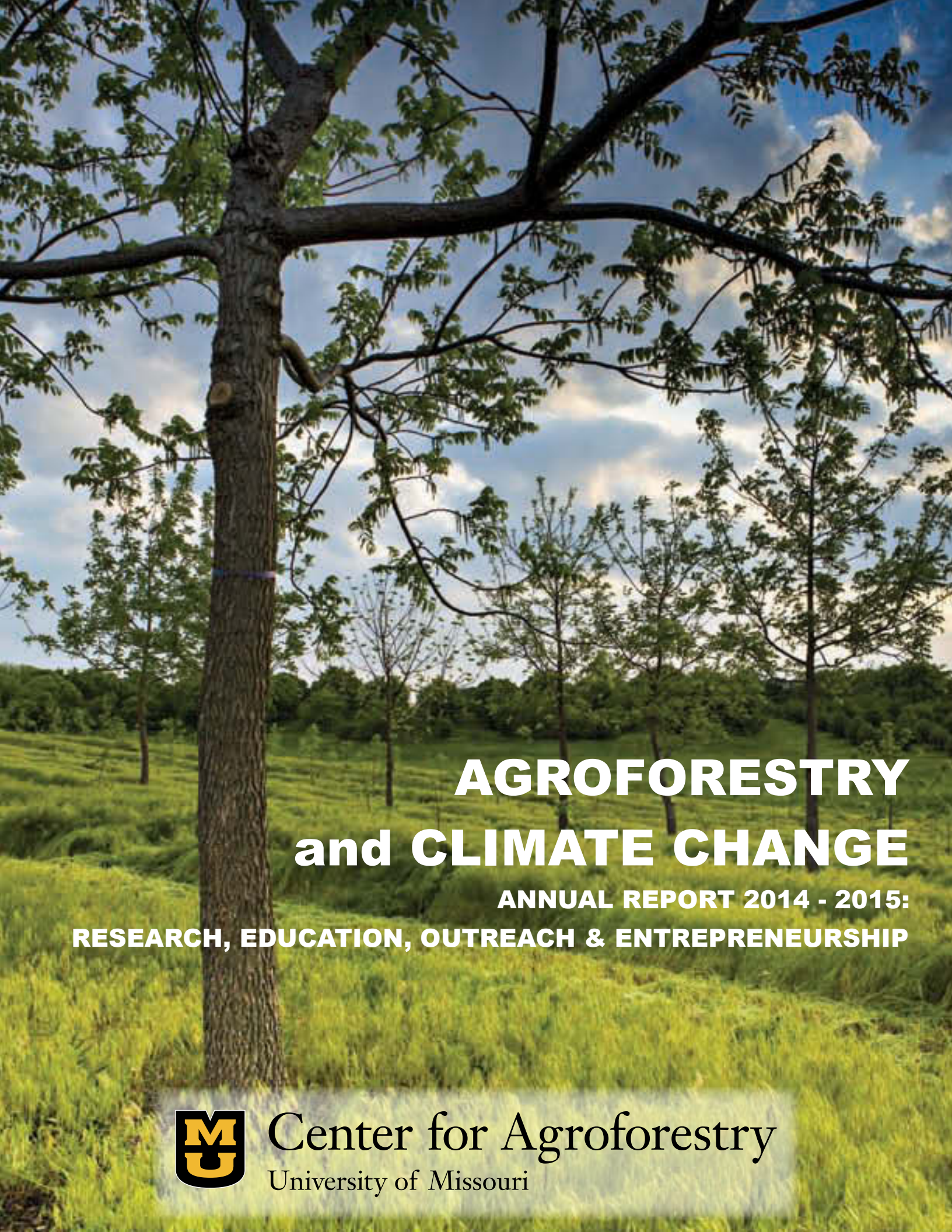

AGROFORESTRY and CLIMATE CHANGE

ANNUAL REPORT 2014 - 2015:

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 several key partnerships with landowners, natural resource professionals, federal and state agencies and non-profit organizations. Through these critical partnerships, UMCA and its partners are producing an expanding list of positive outcomes for landowners, the natural environment and society as a whole.

UMCA Mission

To initiate, coordinate and enhance agroforestry activities to meet the environmental, social and economic needs of land management within the state of Missouri, North America and the temperate zone worldwide.

To accomplish our mission, UMCA:

- Conducts, coordinates and promotes interactive 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 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 a 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: Drs. Michael Gold and Carol L. Williams
Design by Taylor Wanbaugh; Layout by Caroline S. Todd

CONTENTS

DIRECTOR'S MESSAGE

The Center for Agroforestry has completed another successful year! The Center has long been a leader in developing agroforestry practices for the temperate zone worldwide with wide ranging impacts based on our research, education, outreach and economic development programs. The annual report highlights a few of the accomplishments of our faculty, staff and students. It was particularly rewarding to see faculty, staff, and students come together to compete for a record number of external grants and winning many of them from local, state, national and international funding agencies.

Some of the accomplishments we are proud of during 2014-2015 include:

Center faculty and staff were PIs or Co-PIs on grants totaling $7.3 million (research expenditure of $3.2 million), covering a broad spectrum of biophysical and socioeconomic research, outreach and entrepreneurial activities in agroforestry.

Both the on-campus and online agroforestry graduate programs have grown considerably with a total of 41 current students and five Graduates.

Outreach programs have reached new heights by providing local, regional, national and international leadership in program delivery; highlights include thematic workshops, monthly Agroforestry in Action webinars, Green Horizon newsletter with a circulation of over 15,000,Agroforestry Academy, return of the Chestnut Roast – our Center's signature field day, among others.

Entrepreneurial development activities have resulted in multiple invention disclosures, three patents, one trademark, one cultivar release and two start-up companies.

The hard work of our faculty, staff, and students, and support of our stakeholders are responsible for our success, especially for our ability to weather the budget difficulties we faced from 2011 through mid-2014. With a very strong and experienced core team working closely with a wide array of collaborators, our program has demonstrated proof of its' diversity, agility, and ability to react quickly to opportunities. In other words, we are both strong and resilient and remain committed to our mission to support the long-term future of rural and urban working farms and forests by achieving economic, environmental and social sustainability. This annual report outlines the many ways by which we accomplished our mission during 2014-2015. We appreciate your continued support of our program and look forward to another productive year in 2016.

– SHIBU JOSE, Ph.D., H.E. Garrett Endowed Professor and Director,
The Center for Agroforestry at the University of Missouri

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

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. Wildlife may find ideal habitat in a forest farming setting.

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 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 in order 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. Clusters enable UMCA scientists to be more efficient in sharing resources (fiscal, physical and human) and ideas and spawn new proposals to successfully leverage core funding.

Ecosystem services

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

At the Missouri State Fair, UMCA Director Shibu Jose discusses with Governor Nixon biofuels & the Center's on-going research into biomass & conversion technologies.

Socio-economic-marketing

The cluster's integrated approach works to understand the social and economic dimensions of a given enterprise, including institutions, and networks, along with market and non-market valuation. Research activities provide an understanding of factors that facilitate or constrain involvement in agroforestry.

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, one of a kind, online agroforestry MS degree and graduate certificate. In addition, Center faculty offer study abroad programs in conjunction with CAFNR international programs.

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; the annual Missouri Chestnut Roast, the Center's premier annual

RESEARCH CLUSTERS

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.

Medicinals/Phytochemistry

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

Silvopasture/Shade tolerance

Integration of Silvopasture into 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; shade tolerance studies on big bluestem accessions and performance of big bluestem under a canopy of cherry bark oak (and shortleaf pine).

PATENTS & TRADEMARKS

Dr. Chung-Ho Lin and his colleagues Drs. George Stewart and Brian Thompson, were able to develop a spore-based biocatalyst for remediation of pollutants and biofuel production and successfully transfer this technology into a U.S. patent based on the results derived from creating Elemental Enzymes, Inc. One of the developed technologies has been successfully transferred to industry.

- Spore-based biocatalyst for remediation of pollutants and biofuel production (Granted, U.S. Application Serial Nos. 13/089,015, USA 14/849,295. 2015; Spin-off: Elemental Enzymes Inc.

Outgrowing their campus-based startup in the MU Incubator, in 2015 Elemental Enzymes moved its headquarters to a 26,000 square foot building in St. Louis with 20 full time positions for scientists and professionals in the region.

Two additional patents were to Dr. Chung-Ho Lin by United States Patent and Trademark Office, and (Elemental Enzymes, Inc.).

- Contaminant reducing functionalized carbon conjugate (Granted 2013, US 13/448,065)
- Nanocarbon-based biocatalyst for remediation of environmental pollutants and (US2013/0280781 A1 Second Divisional Patent)

Dr. Mark Coggeshall and commercial partner Forrest Keeling Nursery run by Wayne Lovelace and Kim Young (MU alumni), trademarked Bucks Unlimited™, a precocious selection of swamp white oak (*Quercus bicolor*) that produces acorns after the sixth year of growth, instead of the typical twenty years. The tree was chosen to be the 175th planted on the Mizzou campus to commemorate the 175th anniversary of MU.

Dr. Jerry VanSambeek and colleagues released a shade tolerant big bluestem (*Andropogon gerardi*) for silvopasture applications.

Collecting water samples at a constructed wetland connected to a wastewater treatment plant to evaluate effectiveness of wetlands in removing pharmaceuticals & personal care products.

PARTNERSHIPS

The Center for Agroforestry at the University of Missouri partners with universities, natural resource entities, agricultural organizations and landowners across our state and the globe to foster an integrated approach to farming across diverse landscapes. We are a Center for entrepreneurship and the environment through the practices of agroforestry.

MU Collaborations

Bioinformatics Institute
College of Agriculture, Food & Natural Resources
Dalton Cardiovascular Research Center
School of Medicine
School of Natural Resources
Mizzou Advantage
Partnerships with MU faculty: Agronomy; Biochemistry; Children & Family Across Cultures; Civil & Environmental Engineering; Entomology; Family & Community Medicine; Family & Policy Research; Fisheries & Wildlife; Food Systems & Bioengineering; Forestry; Grape & Wine Institute; Horticulture; Human Development & Family Sciences; Life Science Center; Molecular Microbiology & Immunology; Plant Sciences; Physics; Rural Sociology; Soil, Environmental & Atmospheric Sciences (SEAS); Veterinary Pathobiology; University of Missouri AES Farms and Centers: Bradford Research and Extension Center; Greenley Memorial Research Center; Horticulture and 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, University of California-Davis, University of California-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
National Agroforestry Center, Lincoln, Neb.
USDA ARS - Cropping Systems and Water Quality Research, Columbia, Mo.
USDA ARS - Dale Bumpers Small Farms Research Center, Booneville, Ark.
USFS - Central Hardwoods Research Unit, Columbia, Mo.
USDA Forestry Research Advisory Council
USDA Natural Resource Conservation Service
USGS Columbia Environmental Research Center

Professional Associations and Businesses

Association for Temperate Agroforestry
Chestnut Growers of America
Commonweal Foundation
Danforth Center of St. Louis
Elemental Enzymes, Inc.
Etimine USA
Flick Seed Co.
Forest & Woodland Association of Missouri
Forest ReLeaf of Missouri
Forrest Keeling Nursery
Hammons Products Company
Metabolon
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 Society of American Foresters
Missouri Tree Farm System
Monarch Media
MS-Omics
National Aviary
Roeslein Alternative Energy, St. Louis
Shepherd Farm
Thar, Inc.
Tiger Energy Solutions, LLC

Donors and Friends

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

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)
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
World Agroforestry Centre, Nairobi, Kenya

STAFF & COLLABORATORS

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Thi L. Ho, Ph.D., Research Scientist
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Ronald S. Zalesny, Jr., USFS
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Greg DiBenedetto, Graduate Certificate
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Chathuri Weerasekara
Donald Whittaker
Niranga Wickramarathne
Jacob Winterbower, Graduate Certificate

AWARDS

Dr. Chung-Ho Lin, 2015 MU Mizzou Advantage Entrepreneurial Award.

Dr. Shibu Jose, 2014 IUFRO Scientific Achievement Award.

Dr. Shibu Jose, 2014 SAF Barrington Moore Memorial Award.

Dr. Thi Ho, 2014 Japan International Award for Young Agricultural Researchers.

Sche-Min Su, 2014 Research Excellence from Missouri senator Tom Dempsey.

Sche-Min Su, 2014 Life Science Week research excellence award, 1st place.

Sche-Min Su, 2014 Excellence in Undergraduate Research award.

Ryan Dibala, 2015 U.S. Borlaug Graduate Research Fellowship.

Ryan Dibala, 2014 Brown Graduate Fellowship.

Agroforestry for Climate Change Mitigation and Adaptation

Agriculture and the world's changing climate

Climate change and variability are ever-increasing challenges for agriculture and natural resource management. Changes in average weather conditions over time, more frequent extreme weather events like drought and flood, and their effects on crop yields, livestock production, pests, diseases, and weeds have become increasingly problematic. Climate change is predicted to continue or even intensify over the coming decades. At the same time a growing global population needs food, feed, fiber and fuel. Agriculture must deliver these goods while protecting precious natural resources. The pace and complexity of changing conditions threatens to overwhelm current agricultural systems. To preserve long-term productivity we need new approaches and new technologies that will ensure agricultural resiliency and adaptability.

Dr. Ranjith Udawatta explains environmental

Climate-smart agriculture

The Food and Agriculture Organization of the United Nations has identified Climate-smart Agriculture as a pathway for achieving greater agricultural resiliency. Climate-smart Agriculture is defined as production systems that address food security and climate challenges simultaneously. Climate-smart Agriculture has a three-pronged goal to increase agricultural productivity and farmer incomes while adapting and building resilience to climate change, and while reducing the factors that contribute to climate change.

Agroforestry practices create options for income diversification and risk reduction, conserving water, protecting soil and water quality, providing habitat diversity, and sequestering atmospheric carbon above and below ground. Through intentional design and integration of trees, shrubs, crops and livestock, agroforestry practices enhance productivity, profitability, and environmental stewardship, and are climate-smart approaches to improve agricultural resiliency. The Center for Agroforestry has numerous activities that support knowledge and practice of Climate-smart Agriculture. Researchers are looking at runoff, water capture and storage, soil carbon and biomass production in agroforestry practices and developing flood, drought, and shade tolerant cultivars with important implications for Climate-smart agriculture.

Runoff, water capture and storage

Drought and flood, and the means to prevent and mitigate them, are in part, issues of human impact on landscape storage of water. Landscape storage is the absorption and holding of water by soil and vegetation across large areas – ranging from fields to whole farms and entire river basins. Landscape storage of water is frequently diminished through activities that compact soil, expose soil, alter hydrology, and convert natural vegetation like wetlands, prairies and forests to other types of vegeta-

tion. Agroforestry practices can improve landscape storage of water by enhancing the water absorbing and holding functions of soil, increasing the total amount of vegetation during growing season, and increasing the amount of perennial vegetation on the landscape.

Research by UMCA's Drs. Ranjith Udawatta, Gene Garrett, Shibu Jose, and colleagues, examines the effects of agroforestry buffers, cover crops, management intensive rotational grazing (MIRG), and prairie restoration on soil infiltration and hydraulic properties, and run-off. They have designed studies comparing agroforestry buffers, grassed buffers, cover crops, and row crop monocultures, and in paired watersheds of different vegetation cover. Through modeling and field monitoring their findings provide evidence that MIRG and perennial vegetation reduce run-off and improve soil moisture. They have also created a tool for evaluating soil water infiltration and potential runoff to aid design of conservation buffers for row crop management to reduce soil erosion and non-point source pollution.

A flume is installed at a field edge to collect and measure run-off.

Findings of their recent studies confirm previous results indicating that buffers improve soil water storage during recharge due to improvements in soil physical properties. Their studies also show that during the growing season buffers use more water that the annual crops as buffers leaf out early and continue to transpire after the cash crop is harvested. These changes in soil water help reduce soil and nutrient losses from agricultural watersheds and thus help improve water quality which in turn reduces sediment and nutrient contributions to hypoxia zones. Research by UMCA faculty and others funded by the Mississippi River Basin Healthy Watersheds Initiative show that conservation practices such as crop rotation, grass waterways, cover crops, buffers, and nutrient management reduce non-point source pollution from agricultural watersheds.

Carbon sequestration

Reduction of atmospheric carbon dioxide (CO_2) is a world goal for slowing the pace of, and mitigating the effects of, climate change. Capture of atmospheric CO_2 through physical and biological processes is the principle way of transferring it into long-term storage in biomass, soil organic matter, and soil carbon. In general, agroforestry practices enhance the carbon storage potential of the landscape. The enhanced carbon storage concept of agroforestry is based on the efficient use of resources by plant communities that are structurally and functionally more diverse and complex than monoculture systems and unmanaged grazing. Multiple vegetation types in agroforestry systems promote larger and more diverse microbial and faunal communities that also contribute to soil carbon.

Researchers at the UMCA, and their colleagues, are examining carbon accumulation and variability within several temperate agroforestry systems compared to other agricultural practices. (See feature article on carbon sequestration.) Their studies have found more carbon within agroforestry buffers and alley cropping systems than conventional corn and soybean systems. Perennial vegetation of agroforestry in annual row crop-dominated watersheds, and management intensive grazing management practic-

es have shown more soil carbon throughout the soil profile. Deeper roots, increased soil microbial activity and greater amounts of soil litter are attributed for these improvements in soil carbon. These studies imply that temperate agroforestry practices can contribute to climate change mitigation strategies of carbon sequestration.

Biomass

Perennial vegetation in agroforestry has many advantages over agricultural monocultures not just in terms of storing carbon in the soil, but also in above- and below-ground biomass. Perennial trees, shrubs, and grasses have greater carbon storage capacity than annual monoculture crops because they allocate higher percentages of carbon to below-ground biomass and often have longer growing seasons. Perennial warm-season grasses, used as forage in silvopasture systems and as biomass for harvest in alley cropping systems, can provide hydrological, water and soil quality, carbon sequestration, feed and renewable energy benefits. A major challenge, however, is potential yield reductions in grasses due to shade, compared to production in full sun. Another challenge is change in chemical and physical characteristics that may affect forage and bioenergy feedstock quality.

UMCA's Drs. Jerry Van Sambeek, Gene Garrett, Kejia Pang and Shibu Jose are evaluating the shade tolerance and vegetation quality of multiple varieties of Big Bluestem (*Andropogon gerardii*), Switchgrass (*Panicum virgatum*), Indiangrass (*Sorghastrum nutans*) and other native grasses and forage legumes. To do this they are growing more than 40 forage species and cultivars in shade-controlling structures and in alley cropping systems at the Horticulture and Agroforestry Research Center. Through their artificial shade experiments they are screening plants using three levels of shade: 100% of full sunlight (no shade), 45% of full sunlight (medium shade), and 20% of full sunlight (dense shade). All species and cultivars have done equivalently well or significantly better under medium shade than the no shade treatment and a few species have tolerated dense shade very well. Their results have shown that crude protein concentration under medium shade is equivalent to the no shade treatment for most species, but increased under dense shade. With regard to relative feed value, they found that grasses and legumes had a high de-

September 2015, Researcher Kejia Pang collects photosynthesis measurements on perennial grasses in an alley cropping system at the Horticulture and Agroforestry Research Center in New Franklin, Mo. Photo by Lijie Zhao.

gree of shade tolerance, but grasses were slightly more tolerant.

The researchers conclude that overall, agroforestry practices featuring medium shade conditions have the potential to produce equivalent or even higher forage yield than open pasture while maintaining comparable level of forage quality. These results are providing important information for calibrating the use of perennial warm-season grasses in agroforestry with the needs of livestock producers and bioenergy producers. Improving the productivity of these systems and the quality of their products may help expand the adoption of Climate-smart Agriculture.

Biochar for improving soil quality

Biochar is a carbon-rich solid material produced by thermal decomposition of biomass under limited supply of oxygen (O2), and at relatively low temperatures (<700 °C). Pyrolysis is the method that is used to produce biochar. It can be used alone or as a component of a blended product, with a wide range of applications. The specific properties of biochar such as high stability against decay and superior ability to retain nutrients in comparison to other forms of soil organic matter enhance the value of this product.

Chathuri Weerasekara working with plants for biochar research in the greenhouse at HARC. Biochar amendments increased crop production and improved water holding capacity of marginal soil.

Biochar can be made from biomass waste materials. Biomass waste materials that can be used for biochar production include crop residues (both field residues corn stover, switchgrass, wood chips and processing residues such as nut shells, fruit pits, bagasse, etc.), as well as yard, food and forestry wastes, and animal manures. The characteristics of biochar depend on its production method and type of feedstock used. The production parameters such as temperature, rate of temperature increase, pre and post processing also affect the quality of resulting biochar including availability of nutrients to crops, physical and chemical properties of crops, and the amount of stable carbon (C) sequestered.

Studies have demonstrated that biochar application can enhance several soil properties such as increase of soil pH, CEC, total C, total N, available P, water holding capacity, exchangeable cations, nutrient cycling and attracting more beneficial fungi and microbes, while decreasing available soil Al, soil strength, and soil bulk density. These factors provide numerous benefits to increase biomass yield and crops yield under different conditions. Furthermore, soil biochar additions can reduce the nutrient leaching and have the capacity to absorb dissolved organic C (DOC) from the soil solution. Hence the ability of biochar to reduce N mineralization and NO3-−N leaching are important in making management options in the agriculture production.

Moreover, biochar is important for improving beneficial microbial populations in the soil. Because of high porous structure and large surface area of biochar it can harbor beneficial soil micro-organisms such as mycorrhizae and bacteria, and enhance the

binding sites for nutrients. Therefore it would increase the bioavailability and plant uptake of key nutrients. In addition, it has been reported positive interactions when N fertilizer and biochar were applied together as more N fertilizer remained in the biochar amended soil than soils without amendments. Therefore, the ability of biochar to retain and prevent leaching of N can increase N fertilizer use efficiency and maintain crop yield under smaller N inputs.

Screening for Flood Tolerance of Herbaceous and Woody Crops

Extreme weather events such as severe droughts and frequent prolonged floods are becoming regular events in the Midwest. Increasing flood and drought tolerance of agricultural crops will be essential to adapting to these new norms. Promising biomass crop species, for deployment in marginal lands along the Missouri and Mississippi river floodplains, include short rotation trees such as cottonwood (*Populus spp.*) and willow (*Salix spp.*), perennial grasses such as giant miscanthus (*Miscanthus giganteus*) and switchgrass (*Panicum virgatum L.*) and annuals like high biomass sorghum (*Sorghum bicolor* L.).

High biomass sorghum cultivar evaluation for flood tolerance established by Dr. Sougata Bardhan at the HARC Flood Tolerance Laboratory.

Identifying and developing flood tolerant cultivars of these species has been a goal for a team of UMCA researchers for the past three years. The objective of this study is to evaluate the performance and suitability of four promising biomass species for survival, establishment, growth and flood tolerance in a Midwestern floodplain. The sorghum minicore collection (from ICRISAT) with 243 cultivars from different parts of the world was also screened for flood tolerance. Fifteen variety/cultivars each for poplar, willow, switchgrass, and sorghum (three replicates) were planted in the flood tolerance lab located at the HARC. Imposed flood treatments were 0, 1, 3 and 6 weeks for the variety trial and 4 weeks for the minicore trial. Various cultivars responded to flooding differently. Some biomass sorghum cultivars were susceptible to lodging. Additional flood tolerance screening was conducted in greenhouse trials following screening in the outdoor flood lab. After the first year, the most tolerant and most susceptible genotypes of sorghum were tested further under field and greenhouse conditions.

Based on these results, two contrasting genotypes (tolerant vs susceptible) were selected to study gene expression responses in apical and basal root zones in response to waterlogging. Waterlogging and control conditions were imposed on 30 days old greenhouse-grown plants of the two genotypes. Tissue samples from the growth zone and basal region of nodal roots of waterlogged and control plants were sampled and used for RNA-seq analysis. Results of the differentially expressed genes (DEG) will provide new insight into sorghum responses to waterlogging and candidate genes for the development of tolerant cultivars.

Overall, results of multiple experiments suggest that selections of tolerant cultivars of biomass feedstocks species can be deployed in river floodplains subject to prolonged flooding, which are not suitable for production agriculture. New cultivars are also under development that may even offer better biomass growth under flooded conditions.

Agroforestry's Role in Global Carbon Sequestration

In December 2015, world leaders from 195 countries met in Paris and agreed on a landmark plan to address global climate change by holding countries accountable for their commitments to carbon emissions reductions and other actions. The agreement calls for all nations to pledge to limits on carbon (C) emissions necessary to keep average global warming less than 2 degrees Celsius above pre-industrial levels. This historic agreement recognizes the importance of "reducing [C] emissions from deforestation and forest degradation, and the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks…[and] sustainable management of forests." Success of the plan depends on the ability of individual countries to not only reduce emissions but to also capture C from the atmosphere and keep it out of the atmosphere.

Carbon sequestration (CS) is the long-term storage of C in oceans, soils, vegetation and geologic formations. Storage of C in vegetation occurs through uptake of atmospheric carbon dioxide (CO_2) during photosynthesis and conversion into plant biomass. Soil storage of C occurs when soil microbes convert dead plant matter into soil organic matter through decomposition. To meet the ambitious goals of the Paris Agreement, the world needs enhanced CS techniques that provide social, environmental, and economic benefits while reducing atmospheric CO_2 concentrations.

Alley cropping on 10% of the U.S. cropland could sequester 24 million tons of carbon per year.

Agroforestry (AGF) practices have been approved as a strategy for soil CS by both afforestation and reforestation programs and under the Clean Development Mechanisms of the Kyoto Protocol. This is primarily due to use of perennial vegetation in AGF practices. Perennial vegetation provides opportunities for above- and below-ground biomass production and potential for greater soil carbon creation. Perennial trees, shrubs, and grasses used in AGF are more efficient in CS than annual monoculture crops and pasture vegetation because they allocate a higher percentage of C to belowground biomass and often extend growing seasons. Agroforestry practices accumulate more C than forests and pastures alone because AGF combines forest and grassland components.

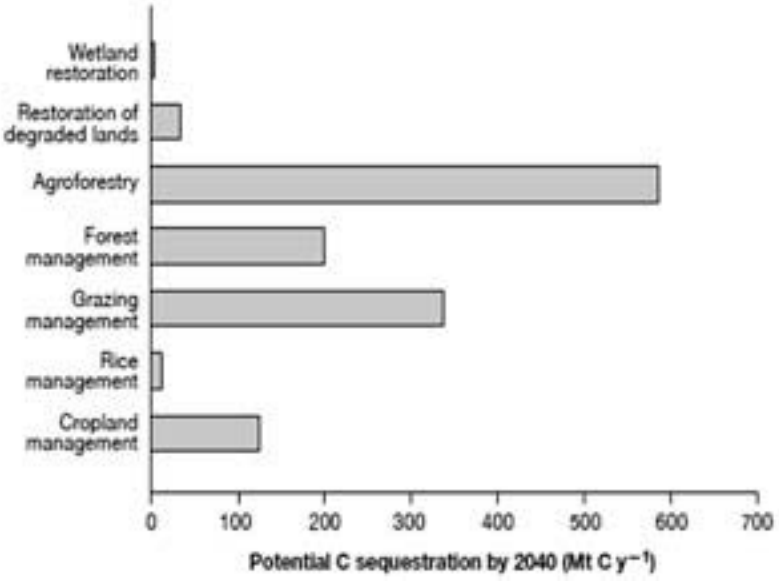
The enhanced CS concept of AGF is based on the efficient use of resources by plant communities in AGF practices. Agroforestry systems typically have more structurally- and functionally-diverse plant communities than crop monocultures or unmanaged grass systems. Diverse plant communities in AGF result in greater capture of available sunlight which drives greater use of CO_2 for photosynthesis and therefore more sequestration in plant biomass and eventually soil carbon. For example, trees, grasses, and shrubs in corn-soybean alley cropping begin photosynthesis before the cash crop is established and continue after the cash crop is harvested, and they partition greater amounts of carbon to belowground biomass (roots). Moreover, the quantity and quality of plant residue supplied by trees, shrubs and grasses in AGF enhances soil C as these materials are decomposed by soil microbes. Multiple vegetation types also promote larger and more diverse microbial and faunal communities which contribute further to soil C. This sequestration potential of AGF varies by the type of practices used (plants and management), climate, soil type, topography, hy-

drology, and ages of the component species of particular AGF systems. In well-managed AGF production systems C can be retained for centuries.

Highly productive riparian buffers, silvopastures, alley cropping systems and windbreaks can play a significant role in CS in soil and biomass. Center for Agroforestry researchers Drs. Ranjith Udawatta and Shibu Jose conducted a synthesis of the available literature for the conterminous U.S., and concluded that agroforestry practices have the potential to sequester more C than current cropping systems. They estimated an average aboveground C stock of 55 tons C per acre for mature riparian buffers with a 50-year cutting cycle. There are 3.5 million miles of river and stream length in the conterminous U.S. upon which conservation buffers could potentially be established. Establishment of a 100 ft. wide riparian buffer along both sides of 5% of total river length would occupy 2 million acres. The potential CS by addition of riparian buffers could be as high as 2 million tons per year.

Well-managed silvopastoral systems can improve overall agricultural productivity while sequestering carbon. For example, soil productivity in traditional cattle management systems declines beyond five years post-forest clearing for establishment of pastures. The result is release of significant amounts of C into the atmosphere. Estimates of C released from low productivity pastures in Latin America range from 14-27 tons per acre in the first 20 years after forest clearing. On the slopes of the Ecuadoran Andes, total soil C increased from 8% under open *Setaria sphacelata* pasture to 11% beneath the canopies of *Inga* spp while soils under *Inga* contained an additional 9 tons per acre in the upper 6 inches of soil compared to open pasture. Silvopasture in the U.S. could potentially sequester 190 million tons of C per year.

A large body of literature both from tropical and temperate regions elucidates the positive effects of AGF on CS by alley cropping. In the southern U.S., greater soil organic matter and microbial biomass were found in pecan (*Carya illinoensis*)-cotton (*Gossypium hirsuitum*) alley cropping as compared to monocrop cotton. In Missouri, C quantities were found to be greater in alley cropping practices as compared to conventional corn-soybean rotation. Unfortunately, adoption of alley cropping has been slow in the US. Cropland in the U.S. occupies about 442 million acres which includes approximately 40 million acres of idle land. Dr. Gene Garrett and colleagues suggest that 98 million acres of highly erodible nonfederal cropland (22% of total cropland) could be suitable for alley cropping. It is estimated that less than 10% of U.S. cropland will be used for alley cropping in the near future. The CS potential of alley cropping on that 10% of cropland could sequester 24 million tons C per year.



According to IPCC, of all the managed land use systems, agroforestry has the greatest potential to sequester C globally.

Source: IPCC, 2000

CARBON SEQUESTRATION

Approximately 230 million acres of cropland in the North Central region of the U.S. need windbreaks to reduce agricultural damages. Additional windbreaks are required to protect homes and roads. It is estimated that 210 million acres under windbreaks would have a sequestration potential of 1.78 billion tons of carbon per year. If only 5% of cropland were converted to windbreaks, 120 million trees planted for farmstead protection, and 2 million conifers were planted for road protection, the result would be sequestration of approximately 4 million tons of C per year after 20 years.

Overall, U.S. agroforestry has the potential to sequester 220 million ton of C per year which is enough to offset nearly a third of the current C emission in the U.S.

A large number of studies have appeared in recent years on CS potential and C stocks of agroforestry systems all over the world. In the West African Sahel, improved agroforestry practices such as live fence and fodder banks sequestered more carbon than traditional parklands. In northwest India, under a poplar-based agroforestry system, the soil organic carbon concentration and pools were higher in soils under agroforestry and increased with tree age. Tree density and plant-stand characteristics such as species richness and age of south Indian home gardens also affected soil carbon sequestration. These case studies add to the growing body of literature indicating that agroforestry systems have the potential to sequester more above- and below-ground carbon compared to traditional farming systems.

In general AGF practices improve soil condition, soil water status, and microclimate and these improve plant growth conditions which further enhance the CS potential of the landscape. Selection of suitable trees, shrubs, and grasses and improving management practices can further improve CS for enhancing Climate-smart agriculture. Additional research and more comprehensive data are needed to improve knowledge of C distributions in all AFS practices across countries. This information will help improve design of AGF systems for enhanced CS and increase the success of the Paris Agreement.

The Annual Missouri Chestnut Roast, Celebrating Agroforestry, attracts 1,500 - 3,000 visitors to Horticulture & Agroforestry Research Center in New Franklin, MO.

Did you know... *Agroforestry could sequester enough carbon to offset a third of the U.S. carbon*

Climate-smart pasturing

Agroforestry practices, including silvopasture, can be used to diversify risk in the face of a changing climate. Changing climatic conditions affect animal agriculture due to changes in forage crop production and quality, and animal health, growth, and reproduction. Livestock and dairy production are more affected by the number of days of extreme heat than average with average temperature. Projected increases in extreme heat events will increase animal stress leading to greater impacts on production. Optimum animal core body temperature must be maintained within a 4°F to 5°F range, larger deviations in temperature create animal stress. Livestock production practices such as silvopasture, which provide partial or total shelter, can reduce the risk and vulnerability associated with extreme heat. Silvopasture practices modify the local microclimate to reduce direct impacts of weather extremes on animal production.

Research has shown that livestock prefer shaded areas in summer. Shade increases beef steer gains by ~0.2 lb./head/day compared to no shade. Milk production in dairy cows can also be increased ~ 15% by providing shade. In addition, beef production from silvopastures is equal to or greater than open pastures in well designed and managed systems.

International

Doctoral candidate Ryan Dibala, working under the supervision of Dr. Jose, is investigating plant neighborhood effects on production and nutrient availability in silvopastoral systems. With financial assistance from the Brown Fellowship and Borlaug Global Food Security Fellowship, Ryan spent the summer of 2015 in Panama establishing ~3.5 acres of multi-strata silvopastoral systems. Silvopasture can be implemented in two ways: by planting trees on to pasture or by planting pasture beneath existing trees. In the pasture, Ryan is examining the neighborhood influences of nitrogen fixing and phosphorous aggregating fodder trees on the growth and survival of commercially important timber seedlings and grass dry matter yield. In the understory of native mixed species tree plantations, he is assessing the growth and nutritional content of several species of popularly planted improved grasses across a gradient of shade intensities. Due to the recent surge of reforestation in the region, there is a need for research on the effects of multiple land use on the growth and survival of mature native trees.

UMCA graduate student, Ryan Dibala, transports *Leucaena* seedlings by horse in Los Santos Province, Panama.

Domestic

At the Horticulture and Agroforestry Research Center (HARC), New Franklin, Missouri, Ryan Dibala is establishing a multi-strata silvopastoral system in the understory of cherrybark oak (*Quercus pagoda*) plantations. Understory plants include red mulberry (*Morus rubra*) saplings, orchardgrass (*Dactylis glomerata*) and red clover (*Trifolium pretense*). Ryan will examine the combined effects of shade and nitrogen fixation on the growth, dry matter yield, and nutritive content of red mulberry leaves to assess the practicality of integrating this alternative forage into rotationally stocked grazing systems.

Did you know… *Cattle can gain up to 20% more weight when provided with adequate shade than without shade.*

Eastern black walnut

The development of improved black walnuts for use in Missouri agroforestry practices (e.g. alley-cropping) continues to focus on: 1) identification of the best adapted and most productive cultivars currently available to landowners; 2) development of an applied breeding program that seeks to maximize future crop yields, both in terms of nut quality and quantity; and 3) defining the genetic basis for host resistance to emerging pests such as thousand cankers disease, using both clonal and seedling-origin pedigreed populations.

The walnut descriptors multi-year dataset has been critical to the identification of the most productive and best adapted accessions in the UMCA collection, leading to the development of landowner recommendations across Missouri based on nut productivity and season length data. These same data led to the identification of which specific cultivars to hybridize in our applied breeding program.

Applied Breeding Program. A total of 12 control pollinated trees from the 2002 seed year were re-propagated in the spring 2014 and outplanted at HARC and the Southwest Center in 2015. These 12 selections are the "best" nut producers derived from the UMCA breeding program to date, based upon cumulative nut data from 2005-2010.

Multiple Pedigreed Population Development. The creation of large full sib populations (in which multiple seedling offspring all share the same male and female parents) will facilitate the development of the first "genetic map" for black walnut. This map will be used to identify specific genetic markers associated with sets of genes which control commercially important traits of interest, such as kernel percent and nut yield. In addition, it will clarify the genetic basis for resistance to emerging pests that threaten black walnuts, such as Thousand Cankers Disease.

Key Findings: Genotyping work was completed in 2011, and 320 full sibs representing a single cross were identified. Another set of 135 individuals represented a second cross. These two "mapping populations" will ultimately allow us to define which genetic markers are associated with which phenotypic trait of interest (e.g. leafing date, anthracnose tolerance, early flowering, kernel percent, walnut twig beetle feeding preference, etc.). In 2014, stem and leaf samples were collected from each full sib to develop a genetic marker library. This library will contribute to the development of the first densely populated genetic linkage map for this species. This genetic marker development effort is supported by the National Science Foundation. Publication of the first genetic map for black walnut is scheduled for early 2016.

Dr. Chung-Ho Lin and his team are identifying the differences found among the black walnut trees in our collection at HARC. As these differences are defined, we will explore ways to improve this species in terms of contributing to healthy human diets.

Did you know...*There are more than 50 health promoting chemicals in black walnuts.*

GLOBAL FOOTPRINT 201

4-2015

- Online/On Campus Agroforestry Masters Students
- Research Collaborators/Others

SPECIALTY CROPS

SPOTLIGHT

"Bucks Unlimited" Swamp White Oak

The 175th commemorative tree at Mizzou, called 'Bucks Unlimited Oak' represents a joint effort by CAFNR's Center for Agroforestry and Forrest Keeling Nursery. Center researchers did the research and development, while Forrest Keeling added its RPM technology to quickly grow large numbers of trees.

'Buck's Unlimited Oak' is a new trademarked swamp white oak (*Quercus bicolor*) tree variety developed by Dr. Mark Coggeshall, assistant research professor of forestry. He developed it at HARC. Swamp white oak is a native tree often found in Midwestern bottomland forests and valleys.

Acorns from the swamp white oak species are the most preferred fall food source for many wildlife species, including white tailed deer and turkey. According to Dr. Coggeshall, no other source of planting stock is also well adapted to the regional growing conditions of the Midwest, and potentially most of the eastern U.S.

Dr. Mark Coggeshall giving a tour at HARC.

'Bucks Unlimited' White Swamp Oaks at Horticulture & Agroforestry Research Center in New Franklin, Mo.

The goal was to select for swamp white oak seed sources that had consistent, heavy acorn production at ~ six years of age (much earlier than similar oaks in the wild), along with greater survivability and faster growth in a variety of climates.

Because of this ability, 'Buck's Unlimited Oak' was trademarked by MU and licensed for production to Forrest Keeling. The company is selling the tree to landscapers, conservationists, landowners and others in the tree's natural growing area of Kansas to Florida to Maine.

Ultimately, it is landowners who most benefit as the tree attracts wildlife to property for recreational viewing and hunting. Good hunting property is worth thousands of dollars more per acre than other property, said Shibu Jose, director of the MU Center for Agroforestry. Hunting, according to Hunting Works for Missouri, supports 24,000 jobs in Missouri with an overall impact of $1 billion.

Story adapted from Randy Mertens · Photography by Kyle Spradley

Did you know...*A farmers annual revenue may increase up to 10% through silvopasture.*

TREE & CROP INTERACTION

Several perennial warm-season grasses native to the Midwest are feedstock candidates for cellulosic biofuel. Integrating these grasses into alley cropping practices has the potential to reduce greenhouse gas emissions, improve soil health and enhance wildlife habitats. Although switchgrass (*Panicum virgatum*) has been identified as a model feedstock species for cellulosic biofuel, Indiangrass (*Sorghastrum nutans*) may be better suited for low-input alley cropping systems. In field trials at the Alley-cropping Shade Laboratory (ACSL) located at MU's Horticulture and Agroforestry Research Center, Indiangrass survival and yield exceeded switchgrass, indicating that Indiangrass is more shade tolerant in alley cropping systems compared to switchgrass.

Researcher Dr. Kejia Pang checks switchgrass cultivar 'Kanlow' under shade.

Drs. Shibu Jose and Sougata Bardhan evaluating a new biomass switchgrass cultivar.

Four native warm-season grasses were established in an experiment of different shading conditions at ACSL in 2010-2011. The experiment includes an open field treatment adjoining alley-cropping treatments with three replications of 20 foot, 40 foot, and 60 foot north-south oriented alleys. Tillers from plants grown in the Shade Tolerance Screening Laboratory (STSL) were used to establish five eastern gamagrass (*Tripsacum dactyloides*), six big bluestem (*Andropogon gerardii*), and thirty little bluestem (*Schizachyrium scoparium*) accessions. Seedlings from the NRCS Plant Materials Center was used to establish 'Rumsey' Indiangrass and fifteen switchgrass cultivars. Photosynthetically active radiation sensors were mounted across each alley to determine daily sunlight received at multiple positions within alleys on cloudless days.

Of the five warm-season grasses evaluated, third year survival rates indicate that eastern gamagrass and Indiangrass are more shade tolerant than little bluestem and big bluestem. Upland and lowland switchgrass ecotypes were found to be intermediate for shade tolerance. Average above-ground biomass per plant decreases as the cumulative average daily sunlight received decreased. Indiangrass showed the least change in biomass production between 75% of full sunlight in the 60-foot alleys and full sunlight in the open plots suggesting a relatively high tolerance to shading and an ability to compete with tree roots for water and nutrients. Early results suggest Indiangrass would be a better species for production of biofuel feedstocks in an alley-cropping practice compared to switchgrass.

EDUCATION

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. 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 January 2016, there are 36 enrolled in M.S. program (in 2014 and 2015, a total of five student graduated with their online M.S.) and five students enrolled in the graduate certificate program (1 completed the graduate certificate in 2015).

Dr. Michael Gold teaches online courses, conducts the annual academy & gives presentations at workshops and conferences.

Jacob Winterbower's (Dr. Gold, Advisor) MS essay was: "Effects of Buffer Width and Site Characteristics on Phosphorous Runoff: A Review of Scientific Literature." Garien Behling's (Dr. Jose, Advisor) essay was: "The USDA Agroforestry Strategic Framework: Reversing the Trends and Consequences of the 20th Century and Saving American Agriculture." Brandon Bless (Dr. Gold, Advisor) MS project focused on the development of two new courses at Sterling College in Vermont, "An Introduction to Restoration Agriculture" and in response to student and faculty interest, a second course "Agroforestry Practices". Brandon presented "Restoration Agriculture Curriculum at Sterling College: Growing Tree Crops and Cultivating the Next Succession of Agriculturalists" at the 2014 Sustainable Agriculture Education Association (SAEA) conference in Raleigh, NC. Michael Hill (Dr. Jose, Advisor) MS essay was: "Dynamic Mineral Accumulation in Agroforestry Systems" which he presented at the 14th North American Agroforestry Conference, June 1-3, 2015, in Ames, Iowa. Stephen Mann's (Dr. Gold, Advisor) essay was: "Ozarks Nature Trails Urban Agroforestry Demonstration and Education project" and he presented "Urban Agroforestry: Connecting Agroecology, Permaculture, Urban Forestry and Urban Agriculture into Urban Food Forests" at the 14th North American Agroforestry Conference, June 1-3, 2015, in Ames, Iowa.

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.

New Study Abroad Program in Indonesia

A new Nature, Culture and Agriculture Study Abroad program in Indonesia (December 27, 2015 to January 18, 2016) was recently offered through the CAFNR Study Abroad office and the MU International Center. Led by UMCA's Dr. Jose and Gregory Ormsby Mori, the program explored themes of agricultural production, conservation of natural resources and Indonesian culture. Local partners included faculty at two host institutions on

the Island of Java: the Institute Pertanian Bogor (IPB) in Bogor and the Universitas Gadjah Mada (UGM) in Yogyakarta. The program consisted of numerous site visits and field trips along with informative presentations at IPB and UGM on the themes of agriculture, forestry, food security, and conservation in Indonesia. Students also had the opportunity to visit the World Agroforestry Centre (ICRAF), the Bogor Botanical Garden, and the Center for International Forestry Research (CIFOR). While traveling between Bogor and Yogyakarta students visited national parks, agricultural landscapes, community managed forestry sites, and marine conservation projects. Yogyakarta is considered to be the cultural capitol" of Indonesia, where both traditional and modern styles of art are found intermingled with music, theatre and other forms of cultural expression. Special opportunities were arranged for academic and cultural interaction with local Indonesian students.

Indonesian Study Abroad team visiting an agroforestry system involving Melaleuca (*pollarded tree pictured), corn & soybean near Yogyakarta.*

Graduate Program on Food Security in the Eurasian Region

As part of a large University of Missouri faculty effort, a number of UMCA faculty are involved in developing courses in a Food Security Master's degree project for the World Bank. The project is focused on curricular development for two Master's degree programs for the faculty at Moscow State University (Russia), one in AgroFood Management and a second on Land and Water Resource Management. The overall project goals are: 1) Building the knowledge and skills needed to critically examine and formulate sustainable, innovative solutions to problems that impact food security and land and water resource management throughout the Eurasian Region; and 2) To promote the development of a network of professionals throughout the Region.

Center faculty are involved in a number of the courses and include Dr. Jose (Ecological Principles of Natural Resources and Agroecosystem Management) and Dr. Jose and Dr. Udawatta (Fundamentals of Land Resource Management for Food Security), Dr. Lin [with Dr. Lupo] (Climate Change, Land Degradation and Desertification and Implications for Food Security), and Dr. Gold [with Dr. Hendrickson and Dr. Williams] (Sustainable Agriculture and Development).

Shibu Jose, UMCA Director and Project Co-Leader, along with colleagues from MU Division of Applied Social Sciences and Monarch Media at Moscow State University, Russia.

OUTREACH

The Center's outreach activities introduce the benefits of agroforestry practices, both economic and environmental, to agricultural and forest landowners, natural resource professionals and consumers. The results of a multi-faceted, sustained commitment to knowledge creation "putting the science behind the practice", information sharing and transfer include: greater adoption of agroforestry practices, comprehensive research to support the 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 and urban areas.

In 2014, with a fresh infusion of financial support in collaboration with the USDA ARS, Booneville, Arkansas, UMCA expanded its outreach capacity with the addition new staff including: former UMCA Director Dr. H.E. "Gene" Garret as Senior Outreach Specialist and Gregory Ormsby Mori as Education and Outreach Coordinator.

During 2014-2015, Center outreach delivered useful information about the benefits of agroforestry to thousands of people through two newsletters (Agroforestry in Action and Green Horizons), launched the Agroforestry in Action webinar series, sponsored events that included workshops and tours, and via the addition of new online resources available on the Center's website (centerforagroforestry.org). Outreach efforts also included exhibits and presentations at local, regional, national, and international events ranging from agricultural field days, to regional growers' conferences, scientific and professional events including Missouri Natural Resources Conference, Great Plains Growers Conference, Northern Nutgrowers Association meeting, Walnut Council meeting, Green Lands Blue Waters Conference, Society of American Foresters convention, biennial North American Agroforestry Conference, ASA/CSSA/SSSA Annual Meeting, and World Agroforestry Congress.

Highlights

Agroforestry Symposium

Since 2010, the Center has hosted an Annual Agroforestry Symposium to highlight and explore in depth a current and compelling topic relevant to agroforestry science and practice.

The focus of the 2014 Symposium was cover crops. The 2015 the Annual Agroforestry Symposium was entitled "Climate-Smart Agriculture: the Role of Agroforestry" had over 180 in attendance plus an additional 350 online viewers. The theme for the 7th Annual Agroforestry Symposium to be held on January 28, 2016, is: "The Future of Pollinators: Why Agroforestry Matters."

Agroforestry Academy

The Agroforestry Academy was established to train the next generation of agroforestry professionals and expose them to agroforestry opportunities through classroom work and farm visits. "We're trying to create a network of knowledgeable people," said Michael Gold, associate director of the Center for Agroforestry. "This is an opportunity to go more in depth. We try to put a lot of content in a week."
The initial project was a joint effort among five Midwestern states — Nebraska, Missouri, Minnesota, Iowa and Wisconsin — that compose the Mid-America Agroforestry Working Group (MAAWG). The innovative program was funded for the first two

2015 Agroforestry Academy attendees and instructors

years as a USDA North Central SARE Professional Development Program and earned a national award from the USDA. The project was named the 2012 Paula Ford Professional Development Program Proposal of the Year.

In 2013, the 1st Agroforestry Academy was held in Columbia, M0. In 2014 the Agroforestry Academy shifted north to Minnesota in partnership with the University of Minnesota. In 2015 Academy returned to Columbia, and saw greater participation from landowners and beginning farmers. The 25 participants from across North America, including California, Connecticut, Indiana, Illinois and Kansas and Ontario, Canada. The Center offered scholarship opportunities this year for military veterans through the "Armed to Farm" program, funded by the National Institute for Food and Agriculture. Ten military veterans attended the academy on the scholarship fund. In the first three years, 81 individuals have participated in the Academy and participant feedback surveys give the Academy very high marks.

Missouri Chestnut Roast

The Center created the Roast in 2003 to showcase the ongoing research in specialty crops and agroforestry at HARC. The Roast was the Center's premier annual outreach event for the next 8 years (through 2010), averaging over 3,000 visitors per year. With a return of fiscal stability in 2014, the Roast was reestablished in 2015. More than 1,500 people attended the Roast at HARC on Saturday, Oct. 17, 2015. Agroforestry practices and specialty crops (including chestnut, black walnut, pecan, pawpaw, elderberry) were highlighted. Guests were able to sample roasted chestnuts, purchase fresh chestnuts from regional vendors, buy chestnut trees from Forrest Keeling Nursery and attend a chestnut cooking demonstration. There was music, children's activities, and tours of HARC and the Historic Hickman House, built in 1819 and fully restored. Over 20 local vendors included demonstrations, samples (including goat cheese, salsa, wine, locally brewed beer, specialty flavored whiskey, nuts and fruits, pies, Buck's pawpaw ice cream) and educational materials.

Missouri Chestnut Roast features a cooking demo, samples, and plenty of chestnuts for purchase.

Agroforestry Tours & Workshops

Center faculty and staff regularly provided in-depth HARC tours for MU students and students from both US and foreign Universities, along with groups from Missouri, the Midwest, across the USA and worldwide. A 3-day tour was arranged for NRCS staff from Arkansas, Missouri and Louisiana to view agroforestry practices at HARC and at selected sites around central Missouri. The Center hosted a wide assortment of international professionals that included: China, Inner Mongolia, Tajikistan, Costa Rica, Mexico, India, Indonesia, Senegal, and Germany. In

Senator Roy Blunt discussing agroforestry's potential to help farmers during his visit to the Horticulture and Agroforestry Research Center.

addition to the MU HARC farm, Center researchers are conducting research and outreach at other MU farms and Centers. For example in 2015: an agroforestry workshop was organized for landowners at the Doug Allen Research and Education Site; an agroforestry tour was organized as part of the Walnut Council annual meeting in St. Charles, MO; a nut growing workshop was held at the MU Southwest Center in Mt. Vernon, MO. Six gourmet mushroom cultivation workshops were held in collaboration with MU County Extension offices and other partners and several mushroom growing demonstration areas were installed at HARC, Wurdack Research Farm and other sites around Missouri.

Outreach Coordinator, Gregory Ormsby Mori demonstrates mushroom log preparation.

Agroforestry in Action Webinar Series

New to the Center's outreach programming, the "Agroforestry in Action Webinar Series" was launched in March of 2015. These presentations showcase agroforestry research and practice, drawing on examples from both the USA and around the globe. Information and recorded webinars can be viewed at: www.agroforestryinaction.org

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 and to an additional 3,500 readers through the postal mail. 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/index.htm

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://centerforagroforestry.org/pubs/action/archive.php

2015 Field Day at Doug Allen's, Laurie, Mo.

Production of Biofuels

Development of a novel continuous-flow saccharification process for advanced biofuel

The 2007 U.S. Energy Independence and Security Act mandates that annual biofuel use nearly triple to 36 billion gallons per year (BGY) by 2022 with 21 BGY coming from advanced biofuels. Although cellulosic advanced biofuel production has been demonstrated on a pilot scale, the high enzyme cost associated with the saccharification process (enzymatic hydrolysis of cellulose to sugars), has been a bottleneck for commercial-scale success. Commercial-scale production requires transformational science to streamline the production process and significantly lower production cost.

UMCA's Drs. Chung-Ho Lin and Shibu Jose and other MU colleagues have teamed up with strategic industrial partners. The transdisciplinary research team created to develop a novel saccharification process for the production of advanced biofuels includes: UMCA, MU Life Sciences Center, Dept. of Physics and Radiology, Dept. of Veterinary Pathology, Dept. of Biological Engineering, Cancer Nanotechnology Platform, and Tiger Energy Solutions, LLC. The novel continuous-flow saccharification process design integrates a recently developed cost-effective enzyme immobilization technique, a readily regenerated enzyme platform, genetically engineered enzymes, and optimized ionic liquid pretreatment processes.

The process design, in brief, incorporates the immobilized genetically engineered recombinant enzymes fused with linkers that are highly specific to the readily regenerated biofilter system comprised of functionalized mesh. The expressed enzymes will be subsequently immobilized to the functionalized biofilter system. Laboratory scale studies are evaluating the conversion efficiency, enzyme stability, platform regeneration cycles, cellulose depolymerization, sugar profiles, production cost and scalability of the bioreactor system.

The developed genetic cassette and cost-effective functionalization and immobilization process can be utilized to 1) rapidly immobilize the enzymes on the designed platforms, 2) express a wide variety of industrial enzymes on the same platform, 3) regenerate and reuse the platforms, and 4) improve chemical stability, thermal stability, and storage shelf-life of the enzymes in the continuous-flow bioreactor system.

The innovative bioreactor system has several advantages over existing technologies, including 1) reduction of enzyme cost by improved chemical stability, thermal stability, and storage shelf-life of the immobilized engineered enzymes, 2) more effective enzyme loading and enzyme synergies for industrial process, 3) regeneration of the enzyme biofilter system (~20- fold) by a simple, low-cost thermal regeneration, 4) elimination of the cost associated with enzyme purification and chemical conjugation processes, 6) efficient recycle/reuse of enzymes, and 7) easily customized enzyme production with the developed genetic cassette.

Upon completion, the research team's innovative continuous-flow bioreactor system will demonstrate conversion efficiency orders of magnitude better than conventional processes, thus making biofuel manufacturing commercially sustainable. The bioreactor system will provide immediate competitive advantages and market differentiation. During the current R&D phase, the project benefits from MU's commitment to accelerating investment activity and growth of its' entrepreneurial culture. This project is expected to attract broad industry interest and facilitate translation of the technology into commercial -scale applications and that Tiger Energy Solutions, LLC, will provide the business framework to accelerate commercial implementation. This project builds upon MU's world-class reputation in the field of sustainable bioenergy research and education.

ENTREPRENEURSHIP

Innovative Technology for Earth Friendly Leather Manufacturing

UMCA's Chung-Ho Lin and his research colleagues at MU have teamed up with Proviera Biotech, a subsidiary of SCD Probiotics in Kansas City to improve upon a novel method of reducing the leather industry's environmental impact with biochemical from probiotics. SCD Probiotics was founded by Matthew Wood (B.S CAFNR 1998). Leather goods remain in high demand and highly regarded as a luxury item among consumers.

SCD Probiotics offers products that use biochemicals derived from probiotics, which displace many traditional chemicals used to process leather. Lin's group is using MU's expertise in analytical chemistry, bioinformatics, microbiology and molecular technology to help improve the company's formula and production techniques. The company's environmentally friendly products could rejuvenate an American leather tanning industry that has been largely shut down due to an inability to economically meet federal environmental standards.

The use of probiotics is a novel, environmentally friendly approach in leather manufacturing. According to Natalie Rada, Proviera Biotech's Senior Business Manager and CAFNR graduate, "Proviera's line of probiotic-derived products are competing in the $4.4 billion global tannery chemicals industry and provide unique benefits and advantages over current chemical and green-technology options."

Lin helps SCD on various quality assurance and quality control method developments for its tannery line of products. According to SCD Probiotics Vice President of Technology, Dr. Narin Tipsrisukond (Ph.D. CAFNR 2003) "Lin's methods have been used in our current manufacturing programs to ensure the highest quality and consistency of products from batch to batch, he also provided testing services for general product properties. We also have a few other testing service projects in progress that are non-tannery related."

Dr. Chung-Ho Lin

The company markets several products, all of which are 100 percent biodegradable, including a degreasing agent, a hydrating and wetting agent as well as a dispersing agent. Improved leather quality and yield, reduced operating costs, reduced environmental impact, reduced odor levels, reduced water consumption and reduced processing time are just a few of the benefits the products offer. Eighty percent of the firm's products are exported.

Proviera's products significantly reduce the toxicity of tannery effluent by displacing chemicals and also degrading the organic material released from the operations. Dr. Tipsrisukond said the company offers products which are showing up in tanneries all over the world. "The reception of our products in the market has been very positive and we intend to increase our footprint in the industry. Finished leather articles processed with our probiotic derived biochemicals are already in the hands of finished leather buyers and on consumer shelves in numerous regions around the globe."

Dr. Lin indicated that his lab also benefits from the collaboration as his students receive hands-on training aligned with industrial needs. In addition, knowledge developed from the research can be applied to other R&D projects in his lab. "This is a win-win for everyone," Lin said. "The collaboration supports our teaching and research missions while assisting the economic development of an innovative Missouri biotechnology company."

Story adapted from Randy Mertens, CAFNR Communications.

Forest farming for medicinals

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. 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*) have been established at the Horticulture and Agroforestry Research Farm (HARC) in New Franklin, MO and at the Doug Allen Project Site (DAPS) in Laurie, MO in 16 plots, four in small canopy gaps and four under the natural forest canopy per site.

It is predicted that soil tests will show higher soil fertility at HARC than at DAPS, and that survival rate for individuals of each species will have significant positive correlation with one or more soil fertility metrics. Photosynthetic rates of each species are predicted to correlate with the average available photosynthetically active radiation (PAR) levels, up to a species-specific light saturation point that is typical of the natural (closed) canopy plots. Final survival rates of each species are predicted to have a significant negative interaction with the higher PAR levels.

Student Badger Johnson preparing forest farming plot for medicinal plants.

Phytochemistry

Walnuts have multiple nutritional benefits as they contain numerous vitamins and minerals and are the only nut that contains a significant source of alpha-linolenic acid (ALA) (2.5 grams per ounce), an omega -3 fatty acid with heart and brain-health benefits. Consumption of walnuts has been linked to many health benefits including decreased risk of cardiovascular disease, reduced levels of cholesterol, stimulated brain functions and prevention of certain cancers (e.g., prostate and breast cancers). A recent animal study published in the Journal of Alzheimer's Disease indicates that a diet including walnuts may have a beneficial effect in reducing the risk, delaying the onset, slowing the progression of, or preventing Alzheimer's disease. More than 50 health-promoting bioactive compounds (phytosterols and phytophenolics) have been identified. However, systematic characterization of the bioactive compounds in walnuts using modern bioinformatics and metabolomics approach has never been explored. In addition, the links between the specific compounds and the health benefits have not been well established. Finally, information about the concentrations of these health promoting compounds in different cultivars across geographic gradients is lacking.

A research project designed to isolate and characterize the bioactive lowering cholesterols phytosterols and health-promoting phytophenolics from black walnuts (*Juglans nigra*) has been initiated. The project objectives include: 1) identification and characterization of the bioactive phytosterols, phytophenolics and other secondary metabolites using targeted and untargeted global metabolomics approach (XCMS); 2) bioassays (e.g., anti-inflammatory and antioxidant) to quantify bioactivity and purification to identify the bioactive compounds; 3) animal studies to monitor the degradation of these compounds in serum/tissues; and 4) transcriptome and gene expression analysis to correlate the levels of the gene expression to the phytochemical concentrations in serum/tissues.

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.

At HARC: Dr. Michael Gold & Dr. Mark Coggeshall discuss black Walnut research during the 2015 Agroforestry Academy.

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 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, pecan, 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.

Dr. Gene Garrett discusses the work being accomplished at the Doug Allen Site.

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.

Dr. Ranjith Udawatta's agroforestry/permaculture planting at Bradford Research Center, Dec. 2015.

GRANTS 2014-2015

AGROFORESTRY

Gold, M., 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., USDA ARS (2012-2017) Agroforestry for Small Farm Sustainability, $2,000,000

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

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

BIOFUEL/BIOMASS

Jose, S., 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.; Lin, C.-H., Co-PI, MU Mizzou Advantage Competitive Grants Programs, (2014-2016) Accelerating Advanced Biofuels Production: Three-pronged Approach, $300,000

Jose, S., MU Provost Office Enterprise Endowment, (2014-2015) Accelerating Advanced Biofuels Production in Missouri: Three-pronged Approach, $75,000

Jose, S., MU CAFNR McQuinn Funds (2014-2015) Accelerating Advanced Biofuels Production in Missouri: Three-pronged Approach, $75,000

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

Lin, C.-H.; 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

Udawatta, R., Co-PI (2012-2015) Perennial biomass crop establishment and environmental impacts in the Midwest, $499,447

EDUCATION

Jose, S., Co-PI; Gold, M., Co-PI, USDA NIFA (2011-2015) Internationalization of Forestry Education, Research and Extension U.S.- Costa Rica Cooperation, $148,007

Lin, C.-H., Co-PI, USDA National Needs Program (2010-2015) Integrating disciplinary diversity in graduate student education to support forest resource management decisions, $245,000

ENVIRONMENTAL SERVICES

Jose, S., 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 (2012-2017) Cover Crop Management for Flooded Areas to Improve Soil Heath, Environmental Quality and Farm Productivity. Conservation Innovation, $268,161

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, $375,000

Lin, C.-H., Co PI, NIEHS/NIHH (2015-2017) Endocrine disrupting activity associated with hydraulic fracturing, $400,000

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

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

Lin, C.-H., Co-PI, MU Mizzou Advantage (2014-2015) Endocrine disrupting activity in groundwater associated with hydraulic fracturing for natural gas and oil, $75,000

Lin, C.-H., Co-PI, USDA NRCS (2010-2015) Mississippi river basin healthy watersheds initiative, $380,000

Lin, C.-H., MU International Office (2014) Development of the Knowledge Exchange Platform between MU and UCR for Enhancing Education and Research Capacity on Bioanalytical Chemistry Research, $3,700

Lin, C,.H., Co-PI, Experiment Crowdfunding (2014) Does fracking contaminated water with hormone disrupting chemicals? $25,000

Lin, C.-H., Co-PI, SIRC (2013-2014) Multidisciplinary, Collaborative Pilot Study on Environmental Toxicants and Children's Development Outcomes, $1,500

Udawatta, R.; Jose, S., Co-PI, Conservation Innovation USDA NRCS/MO Dept. of Natural Resources (2012-2016) Multipurpose Cover Crop and Conservation

GRANTS 2014-2015

Practices for a Sustainable Agricultural System to Improve Soil Heath, Environmental Quality and Farm Productivity, $1,100,000

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

Udawatta, R., 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

OUTREACH

Gold, M., USDA NCR SARE (2013-2014) Increasing agroforestry adoption and networking in the Midwest through targeted professional development, $74,842

Gold, M., USDA NCR SARE (2013 – 2014) Create an Agroforestry Planning and Design Handbook in Support of Natural Resource and Agricultural Professionals, $8,000

Gold, M., Co-PI, USDA NAC (2011 – 2013) Expanding learning partnerships to increase the adoption of agroforestry by farmers, ranchers, woodland owners in the USA, $30,000

Jose, S., Missouri Department of Conservation (2009-2015) Green Horizons Newsletter, $46,250

Jose, S., Co-PI USDA NIFA (2014-2019) Armed to Farm: Veteran Labeled Marketing, Education and Research Strategies to Soldier Success for Military Veteran Farmers, $499,978

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

Gold, M., Missouri Dept. of Agriculture (2013-2015) Growing Missouri's Chestnut Industry - Harvesting, Marketing and Financial Decision-Making, $40,491

Gold, M., USDA NCR SARE – R&E (2010-2014) Developing Successful Marketing Strategies for Elderberry Growers and Value Added Processors: A Model for Specialty Crop Development in the U.S. Midwest, $105,427

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

SPECIALTY CROPS

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

Coggeshall, M., NSF (2011-2015) TRPGR: Comparative genomics of environmental stress responses in North American hardwoods, $357,028

Gold, M., Co-PI, Missouri Dept. of Ag. - Specialty Crops Block Grant Program (2012 – 2013) Hosting the First International Elderberry Symposium (June 2013) to Fast-track the Growth of Missouri's Elderberry Industry, $30,000

Gold, M., Co-PI, USDA NIFA AFRI Foundation Grant (2012 – 2013) the Organization and Hosting of the First Int'l Elderberry Research Symposium in Missouri, $25,000

Hammons, B.; Thomas, A., Co-PI, Missouri Dept. of Ag. - Specialty Crops Block Grant Program (2013 – 2015) development of a Combined Black Walnut Harvester-Huller that will Transform Harvest Efficiency and Producer Profitability, $24,500

Jose, S., Missouri Department of Conservation (2009-2016) Tree Improvement Program, $217,500

Thomas, A., Co-PI, Missouri Dept. of Ag. - Specialty Crops Block Grant Program (2015) Determining and Mitigating the Potential Occurrence of Cyanide in Elderberries, $29,775

TREE/CROP INTERACTIONS

Jose, S.; VanSambeek, J., Co-PI, USDA Forest Service (2014-2015) Genetic variation in adaptive traits to reduced light for native grasses and root competition from native hardwoods, $71,000

Dusty Walter teaches a future forester proper technique in chainsaw operation.

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ABSTRACTS

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Akdemir, E., S. Anderson, and R. Udawatta. 2015. Influence of agroforestry buffers and row crop management on soil hydraulic properties. 70th Annual Soil and Water Conservation Society Conference. Coming Home to Conservation, Putting Science into Practice. Abstract Book. JULY 28, 2015. Sheraton Greensboro at four seasons, Greensboro, NC.

Carlson, J.E.; Staton, M.; Addo-Quaye, C.; Romero-Severson, J.; Schlarbaum, S.; Coggeshall, M.; Liang, H.; Gailing, O.; Shumaker, K.; Orendovici-Best, T.; Zembower, N.; Wheeler, N. 2014. Genomic resources for North American hardwoods. XXII International Plant and Animal Genome Conference, San Diego, CA.

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Chandrasoma, J., P. Weerasinghe, R.P. Udawatta, and P.I. Yapa. 2015. Making nitrogen enriched biochar and its effects on crop performance and soil properties. Agroforestry as a Catalyst for On-farm Conservation and Diversification. 14th North American Agroforestry Conference, June 1-3, 2015, Ames, Iowa, USA.

Chandrasoma, J., R.P. Udawatta, S.H. Anderson, and A.L. Thompson. 2015. Soil hydraulic properties as influenced by prairie restoration. Agroforestry as a Catalyst for On-farm Conservation and Diversification. 14th North American Agroforestry Conference, June 1-3, 2015, Ames, Iowa, USA

Chatwin, W.B.; Heim, C.R.; Coggeshall, M.V.; Romero-Severson, J. 2015. Best under stress: Does an episodic hybrid advantage suppress reproductive barriers in oaks? 18-21 October, 2015. 8th International Oak Society Conference. Lisle, IL

Gantzer, C.J., R.P. Udawatta, and T. Reinbott. 2014. Cover crops, native pollinator species field borders, and riparian buffers for environmental quality. 69th Soil and Water Conservation Society International Conference "Making Waves in Conservation" 27-30 July, Lombard, Illinois.

Gantzer, C., B. Svoma, S. Anderson, R. Udawatta, and R. Miles. 2015. Long term research- soil water availability. 70th Annual Soil and Water Conservation Society Conference. Coming Home to Conservation, Putting Science into Practice. Abstract Book. JULY 28, 2015. Sheraton Greensboro at four seasons, Greensboro, NC.

Gold, M.A. 2015. The Agroforestry Academy - A crash course to educate natural resource professionals. Society of American Foresters Conference, 5-6 November, 2015. Baton Rouge, LA.

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Heim, C.R.; Coggeshall, M.V.; Konar, A.; Romero-Severson, J. 2015. Development of new genomic resources for northern red oak (Quercus rubra L.) 18-21 October, 2015. 8th International Oak Society Conference. Lisle, IL

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Lane, T.; Davitt, D.; Cook, M.; Henry, N.; Orendovivi-Best, T.; Zembower, N.; Koch, J.L.; Coggeshall, M.V.; Carlson, J.E.; Staton, M.E. 2015. Developing genomic resources for green ash through deep transcriptome sequencing and low-coverage whole genome sequencing Conference: International Plant and Animal Genome Conference XXIII

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HIGHLIGHTS

Agroforestry practices help landowners diversify products, markets and farm income; improve soil and water quality; and reduce erosion, non-point source pollution and flood damage. The integrated practices of agroforestry enhance land and aquatic habitats for fish and wildlife and improve biodiversity while sustaining land resources for generations to come.

UMCA Philosophy:

"A farm can be regarded as a food factory and the criterion for its success is saleable products. Or, it can be regarded as a place to live, and the criterion for its success is harmonious balance between plants, animals and people; between the domestic and the wild; and between utility and beauty." - Aldo Leopold

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- Shibu Jose, Director of UMCA, was appointed to the Forestry Research Advisory Council (FRAC) by U.S. Secretary of Agriculture Tom Vilsack in 2014. He currently serves as chair-elect of FRAC.
- During 2014-2015, three patents were granted by United States Patent and Trademark Office to Dr. Chung-Ho Lin and colleagues and one of the developed technologies has been successfully transferred to industry (Elemental Enzymes, Inc.)
- In March 2015, the UMCA launched the Agroforestry in Action Webinar Series.
- A new Nature, Culture and Agriculture Study Abroad program in Indonesia (December 27, 2015 to January 18, 2016) was approved by the CAFNR Study Abroad office and the MU International Center.
- A number of MU faculty are involved in developing course in a Food Security Master's project for the World Bank. The project is focused on curricular development for two Master's degree programs for the faculty of Moscow State University (Russia), one in AgroFood Management and a second on Land and Water Resource Management.
- Mark Coggeshall, assistant research professor has brought Quercus bicolor, trade name Buck's Unlimited Oak, to the market.