online resources, and/or trainings. It is critical for teachers to be well educated on these topics so they can engage children in gardening and agroforestry education. Teaching teachers should be done by those who are knowledgeable about gardening and agroforestry, who can explain why agroforestry and gardening is important, and who can help make teachers connect gardening concepts with existing educational goals. It may also be important that garden trainers are either part of the staff or someone who has frequent contact with staff in order to provide on-going support to teachers.

This project has greatly benefitted from the support of the Center of Agroforestry and its affiliates. UMCA's Hannah Hemmelgarn have been engaged in planning and executing the expansion of the garden and adding plants and trees over the past few years. Continued education and support will further our success in providing a model program for early childhood centers and the community as a whole. Future endeavors include a take-home garden curriculum, further developing a teacher-cook garden team, launching a take-home garden literacy program, and developing a community outreach program. *~ submitted by Danielle Turley, Ph.D. student, MU Dept. of Human Development & Family Science. Article has been submitted to the journal "Young Children"*

South end of the MU Children's Learning Garden. All photos for this article submitted by Danielle Turley.

EDUCATION

Agroforestry education for high school agriculture science: preparing the next generation.

Agroforestry content is severely underrepresented in secondary education environments, where a growing number of agriculture students are exposed to agricultural focus areas that guide their life-long career paths. In Missouri, the focus state for this pilot agroforestry education project, more than half of these students will pursue an agricultural profession after high school. Nationally, more than 70% of farm operators do not pursue a college degree, further indicating the foundational role of the high school agriculture program.

Students who participate in a high school agriculture program in the U.S. may be involved not only in-class, but also will compete for regional, state, and national awards at one of 25 subject-specific Career Development Events. The majority of these students also take part in entrepreneurial Supervised Agricultural Experience Projects to demonstrate their capacity to apply agriculture concepts to real world scenarios. In each of these components of agricultural education, high school agriculture teachers facilitate student learning. In Missouri, 480 high school agriculture teachers play an important role in crafting and delivering an education for more than 35,000 students.

When high school agricultural educators are prepared to deliver agroforestry content to the students they interact with on a daily basis, these students will be equipped with the tools to carry that knowledge into their careers in agriculture. What this means for landowners is greater access to skilled professionals who can assist with agroforestry implementation.

This professional development project is being piloted in Missouri, where agricultural educators will have an opportunity to engage with the curriculum we've crafted in order to collaboratively prepare the materials and training program for delivery in other states. One source of motivation for these educators to seek new course materials is the desire to advance their students' understanding of the most up-to-date content in agriculture. The scientific and natural resources community is thus a critical player in the ongoing development of agriculture and agroforestry high school curriculum materials that represent recent findings and their applications to practices on the ground.

The goal of this project is to begin the process of implementing high school agroforestry education in order to grow a general understanding of agroforestry among young agricultural professionals that may have substantial long-term impact on agroforestry opportunities and agroforestry enrollment in post-secondary education programs. To do this, the University of Missouri Center for Agroforestry has collaborated with high school agricultural educators and professional development organizers to introduce an agroforestry curriculum to the 2017 agriculture science program in Missouri.

High school educators practice inoculating logs with mushroom spores.

With the support of a SARE Professional Development Program grant (Gold, Ball, Stelzer and Hemmelgarn), 28 educators (of 90 total to be reached by 2019) have been trained to employ a set of agroforestry lessons and hands-on activities. These educators, who are diverse in teaching experience and location within Missouri, were provided with agroforestry curriculum materials and subsequently completed in-class problem-solving activities, field exercises, and hands-on practice during one of two summer professional development programs designed to grow their content knowledge and pedagogical knowledge for teaching agroforestry.

During each of the two one-day agroforestry educator professional development programs, teachers were asked to complete a pre- and post-workshop survey. The surveys were designed to describe participating teacher demographics, assess teachers' agroforestry content knowledge growth, and estimate the growth

in agroforestry content hours the teachers would offer in their classes as a result of the program. Based on this survey data, the sum of the 28 teachers' growth in planned implementation of agroforestry content amounts to an additional 270 hours of agroforestry-related class time.

Additionally, interviews with teachers one school year after the first professional development program indicated ways that the materials can be further promoted for both teachers and students. The inclusion of agroforestry content in Career Development Event assessments, the engagement of students with short-duration agroforestry-related Supervised Agricultural Experience projects, and the support of teacher learning networks to extend the reach of the agroforestry curriculum materials are future directions for this project.

High school curriculum materials now available online:
www.centerforagroforestry.org/education/HSCurr.php

Online Agroforestry M.S. and Graduate Certificate Programs

Responding to unmet needs of full-time working professionals interested in obtaining in-depth agroforestry knowledge via formal agroforestry graduate education, UMCA developed the online Agroforestry M.S. (30 credit) and Graduate Certificate (12 credit) program which launched in 2011 with all courses online by the fall of 2013. MU agroforestry program courses are all online, including courses on biophysical and socioeconomic foundations of agroforestry. As long as an individual has an Internet connection, it is feasible to complete the coursework.

Interest in the online programs has grown rapidly in the U.S. and abroad. As of December 2017, there are 36 enrolled in M.S. program. Since its inception a total of twenty students graduated with online M.S. with at least six scheduled to graduate in 2018.

Military Tuition Award for Online Students

The University of Missouri provides military personnel, veterans and their families (qualified dependents) with a 10 percent reduction on base tuition for undergraduate and graduate distance degree and certificate program credit hours. The Mizzou Online Military Tuition Award applies to distance students after they are admitted to the university and enrolled in their respective programs.

OUTREACH

In addition to UMCA's role in agroforestry research, education, and economic development another core pillar of our mission is outreach to Missouri agricultural and forest landowners, natural resource professionals and consumers, introducing them to the economic and environmental benefits of agroforestry practices. These efforts involve a multi- faceted, sustained commitment to knowledge creation, information sharing and transfer that result in greater adoption of agroforestry practices, establishment of new specialty crops and associated value-added industries, increased consumer demand for specialty crops, reduced non-point source pollution, increased habitat and wildlife biodiversity, and increased opportunities for agritourism and economic development in rural areas.

Our outreach program has seen some changes during 2017. In March of 2017, UMCA celebrated the retirement of its founder and former director Dr. H.E. "Gene" Garret, who since 2014 has served in the role of Senior Outreach Specialist. We thank Dr. Garrett for his service, his vision and unwavering support to advancing the science and practice of agroforestry. Gregory Ormsby Mori continues to serve as UMCA's Outreach Coordinator and as of December 2017, is joined by Hannah Hemmelgarn as UMCA's Educational Program Coordinator.

UMCA outreach efforts during 2016-7 continued to deliver useful information about the benefits of agroforestry to thousands of people through multiple channels including UMCA sponsored events such as workshops, trainings and agroforestry tours, through online resources available on the UMCA website (centerforagroforestry.org) and through exhibiting and presenting at events ranging from agricultural field days around Missouri, to regional growers conferences throughout the Mid-west, to scientific and professional fora such as the Missouri Natural Resources Conference, the North American Agroforestry Conference and the Society of American Foresters

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2016 Agroforestry Symposium, visiting with Bo Young, Nasser Ayoub, Gene Garrett, Shibu Jose.

crops, reduced non-point source pollution, increased habitat and wildlife biodiversity, and increased opportunities for agritourism and economic development in rural areas.

Agroforestry Symposium

Since its inception in 2010, the UMCA Annual Agroforestry Symposium has grown to be a major event on campus highlighting and exploring in depth a current and compelling topic relevant to agroforestry science and practice. The event regularly draws over 300 in person attendees with many more viewing online through livestreaming. The 7th Annual Agroforestry Symposium held on January 28, 2016 explored the theme "The Future of Pollinators: Why Agroforestry Matters" with Scott Hoffman Black, Executive Director of the Xerces Society as the keynote speaker. The focus of the 8th annual UMCA Agroforestry Symposium held on January 28, 2016 was " Medicinal Plants in Agroforestry: Enhancing Health, Conservation and Livelihoods" with Tom Newmark former CEO of New Chapter and founder of the Carbon Underground as the keynote. Information on future symposia and recorded presentations from of past symposia can be found on the UMCA website at: http://centerforagroforestry.org/events/symposia.php

Agroforestry Academy

The University of Missouri's Center for Agroforestry held its fourth and fifth annual Agroforestry Academy in July 2016 and 2017. The inaugural Agroforestry Academy held in 2013 was a joint effort between agroforesters from five Midwestern states that compose the Mid-America Agroforestry Working Group (MAAWG) and was designed to train the next generation of agroforestry professionals and expose them to agroforestry opportunities through classroom work

Above 2016, below 2017 Agroforestry Academy attendees and instructors.

and farm visits. The innovative program earned a national award from the USDA. In 2014 the Agroforestry Academy was held in Minnesota. Since returning to Columbia Missouri in 2015, the Academy has broadened its scope to include greater participation by land owners and beginning farmers from around the region and beyond, including military veterans who received scholarships through the "Armed to Farm" program, established by the National Institute for Food and Agriculture (NIFA). As of 2017 the Agroforestry Academy has trained 125 future agroforesters from 25 states as well as hosting international participants from Canada, Taiwan and China. In 2018, through participation in a OAO 2501 grant, the Agroforesty Academy will place a greater focus on attracting underserved farmers and landowners.

Missouri Chestnut Roast

Since 2003, over 20,000 people have joined in the festivities at the Missouri Chestnut Roast held in early October at the Horticulture and Agroforestry Research Center (HARC) in New Franklin. During 2016 and 2017, the Chestnut Roasts were blessed with fine weather and had a robust turnout. The event showcases UMCA's effort to development and support viable specialty crop industries that include chestnut, black walnut, pecan, elderberry, and pawpaw for Missouri farmers and also highlights agroforestry practices, ongoing research faculty and many of the Center's partnerships (e.g. Missouri Department of Conservation, Forrest Keeling Nursery, etc.) . Visitors sampled roasted chestnuts and enjoyed great food, vendors, music, farm tours and live demonstrations. Additional highlights include activities for children and tours of the Historic Hickman House. Be sure to join us for the 2018 Missouri Chestnut Roast scheduled for Saturday, October 6, 2018.

Agroforestry Tours & Workshops

The Horticulture and Agroforestry Research Center in New Franklin, MO is the central resource for the Center for Agroforestry and our staff regularly provide in-depth tours at the HARC for visitors both local and international. Over the past 2 years, UMCA hosted numerous visitors including policy-makers, farmers and natural resource professionals from Missouri and neighboring states and researchers visiting from around the globe including China, Italy, Mexico, Ukraine, and France.

In 2016 and 2017, UMCA has hosted an agroforestry workshop for landowners and natural resource professionals at the Doug Allen Research and Education Site located in Gravois Mills, MO, Lake of the Ozarks. The Agroforestry Field Day held on May 13, 2017 highlighted forest farming practices and natural resource management. It was the final time we were joined by Mr. Allen, who passed away on November 7, 2017. Mr. Allen has left an enduring legacy to his commitment to sustainable land use in Missouri bequeathing the Doug Allen Research and Education Site to the University of Missouri Center for Agroforestry. We are deeply grateful to Mr. Allen and will continue to honor and advance his vision of sustainability and prosperity for Missouri small farmers and land managers.

Fun at the Missouri Chestnut Roast ~Photo credit, Logan Jackson

Forest farming and silvopasture were two areas of emphasis for UMCA outreach and during 2016-2017. Over 10 forest farming and mushroom cultivation workshops were held in collaboration with MU County Extension offices and other partners around the state. Mushroom growing demonstration areas have been installed at multiple MU Agricultural Research Centers and other sites around Missouri. With an increasing emphasis on silvopasture as an attractive land use approach for Missouri ranchers and landowners, UMCA continues to engage with stakeholders around the region to coordinate research, outreach and technical support for silvopasture adoption. A silvopasture showcase was held at Greg Judy's Green Pastures Farm in Clark, MO on October 4, 2017 with 50 people in attendance.

OUTREACH

Agroforestry in Action Webinar Series

Launched in March 2015, the UMCA Agroforestry in Action Webinar Series hosts monthly presentations that showcase recent and compelling advances in agroforestry research and practice. The series invites speakers from both the USA and from around the globe to share updates on their work. Highlights from 2016 and 2017 include a presentation by Dr. Antonia J. de Araujo "Agroforestry in Southern Brazil" in April 2016, a joint presentation on professionalization of Agroforestry by Andy Mason, retired US Forest Service, Kate McFarland, National Agroforestry Center and Shibu Jose, Director MU School of Natural Resources in May 2017 and the presentation by Kevin Wolz of the University of Illinois Urbana-Champaign titled " Frontiers in Alley Cropping: Leveraging Multiple Species and Tree Crops," in December, 2017. More information on the Agroforestry in Action Webinar Series and recorded versions of past presentations can be found through the webinar tab on the UMCA website:

https://agroforestryinaction.wixsite.com/agroforestryinaction

Green Horizons & Agroforestry in Action Newsletters

Green Horizons (GH), published since 1997, is a free newsletter published by the Center three times a year, currently offered in conjunction with the Forest and Woodland Association of Missouri. GH is distributed online to over 12,000 readers. The newsletter has an active editorial board and twelve external sponsors representing Missouri's forestry and natural resources industries. Articles feature a variety of topics related to forestry and agroforestry, including forest health and management; forest industry; community and urban forestry; nut trees and other value-added products produced through agroforestry; upcoming forestry and natural resources events; tree health and care; and new market opportunities.
http://agebb.missouri.edu/agforest/ for Green Horizons

Agroforestry in Action is a monthly e-newsletter that focuses on the activities and accomplishments of Center faculty, staff, collaborators and visitors. Agroforestry in Action recognizes awards and honors, has a monthly events calendar, and features Center research, teaching, outreach and entrepreneurial activities and their impacts.

http://www.centerforagroforestry.org/pubs/action/archive.php for Agroforestry in Action newsletter

International Engagement

UMCA faculty and staff regularly collaborate with international partners and engage in a range of international activities.

Jose, S. 2017. Temperate agroforestry in the 21st Century: A North American perspective. 11th National Congress of the Italian Society of Silviculture and Forest Ecology. October 10-13, Rome, Italy (Keynote)

Green Lands Blue Waters 2016 annual conference was held on the beautiful University of Missouri-Columbia campus.

Jose, S. 2017. Ecological interactions in agroforestry: Lessons learned from North America. Institute of Agro-Environmental and Forest Biology (IBAF), October 9, Porano, Italy.

Jose, S. 2017. Designing sustainable silvopastoral systems: A three-pronged approach. IX International Congress on Silvopastoral Systems, September 5-8, Manizales, Colombia (Keynote)

Jose, S. 2017. Temperate agroforestry in the 21st Century. Southwest Agriculture and Forestry University, June 7, Yangling, China.

Jose, S. 2016. Designing silvopastoral systems: From resource availability to management interventions. World Congress of Silvopastoral Systems, September 26-30, Evora, Portugal (Opening Keynote)

Jose, S. 2016. Imperata cylindrica invasion of the longleaf pine (Pinus palustris) forests of the U.S Southeast: Impacts on resource availability, understory plant diversity and ecosystem productivity. IUFRO Regional Conference, October 24-27, Beijing, China.

Jose, S. 2016. Temperate agroforestry and its relevance to the US economy and the environment. Jan 11, Bogor Agricultural University, Bogor, Indonesia.

UMCA Outreach Coordinator Gregory Ormsby Mori in partnership with local NGO Ya'ache and the University of Belize, designed and presented a three day intensive Agroforestry workshop for farmers and natural resource professionals in Punta Gorda Belize in June, 2016.

Mr. Ormsby Mori has also played a role in facilitating outreach, professional networking and collaboration between agroforestry communities in USA and Canada and in Mexico, hosting an international agroforestry policy forum, a special technical session on Mexican agroforestry a delegation of Mexican agroforesters at the 15th North American Agroforestry Conference. Mr. Ormsby Mori was invited speaker at the inaugural national meeting of the newly formed Mexican Agroforesty Network held in La Paz, Mexico on October 31, 2017.

In May, 2016, UMCA Economist Dr. Zhen Cai, visited the School of Economics and Management (SEM), within Beijing Forestry University, Beijing, China. While there she presented lectures on forest management and agroforestry economics for graduate students and faculty members. Dr. Cai also presented a series of eight lectures to a group of graduate students under the Asia-Pacific Network for Sustainable Forest Management and Rehabilitation (APFNet) Scholarship Program. The students, who came from Cambodia, Nepal, Myanmar, Peru, Finland, and Inner Mongolia, studied agroforestry economics and decision methods for forest resource management. Dr. Cai also met with the Director of the Forestry Economics and Development Research Center, in the Chinese State Forestry Administration, to discuss potential collaboration on the introduction of pawpaw (Asimina triloba) into China.

Ten Indonesian Agroforestry Graduate Students, Funded by USAID, PRESTAS and Fulbright, Joined the Center for Agroforestry to Pursue MS Degrees in 2016 and 2017.

Ade Ayu Dewayani is pursuing a Master's Degree in Agroforestry under the supervision of Dr Chung-Ho Lin. She is interested in conducting research related to the use of genetically modified bacteria in habitat restoration processes in Indonesia.

Kania Dewi Rahayu is pursuing her MS in Agroforestry supervised by Dr. Shibu Jose. She is interested in conducting research related to agroforestry systems for conserving wildlife habitat.

Ainun Pizar Seruni is now pursuing her MS Degree in Agroforestry supervised by Dr. Francisco Aguilar and Dr. Zhen Cai. She conducted research to Characterize Smallholder Parcelized Cut-And-Carry Confined Livestock Systems In Central Java, Indonesia.

Haryo Ajie Dewanto is pursuing an MS Degree in Agroforestry supervised by Dr. Ranjith Udawatta and Dr. Shibu Jose. He is interested in conducting research on agroforestry systems for ecosystem restoration in degraded peat swamp forest ecosystems.

Agroforestry MS students from Indonesia visit with Dr. Jeanne Sinquefield.

Novianus Efrat received his BS in Agricultural Technology from Bogor Agricultural University. Currently a Fulbright Scholar, he is pursuing his MS degree in Agroforestry supervised by Dr. Shibu Jose and Dr. Chung-Ho Lin, focused on renewable energy.

Dorin Lida Kusumawardani is currently enrolled the Agroforestry MS Program at University of Missouri (2017/2019) under the supervision of Dr. Francisco Aguilar.

Muhamad Nurhuda "Huda" Nugraha is enrolled in the Agroforestry MS program at MU (2017/2018) under the supervision of Prof. Ben Knapp.

Amanda Dwikarina is pursuing a Master's Degree in Agroforestry under the supervision of Dr. Chung-Ho Lin. Her research interest is related to the use of natural resources as biomedicine.

Dienda Citasyari Putri Hendrawan is an agroforestry MS student under the supervision of Dr. Zhen Cai and Dr. Francisco Aguilar.

Dayu Kemalasari Soraya is pursuing an MS Degree in agroforestry supervised by Dr. Hank Stelzer. Her research is focused on the sustainability of supply chain management in the wood working industry.

International Scholars Hosted by UMCA

UMCA hosted visiting scientist Shu-Yu Hsu, from the Department of Marine Environment and Engineering, National Sun Yat-sen University, Kaohsiung, Taiwan. In 2016-2017, she worked with scientists at UMCA and MU Life Science Center on the bioremediation of dioxins. She helped the team to transfer innovative spore-based remediation technology to the An-Shan site in Taiwan that is heavily contaminated by dioxins. National Sun Yat-sen University and MU signed an MOU in 2013 to facilitate the international collaboration and exchange activities. The findings of the project were presented at 15th Annual Great Plains Infectious Disease Meeting November 4 and 5th, 2016.

Dr. Darcy Gordon, a visiting scholar from Italy, worked with UMCA on a chestnut post-harvest project, evaluating long-term refrigerated storage life of a select number of highly rated Chinese chestnut cultivars.

Dr. Adolfo Rosati, a research scientist at the Council for Agricultural Research and Economics (CREA), in Italy, since 1996, was a Fulbright scholar with UMCA. He measured and modeled light transmission below trees in agroforestry systems, and use-efficiency by understory crops. He works on eco-physiology, particularly light and nitrogen partitioning within canopies, modelling photosynthesis, floral and fruit biology, and tree growth. He is actively involved in AGFORWARD (www.agforward.eu), the largest agroforestry project funded by the European Commission. Dr. Rosati is a founding member of the European Agroforestry Federation (EURAF) (www.agroforestry.eu) and serves in its executive committee.

Dr. Jeanne Dollinger joined UMCA as a visiting postdoctoral researcher in phytochemistry in 2017, and worked with Dr. Chung-Ho Lin. Dr. Dollinger comes from the French Institute of Agricultural Research (INRA). She was awarded a year-long scholarship from INRA to investigate the potential of agroforestry practices to reduce pesticide losses from croplands. Her research at INRA deals with micropollutant fate in agricultural landscapes and more specifically, how landscape elements such as ditches, riparian buffers, hedgerows, etc., can be designed or managed in order to buffer water pollution from pesticides.

In July, 2017, in partnership with an Asian Development Bank project, UMCA hosted and provided agroforestry training for a delegation from the Provincial forestry Department of Henan China.

UMCA faculty and staff, School of Natural Resources Director, Shibu Jose, attend a campus wide forum to learn more about Indonesian students and show appreciation of international contribution to the MU campus.

Decoding Science

As Sagar Gupta watched a 3-D printer on a lab countertop construct a jumbo pencil eraser-sized, white plastic cylinder of what looked like a shell holding inter-woven letter Xs, he remarked that the only limitation to what you can print is the size of the printer. "The timing is perfect, otherwise we wouldn't have been able to afford it," Chung-Ho Lin said of the availability of cheaper 3-D printers within the past couple years.

The two men were acutely aware, as the printer continued its methodical manufacture, that they may be architects of the first steps in a bio-chemical revolution.

It's a revolution that could be hugely profitable financially and may help to save lives on battlefields, clean up some kinds of pollution and enable humans to venture further into space for a cheaper cost, among other things.

To understand how this cross-disciplinary team working in George Stewart's lab at the Bond Life Sciences Center got there, we have to back up a little bit.

From a bottleneck to a bioreactor

Their work began three years ago with a project to develop technology to reduce the cost of converting cellulose into glucose for biofuels — essentially the process by which raw plant fiber from wood or leaves is turned into a sugar that can be more efficiently burned to produce energy. "That has been the bottleneck for the biofuel industry," said Lin.

The team — consisting of Lin, a research assistant professor at MU's Center for Agroforestry; Stewart, Hsinyeh Hsieh and several undergraduate and recently graduated students including Gupta — already developed E. coli bacteria that can mass-produce engineered enzymes to convert cellulose into glucose. These enzymes speed up the reactions and reduce the cost because they have linkers attached to them — protein hooks that let them be recovered after a single use as catalysts in biological reactions, rather than having to throw them out. Hsieh said she developed this with Stewart's input, and the assistance of a recently graduated student, Che-Min Su.

However, the team needed a platform for the linkers to hook onto — something they could continuously use to reel in their catch.

The answer in their search for the correct platform arrived when affordable 3-D printing technology came onto the market. With their own 3-D printer in-house, they custom-designed different platforms for their experiments and completely bypassed having to shop around with different fabrication companies.

Sagar Gupta holds vial of carbon solution. Most of the team's prototype designs for bio-reaction sites are made of carbon, some are bio-degradable.

All of the ingredients were there with that plastic cylinder Gupta and Lin watched print. The team now had a cheap way to mass produce and repeatedly recover enzymes. With this capability, they could produce a more efficient bioreactor — a controlled, isolated system in which desired reactions can take place with higher outputs of quantity and quality of a desired product.

It's much like the more familiar concept of a nuclear reactor, which controls and isolates a nuclear chain reaction to harvest the most energy possible. The catalysts in that reaction are radioactive particles that give off heat as they decay. In a physical reaction, the heat released boils liquid water into gaseous steam, and the steam turns a turbine generator that makes electricity.

But in the team's bioreactors, catalysts are enzymes that chemically react with cellulose and transform it into glucose instead of electricity. The glucose can be fermented further into butanol that can ultimately be used for liquid fuels to power vehicles.

Money and blood

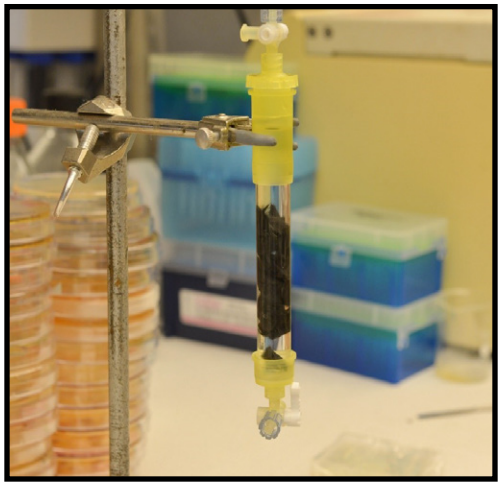
While only at a bench-top, proof-of-concept scale, the team's first bioreactor has lasted more than four months. With prospects to increase its size, they "could be saving at least $10 to $12 million per year on an industrial scale," said Gupta. Gupta graduated in May from MU with an MBA, and now works for Lin.

That estimate is just for one individual bioreactor. Begin to multiply it, and the cost-savings add up very

quick. “Nowadays, probably a majority of pharmaceutical companies have already switched their manufacturing process into the enzymatic process. One thing nice about the enzymatic process is that it can eliminate [the need for] a lot of hazardous chemicals. They also tend to have a better yield,” Lin explained.
Lin added that there is a bonus of complexity within this kind of 3-D platform system. Individual enzymes have different linkers, and this allows for multiple enzymes to catalyze reactions and be recovered on the platform at the same time. This is especially cost-saving because the conversion of cellulose into glucose requires three different kinds of enzymes.
“Because of this high specificity, we don’t need any enzymatic purification process,” he said.

Once the enzymes hooked to a platform start to naturally decay, the team can simply remove the decayed enzymes by a hot water bath and soak it in a new batch of enzymes, just like swapping out an empty printer cartridge for a full one with fresh ink.
While their primary focus is on biofuels, they are very aware that more efficient and cheaper bioreactors could have huge implications for a broad spectrum of industries.

One use they are developing could effectively transform one blood type into another using enzymes.
“This is not a completely new technology, but in the past, I would say back in the 90’s, some people tried some clinical trials and they ran into a problem, because a lot of times after the conversion, [loose] enzymes would get into the recipients’ bloodstream and cause an autoimmune reaction,” said Lin. However, by being able to immobilize enzymes with their linkers on this 3-D device, they should be able to get around that problem, he said.



Bio-reactor column stands packed with carbon fibers submerged in enzymes. If the column was hooked up a continuous flow system, substrate would be pumped through it to spur biochemical reactions on the surface of the carbon fibers, or whatever other type of site is packed inside.

“I think there’s great potential for the soldier on the battlefield,” Lin cited as an application for the technology. A field doctor or medic wouldn’t have to worry about waiting on a certain type of blood for a transfusion, because they could convert another batch of blood into a universal-donor type.

Another team member, Hien Huynh explained that the more enzyme you add in ratio to the substrate, in this instance blood, the faster the conversion process will go — “maybe just 30 minutes.”

Hsieh wrote that “Blood type conversion would be the ultimate challenge for our bioreactor, because it has so many clinical aspects to be concerned [about] and conquered. It is a challenge but our [multi-disciplinary] team is willing to take it on and make it work.”

Lin said that the team has already submitted a letter of intent to the U.S. Department of Defense, “hopefully to secure some support for the blood-conversion application.”

Enzymes in action
There are other potentially massive implications for the battlefields of the future. “You can immobilize anti-microbial, anti-fungal and anti-inflammatory enzymes on a surface to use as a wound-healing patch,” Lin said, noting that such a patch could be used on the battlefield, as well as for cosmetic surgery recovery.
But the applications don’t stop there. Other uses could use enzymes to clean up TNT residues leeching out of unexploded ordinance like cluster bomblets, mortars, rocket-propelled grenades and landmines buried in the ground before the toxic residues contaminate groundwater.

Even within the confines of biofuels, there’s a strong military market. By 2020, the Navy wants 50 percent of its total energy consumption to come from alternative sources as opposed to petroleum-based fuels — part of a broader strategy to go green. The U.S. military in the near future wants to reduce the cost of its energy consumption and secure a stable domestic supply of energy.

According to the U.S. Government Accountability Office, from fiscal years 2007 to 2014, the Department of Defense bought 32 billion gallons of petroleum-based fuels at a cost of $107.2 billion.

Away from the military sphere, Lin detailed other uses for cheaper, higher quality enzymes. It could purify and recycle urine into clean water on space flights on for astronauts or convert waste into energy with an ammonia fuel cell that’s already available.

Mass-produced enzymes can be used for water treat

Hien Huynh packs a bio-reactor column with carbon fiber bio-reactor sites that look like feathers. The sites are coated in enzyme before being packed into the column.

ment on earth, too. Pollutants like dioxin and herbicides like atrazine that contaminate soil can be bioremediated in the same way that TNT residues can be cleaned up. The food industry already uses enzymes as flavor removers to remove strong tastes from products like beer.

A bright bioreactor future

To call the team's work revolutionary might be a bit premature. There is a whole process ahead of them, including patent filing and university reviews, before the team can approach investors with the assurance their discoveries are legally protected. And, future investors will ultimately help determine how the technology is used.

But, Lin and the others might just have found themselves in the right place at the right time to make major breakthroughs, and that's not all due to just advancements in technology.

"We have identified new directions and found a new niche to be competitive. I think the most important resource we have is people, and their brains," Lin said.

Hsieh wrote that "To assemble a successful team is to put the right talent in the proper position and to inspire them to challenge themselves. I was lucky to come across so many young, talented students who are eager to learn and work hard for their bright future on MU's campus."

Hsinyeh Hsieh, a veterinary pathobiology research scientist in George Stewart's Bond LSC lab, coordinates this project. Hsieh is an expert in gene fusion, enzyme production and characterization and enzymatic blood type conversion. Stewart is a medical bacteriologist, McKee Professor of Microbial Pathogenesis and chair of Veterinary Pathobiology at MU. Chung-Ho Lin, research associate professor of agroforestry bioremediation, works with Stewart and Hsieh to develop concepts, design prototypes and assemble the rest of the team — students and recent graduates — that optimizes the enzymatic reactions and the physical and chemical aspects of their bioreactor system. Minh Ma is a junior studying biochemistry. Mason Schellenberg studies bioengineering, will be a senior and worked to find the most efficient platform design that the team's 3-D printer could produce. Hien Huynh is a recent graduate who works on immobilizing enzymes. In addition to his MBA, Gupta also has a background that includes nano-technology, molecular engineering and financing. He concentrates on the feasibility and market potential of the team's work.

Tiger Energy Solutions, LLC is the team's industry partner — a spinoff startup from the team's research project . Their focus in the development of a cheaper and higher quality method of converting cellulose into glucose for biofuels is to produce aviation biofuel. Tiger Energy serves as the interface between the team and industry while the team's work is scaled-up for commercialization. story by Roger Meissen, Bond LSC Marketing/Communications; photos by Phillip Sitter, MU Journalism graduate.

Minh Ma simulates the end result of a successful operation of the bioreactor. She extracts and separates samples of real glucose product produced by the reactions in the column. A stronger yellow color in the solution indicates a higher concentration of glucose.

MU/UMCA OUTLYING FARMS & CENTERS

Horticulture and Agroforestry Research Center (HARC)

HARC is one of the University of Missouri's Agricultural Research Centers, 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 ecoregions.

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 at the University of Missouri. 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.

Madeline Wimmer, research specialist, MU Plant Science, gives an overview of growing wine grapes in the US/Missouri during the 2017 Chestnut Roast.

Interdisciplinary cooperation allows researchers from multiple disciplines, including tree breeding and improvement, entomology, plant pathology, horticulture, agronomy, animal science and agroforestry, to combine research efforts to address an array of economic and environmental issues. Specialty crops featured include major germplasm collections of

At Wurdack: Dr. Hank Stelzer discusses forest management with Missouri landowners during the annual field day.

northern pecan, eastern black walnut, and Chinese chestnut, along with research on 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 and flood tolerance studies.

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 integrated livestock, forages, forestry silvopasture (agroforestry) and wildlife management practices that are economically viable, environmentally sound and sociologically acceptable for the Ozark Region of Missouri. Wurdack is operated using Best Management Practices and 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. Farm activities emphasize management practices that promote sustainable agricultural production while protecting the natural environment and the quality of life for citizens of Missouri's Ozark region.

Southwest Research Center

Established in 1959, this Center addresses the main agricultural concerns of area industries including dairy, beef, forage and specialty crop production. Horticultural research, including black walnut, pe-

MU/UMCA OUTLYING FARMS & CENTERS

Field Day at Greenley Research Center.

can, 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 has been instrumental in the development of three new "endophyte-free" tall fescue varieties – "Missouri 96," "Mozark" and "Martin" – as well as an orchardgrass variety, "Justus." Small grains research focuses on variety testing and development, proper fertilization practices and harvest management alternatives.

Greenley Research Center

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 production are being implemented. UMCA has maintained a long-term (25 years) 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, 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.

Doug Allen Research & Education Site

The Doug Allen Research and Education Site contains 521 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 fifteen years of research into as a potential source of short and long-term income for landowners.

Left to right: Dr. Ranjith Udawatta, graduate student Lalith Rankoth, Dr. Zhen Cai, and graduate student Chathuri Weerasekara, planting seedlings to establish a riparian area,

GRANTS 2016 & 2017

AGROFORESTRY

Gold, M., PI, USDA Forest Service (2013-2017) Agroforestry as a climate change mitigation and adaptation tool for agriculture in temperate regions - Developing an annotated bibliography, $20,000

Jose, S., PI, USDA ARS (2012-2017) Agroforestry for Small Farm Sustainability, $2,000,000

Jose, S., PI, USDA ARS (2012-2016) Pasture Management Strategies to Reduce NPSP and Enhance Integrated Production Systems that Include Agroforestry, $73,000

BIOFUEL/BIOMASS

Jose, S., PI: Bardhan S., Co-PI, Etimine USA (2015-2016) Role of Boron in Biofuel Crop and Row Crop Production, $65,000

Jose, S., PI for MU, US DOE and DBT India (2012-2017) U.S.-India Consortium for the Development of Sustainable Biomass and Biofuels, $24,000,000 total; $5,400,000 MU portion.

Jose, S., PI; Lin, C.-H., Co-PI, MU Mizzou Advantage Competitive Grants Programs, (2014-2016) Accelerating Advanced Biofuels Production: Three-pronged Approach, $350,000

Jose, S., PI, Roeslein Alternative Energy, LLC (2015-2016) Managing Native Prairie for Biomass Production and Wildlife Conservation, $108,000

Lin, C.-H., PI; Jose, S., Co-PI, MU Mizzou Advantage Competitive Grants Programs, (2014-2016) Development of a Novel Continuous Flow Saccharification Process for Advanced Biofuel Production, $50,000

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.

EDUCATION

Gold, M., PI, USDA NCR SARE PDP (2017-2019) Missouri Agroforestry Summer Institutes: High School Educator Training for Curriculum Delivery. $70,334.

Hemmelgarn, H., Mizzou Advantage Graduate Student Travel Grant to IUFRO conference, Ontario, Canada. (2016) An Experiential Approach to Agroforestry Education: High School Educator Professional Development. $1,000.

ENVIRONMENTAL SERVICES

Costello, C., World Wildlife Fund (2016) Developing Hospitality Food Waste Audit and Measurement Procedure. $43,000.

Fidalgo, M., PI; Lin, C.-H., Nagel, S., Co-PIs, USGA (2016-2018) Total Endocrine Disrupter Chemical (EDCs) Concentration in Natural Waters. $44,000.

Fidalgo, M., PI; Lin, C.-H., Mayhan, B., Trauth, K., Co-PIs, EPA Region 7 Grant (2017-2019) Pesticide Landscape-Based Monitoring Method Development and Strategy. $40,666.

Fidalgo, M., PI; Lim, T., Lin, C.-H., Co-PIs, Mizzou Advantage URT (2017) Program Degradation of Antibiotics from Concentrated Animal Feeding Operations Wastewater by Heterogeneous Fenton Reaction. $10,000.

He, Z. PI; Deng, B., Han, T., Nair, S., Hu, Z, Co-PIs, NSF CNS (2015-2016) CPS: Synergy: Collaborative Research: Cyber-Physical Sensing, Modeling, and Control for Large-Scale Wastewater Reuse and Algal Biomass Production. $670,000.

Jose, S., PI, USDA NRCS (2013-2018) cyber-linked watersheds, $160,000

Jose, S., Co-PI, USDA NRCS CIG (2014-2017) Improving Soil Water Retention in Sandy Soils using SWRT Membranes, $476,000

Jose, S., Co-PI, USDA NRCS/MO Dept. of Natural Resources Environmental Quality and Farm Productivity. Conservation Innovation (2012-2017) Cover Crop Management for Flooded Areas to Improve Soil Heath,. $268,161

Lim, T., PI; Costello, C., Co-PI, National Pork Board (2016 - 2017) Sustainability evaluation of a solid-liquid manure separation operation. $71,993.

Lim, T., PI; Lin, C.-H., Wan, C., Co-PIs, MU Research Board (2016-2018) Degradation of Veterinary Antibiotics via Anaerobic Digestion. $49,000.

Lin, C.-H., PI, MO Dept. of Agriculture (2016-2018) Identify Novel Uses of Black Walnut and Its Byproducts. $29,500.

Lin, C.-H., Co-PI, MU Mizzou Advantage Undergraduate Research Teams (URT) Programs (2016-2017) Degradation of Antibiotics from Concentrated Animal Feeding Operations Wastewater by Heterogeneous Fenton Reaction. $10,000.

Lin, C.-H., Co-PI, MU Research Board (2016-2018) Degradation of Antibiotics from Concentrate Animal Feeding Operations Wastewater by Heterogeneous Fenton Reaction. $36,936.

Lin, C.-H., USGS (2017) A novel artificial hormone receptor for the sensing of total Endocrine Disruptor Chemicals (EDCs) concentration in natural waters. $44,000.

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

Lin, C.-H., Co-PI, MU Research Board (2016-2017) Degradation of Veterinary Antibiotics via Digestion, $47,940

Lin, C.-H., Co-PI, NIH/NIAID R21 (2015-2017) a cyclic di-GMP signaling of spores of Bacillus anthracis, $413,373

Lin, C.-H., Co-PI, NIEHS/NIHH (2015-2017) Endocrine disrupting activity associated with hydraulic fracturing, $427,273

Lin, C.-H., Co-PI, EPA (P3) Program (2015-2016) Water quality monitoring at hydraulic fracturing sites using molecularly imprinted porous hydrogels, $15,000

Lin, C.-H., Co-PI, MU Mizzou Advantage (2014-2016) a novel spore display system for bioremediation of dioxins, $50,000

Lin, C.-H., Co-PI Mizzou Advantage (2014-2016) Environmental toxicants and low-SES children's health and learning, $30,000

Lin, C.-H., Co-PI, MU Mizzou Advantage (2014-2016) Endocrine Disrupting Activity Associated with Hydraulic Fracturing for Natural Gas and Oil, $75,000

Nelson, K., Motavalli, P., Thompson, A., Udawatta, R., Lory, J. Missouri Fertilizer and Ag Lime Board. (2016-2019) Impact of Cover Crops on Nutrient Loss in a Terraced Fields. $87,000.

Thomas, A., Co-PI, US NIH (2010-2016) University of Missouri Center for Botanical Interaction Studies, $7,700,000.

Udawatta, R., PI, USDA NRCS/MO Dept. of Natural Resources (2012-2017) Cover Crop Management for Flooded Areas to Improve Soil Heath, Environmental Quality and Farm Productivity. Conservation Innovation, $268,161.

Udawatta, R., Co-PI (2013-2016) Hydrologic Regime and Nitrogen Cycling: Understanding the Difference between Claypan and Loess Watersheds in Missouri, $192,510.

Udawatta, R., Anderson, S. SNR Mini-Grant Program (2017-2018) Micro-tomographic Evaluation of Geometrical Soil Pore Parameters and Water Transport to Quantify Environmental Services of Conservation Practices. $5,000.

Udawatta, R., Gantzer, C., Kremer, R., Jose, S., Anderson, S., Reinbott, T. USDA-NRCS (2012-2017) Cover crop management for flooded areas to improve soil health, environmental quality, and farm productivity $268,000.

Udawatta, R., PI; Jose, S., Co-PI, Conservation Innovation USDA NRCS/MO Dept. of Natural Resources (2012-2016) Multipurpose Cover Crop and Conservation Practices for a Sustainable Agricultural System to Improve Soil Heath, Environmental Quality and Farm Productivity, $1,100,000.

Udawatta, R., PI; Jose, S., Co-PI, USDA NRCS (2009-2016) Mississippi River Basin Initiative (MRBI) multiple sites, $1,279,384.

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

Udawatta, R., PI; Jose, S., Co-PI, USDA NRCS (2016-2018) Monitoring and Modelling of Mississippi River Basin Healthy Watershed Initiative (MRBI) Edge of Field Monitoring and Environmental benefit evaluation $169,846.

Udawatta, R.P. and S. Jose. 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., Lerch, R., Liu, F., Yang, J., NIFA (2013-2017) Hydrologic Regime and Nitrogen Cycling: Understanding the Difference between Claypan and Loess Watersheds in Missouri. $194,000.

OUTREACH

Jose, S. Co-PI, USDA NIFA (2015-2018) Armed to Farm: Soldiering the Success of Military Veterans in New Poultry, Livestock and Agroforestry Enterprises, $500,000.

SILVOPASTURE

Jose, S., USDA ARS (2012-2016) Pasture Management Strategies to Reduce NPSP and Enhance Integrated Production Systems that Include Agroforestry, $73,000.

SOCIOECONOMICS/ MARKETING/ ENTREPRENEURIAL

Lin, C.-H., MU Mizzou Advantage (2014 -2016) Development of a novel continuous-flow saccharification process for advanced biofuel production, $50,000.

Lin, C-H., PI, SCD Probiotics Gift Fund (2017) Identification of the odorous biomolecules in production of probiotics products. $15,000.

Lin, C.-H. PI. Tiger Energy (2016-2019) $200,000.

Lin, C.-H. PI. NutraPet Systems/ Caribbean Probiotics Industries & Kelly Foods Corp. (2017) Assessing the Effects of FloraZil+ on Lactobacillus Richness and Abundance in Dogs Using Next-Generation Sequencing. $25,000.

SPECIALTY CROPS

Coggeshall, M., USDA-NIFA (2012-2017) Development of disease resistant walnut rootstocks: Integration of conventional and genomics approaches. $164,043.

Jose, S., PI, Missouri Dept. of Conservation (2009-2017) Tree Improvement Program, $226,250.

Lin, C., Cai, Z., Coggeshall, M., Gold, M., Roy, A., Co-PIs; Missouri Dept. of Agriculture Specialty Crop Block Grant Program (2016-2017) Identify Novel Uses of Black Walnut and its Byproducts. $29,500.

Nelson, K., Motavalli, P., Thompson, A., Udawatta, R., Lory, J., Co-PIs. MO Fertilizer and Ag Lime Board (2016-2019) Impact of Cover Crops on Nutrient Loss in a Terraced Field. $87,000.

Thomas, A., Greenlief, C., McGowan, K., Byers, P. Missouri Dept of Agriculture, Specialty Crop Block Grant Program (2017) Development of Elderberry Flowers as a Viable Specialty Crop. $22,520.

Thomas, A., Johnson, M., Greenlief, C., Missouri Department of Agriculture, Specialty Crop Block Grant Program (2015 - 2017) Determining and Mitigating the Potential Occurrence of Cyanide in Elderberries. $29,775.

Warmund, M. R., PI, Missouri Dept. of Agriculture Specialty Crop Block Grant (2016) Effect of *Puccinia bolleyana* Rust on Elderberry Plant Growth, Yield, and Juice Characteristics. $21,334.

Warmund, M., PI, MDA Specialty Crop Grant (2016-2017) Effect of Elderberry Rust on Plant Growth, Yield, and Juice. $26,325.

Warmund, M. R., Van Sambeek, J., Northern Nut Growers Association (2016 -2017) Enhancing eastern black walnut germination and early seedling growth with gibberellic acid. $4,800.

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Williams, C., Co-PI. Roeslein Alternative Energy, LLC (Sept. 2016-Jan. 2017) Native grassland restoration. $74,500.

TREE/CROP INTERACTIONS

Jose, S., Van Sambeek, J. Co-PIs, Evaluating genetic variation in shade tolerance warm-season grasses proposal for continued support of a student worker. Amendment 2 of existing RJVA to support student worker. $6,300.

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MS Final Projects/MS Theses/ Ph.D. Dissertatiions

Dang, Nguyen. 2017. Quantifying light under tree canopies and its effect on chemical composition and cultivar performance of switchgrass as a biofuel feedstock in a hardwood alley cropping practice. Thesis report. Van Hall Larenstein University, Velp, The Netherlands.

Evans, Meredith. 2017. Online M.S. Developing an Equine Silvopasture Project: An On-Farm Case Study. Dr. Michael Gold (Major Professor).

Frentzel, Dylan. 2017. Online M.S. Agroforestry: A Path Toward Sustainable Agriculture in New Mexico. Dr. Michael Gold (Major Professor).

Hemmelgarn, Hannah. 2017. M.S. Agroforestry Education for High School Agriculture Science: A Case Study of the Novel Content Implementation Process. Dr. Michael Gold (Major Professor)

McGowan, Kelly. 2017. M.S. Flower Production and Effect of Flower Harvest on Berry Yields Within Six American Elderberry (Sambucus canadensis) Genotypes. Dr. Andy Thomas (Major Professor).

Park, Jihyun. 2017. M.S. Identifying bioactive phytochemicals in spent coffee grounds for cosmetic application through global metabolite analysis. Dr. Chung-Ho Lin (Major Professor)

Wickramarathne, Niranga M. 2017. M.S. Thesis. Groundwater Nitrogen and Phosphorus Dynamics Under Cattle Grazing and Row Crop Management in Two Contrasting Soils in Missouri. Dr. Ranjith P. Udawatta (Major Professor)

More 2016-2017 Highlights

USDA ARS Booneville AR funding collaboration continues.

Two patents were granted by United States Patent and Trademark Office, and one of the developed technologies has been successfully transferred to industry (Elemental Enzymes Inc.).

Two new NIH grants, and one new EPA grant, were awarded totaling over $1.2 million.

UMCA/CAFNR offered its' first ever Study Abroad Program in Indonesia

Research: Building upon the Center's ongoing research collaboration with the ARS, UMCA researchers are serving as PI or Co-PI in new and existing grants and contracts totaling $11,015,803 in FY 2017.

Research: Center faculty, in collaboration with a large number of other researchers, published a total of 50 refereed articles and 8 book chapters in 2016 and 2017.

Education: In 2017, our online MS was rated as the #1 online environmental science program in the USA! https://www.guidetoonlineschools.com/degrees/environmental-science#best-value-masters

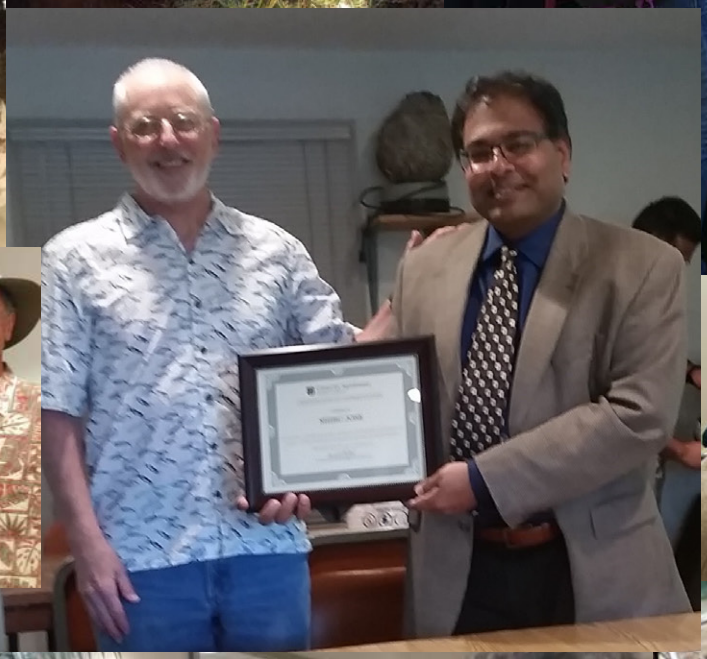
Education: Missouri's FFA curriculum will be enhanced through the addition of six-modules of experiential learning agroforestry content to the existing Agriculture Science II curricula. It will integrate sustainable land use models exemplified by agroforestry into the foundational education of young farmers and agriculture professionals.

Economic Development: A collaboration with the MU Department of Veterinary Pathobiology and Elemental Enzymes Inc, developed novel spore-based enzyme display systems, which can genetically display high levels of proteins on the spore surface. Results of soil analysis showed that more than 98% of atrazine in contaminated soil was removed by the AtzA-spore system.

Economic Development: A collaboration with Tiger Energy Solutions has developed an enzymatic biocatalyst system for blood type conversion (resulting in production of universal blood type O).

Economic Development: New patent granted by US Patent & Trademark Office. Multi-Enzyme Platform Production of Specialty Chemicals, Biofuels, and Blood Type Conversion.

2016-2017 in Action



The 10th Annual Agroforestry Symposium will be held at the MU Bond Life Sciences Center on the University of Missouri campus in Columbia, Missouri, Thursday, January 31, 2019, 8:30am-6:00pm Keynote speakers are 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. The event is free and open to the public.

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