



**Institute for a Secure & Sustainable Environment
2019-2020 Annual Report to THEC**



ISSE Mission Statement

The University of Tennessee's Institute for a Secure and Sustainable Environment (ISSE) seeks to promote the development of policies, technologies, and educational programs that cut across multiple disciplines, engage the university's research faculty and staff, and grow in response to pressing environmental and security issues facing the state, the nation, and the globe.

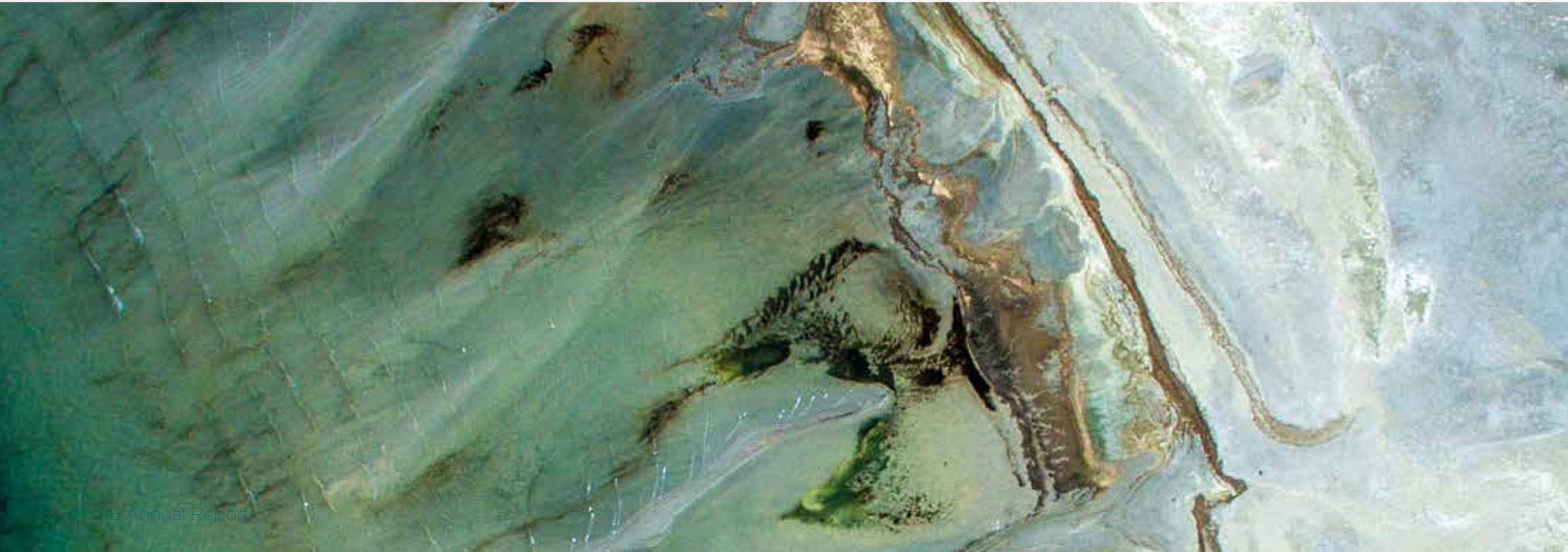
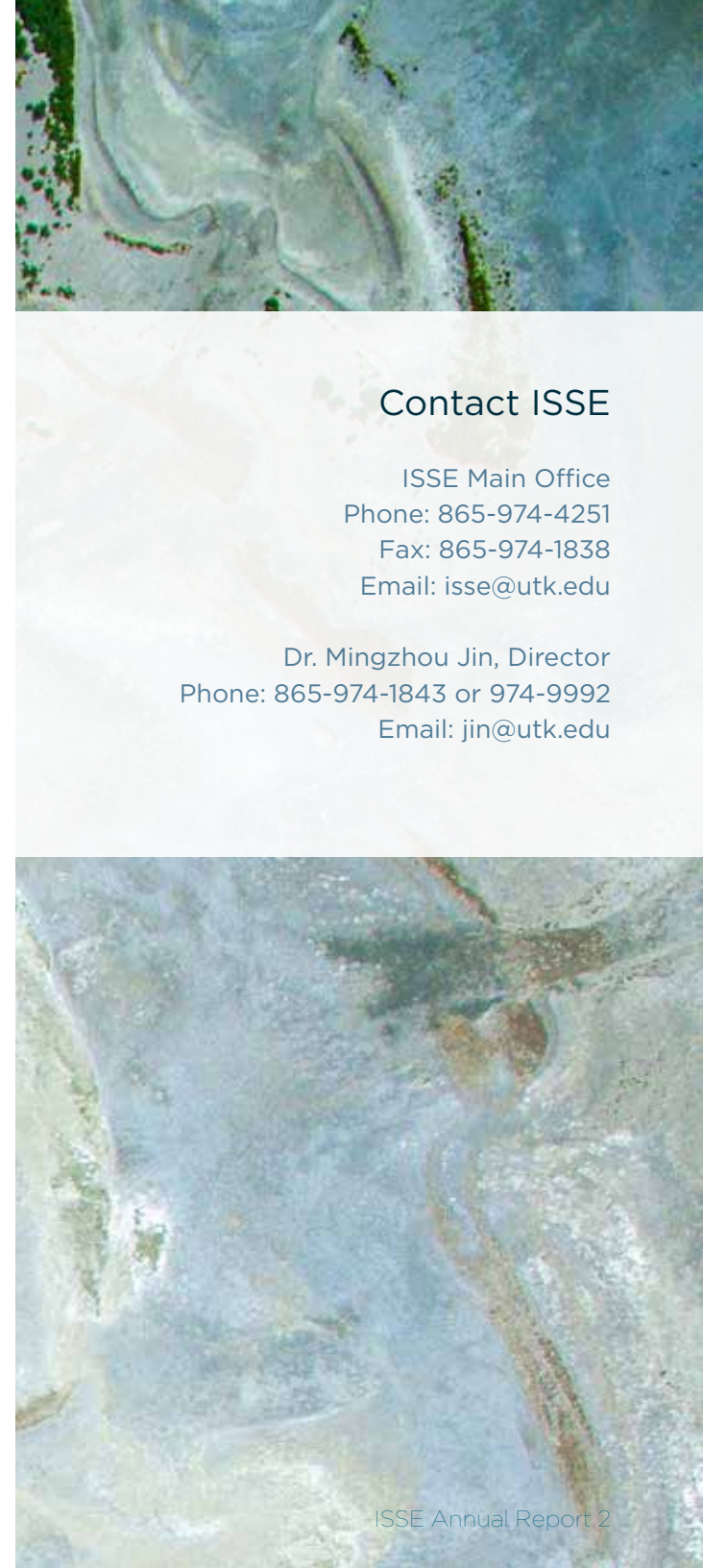


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Message from the Director

Despite the unprecedented challenges, 2019-2020 has proven to be significantly productive for ISSE research, education, outreach, and publications and presentations. I would like to highlight a few of our accomplishments from this timeframe.

ISSE took leadership in developing a number of interdisciplinary proposals.

- Dr. Jin assembled a team to develop an NSF Graduate Training Program proposal to harness immense amounts of data related to food security and sustainability.
- ISSE organized information sessions to help UT researchers prepare proposals for NSF's Food-Energy-Water Nexus program.
- Tennessee Water Resources Research Center (TNWRRC) organized information sessions on preparing proposals for US Geological Survey USGS 104(g) and 104(b) grants.
- Dr. Terry Hazen, Methane Center director, received an NSF Engineering Research Center (ERC) planning grant and is leading an interdisciplinary team to develop an ERC proposal handling environmental issues and mitigation related to fracking and other wastewater problems.
- ISSE continues to facilitate joint NSF research projects that address global crop sustainability. These are interdisciplinary projects and are led by Dr. Jin and UTIA's Dr. Andrew Muhammad.



Also, Dr. Jon Hathaway and Dr. John Schwartz were awarded a new EPA Project, Restoring Floodplain Wetlands Using Regenerative Stormwater Conveyances.

ISSE has strengthened its research connections with Tennessee Department of Environment and Conservation (TDEC) and Oak Ridge National Laboratory (ORNL), especially in research concerning soil moisture, fire, and food waste.

In education, Kalina Scarbrough, an undergraduate in Industrial & Systems Engineering, is developing machine learning models to analyze sensor data for an ISSE Seed Project with Dr. Anahita Kojandi and Dr. Jon Hathaway. Ms. Scarbrough recently won Third Prize in the Institute of Industrial & Systems Engineers Operations Research Undergraduate Competition. She presented her work at the virtual conference this year when the judges selected the winners.

ISSE's outreach is growing with new and expanded programs that support local economic and environmental sustainability. Among our state,

regional, and national collaborators are Tennessee Valley Authority (TVA), Tennessee Department of Environment and Conservation (TDEC), Appalachian Regional Commission (ARC), and the National Park Service (NPS).

East TN Clean Fuels launched its Southeastern Corridor Council this year. Coalition staff from 10 states are sharing ideas to address different types of alt-fuel signage and filling in gaps in alt-fuel corridors. The council hosted more than 25 state DOTs and other state departments on a webinar to talk about the existing issues and barriers and work to secure their partnership going forward.

We are proud of Dr. Tim Ezzell's director role in the Appalachian Leadership Institute, a joint project with the Howard H. Baker Jr. Center for Public Policy and ARC. In the quest for a cleaner environment, ISSE has increased its statewide reach through the East Tennessee Clean Fuel Coalition and the Drive Electric Tennessee. A timely example of ISSE's service to the university stems from

Dr. Terry Hazen's work, in collaboration with various officials and expert researchers, exploring every possible avenue for preventing the spread of COVID-19 on campus. Hazen and members of his lab are performing an anonymous method of surveillance testing on the buildings lived in by student residents.

Such work can only be realized through the vision and hard work of our staff and those with whom we collaborate, particularly the Tickle College of Engineering. We are beholden to you all. I hope you enjoy reading about our past year!

Executive Summary

During 2019-2020, ISSE continued to expand its research and outreach, and this report describes the activities carried out by ISSE staff, students, and ISSE-affiliated faculty.

ISSE has a robust internal operation with 14 staff and six faculty members as well as several visiting scholars. Our 12 affiliated faculty members represent the departments of Ecology & Evolutionary Biology, Biosystems Engineering & Soil Science, Sociology, Economics, the Baker Center for Public Policy, Civil & Environmental Engineering, and Industrial & Systems Engineering; our seven advisory board members come from UTK, UTIA, ORNL, TVA, and TDEC.

Each ISSE program has conducted significant research: water resources through four US Geological Survey projects; methane hydrates and global soil moisture datasets; ways to establish a US-China transdisciplinary research coordination network for identifying grand challenges at the nexus of food-energy-water systems (FEWS); and trends in Appalachian tourism and diversity. ISSE research projects have engaged more than 50 UT faculty members, one post-doc, and many graduate and undergraduate students.

ISSE awarded four new seed projects in FY19. These projects, which have been underway for one year, support research related to sustainability, especially projects investigating water, energy, and food sustainability that have potential

for external funding opportunities. ISSE's external funding sponsors include US Geological Survey, US Department of Energy, UT-Battelle & Oak Ridge National Laboratory, and the National Science Foundation Innovations in Food, Energy, and Water Systems (INFEWS).

Besides a healthy list of conference presentations and publications—most in peer-reviewed journals—ISSE's work has received extensive media coverage, transferred knowledge and information through a variety of programs and activities, created and shared large datasets, and fostered international exchanges. Many ISSE faculty have been recognized by their peers with honors and awards.

ISSE has increased its training and education programs with new courses and an expanding base of participants across the state. While ISSE's efforts in outreach and collaboration reached into many sectors within our state and region, East Tennessee Clean Fuels has built strong connections throughout the region with its development of the Southeastern Corridor Council. Coalition staff from 10 states and 25 state DOTs are sharing ideas to address several different types of alt-fuel signage and filling in gaps in alt-fuel corridors. In November of last year, Dr. Jin convened a panel at the 2019 International Conference on Cleaner Production and Sustainability to discuss the research gaps and future directions of cleaner production and circular economy based. About thirty international researchers joined the discussion, including 10 US researchers.



ISSE Centers & Programs

The Institute for a Secure & Sustainable Environment was established as a Center of Excellence by the Tennessee Higher Education Commission in April 2006. These are ISSE's current programs.

Centers

FEWSUS International Research Coordination Network

Environmental change, population growth, and accelerating consumption of food, energy, and water (FEW) resources bring grand challenges for urban sustainability worldwide. Many countries share common FEW trajectories, a strong science and technology base, and a perceived commitment to urban environmental sustainability. Evolving global change requires a transdisciplinary international network to develop a global research agenda to address the impacts of regional and global FEW systems on urban. The goal of this NSF-funded international Research Coordination Network (iRCN) is to chart a new path forward within the framework of the FEW nexus. Dr. Joe Zhuang leads this iRCN, together with an interdisciplinary team from the UT Institute of Agriculture, Tickle College of Engineering, Haslam College of Business, and UT College of Art and Science.

Tennessee Water Resources Research Center (TNWRRC)

TNWRRC is a federally designated state research institute supported in part by the US Geological Survey. The center was established following

enactment of the Water Resources Research Act of 1964. TNWRRC partners with the state of Tennessee as a primary resource to develop and implement programs that can achieve sustainable quantities of quality water in Tennessee and the nation. Dr. John S. Schwartz directs TNWRRC and is a professor in Civil & Environmental Engineering.

East Tennessee Clean Fuels (ETCF)

ETCF works to increase the use of cleaner American fuels and vehicles and energy saving transportation technologies to improve air quality and health, curb dependence on imported petroleum, and support Tennessee's economy. Its mission is to implement alternative fuel projects in East Tennessee and to make ETCF a sustainable coalition of involved participants from across East Tennessee. ETCF is a 501(c)3 under the umbrella of Transportation Energy Partners. Mr. Jonathan Overly is the Executive Director and Coordinator.

Methane Center

The Methane Center integrates science, engineering, and business models to create a broad conceptual understanding of CH₄ (methane) as a driver of ecosystem processes and services. Center researchers use this understanding to create a lifecycle assessment framework for environmentally sustainable generation, management, and utilization of CH₄. The center's mission is to provide fundamental and technological research advances and training in CH₄ environmental science. The aim is to produce young engineers and scientists who are dedicated to effective communication of scientific findings to inform and stimulate the public and provide structured

rationale for economic and environmental policy decisions and regulations. Dr. Terry Hazen directs the Methane Center.

Programs and Initiatives

Appalachian Leadership Institute (ALI)

ISSE partnered with ARC to launch this program focused on the unique challenges and solutions around Appalachia's economic development. ALI trains community leaders who live and work in the region through skill-building seminars, best-practice reviews, and field visits across the 13 states that make up the Appalachian region. The goal is to create leaders who can help the region adapt to these changes and use opportunities to create thriving, equitable, and sustainable communities. Dr. Timothy Ezzell is the PI for this program and a Research Professor in Political Science.

Worker Health and Safety Training at Department of Energy Facilities

DOE Worker Training was developed to protect and inform DOE communities and their workers by delivering quality and flexible safety and health training to target populations of hazardous waste workers and emergency responders. Its mission is to prevent work-related harm by training workers to protect themselves and their communities from exposure during hazardous waste operations and transportation, environmental restoration at nuclear weapons facilities, or chemical emergency responses. Dr. Sheila Webster (retired) is the PI and Rex Short is Senior Research Associate and Trainer.

ISSE Advisory Board, Faculty & Staff

ISSE Advisory Board	
Stan D. Wullschleger	Director, Environmental Sciences Division; Director, Climate Change Science Institute, Oak Ridge National Laboratory
Xin Sun	Director, Energy & Transportation Science Division, Oak Ridge National Laboratory
Brenda Brickhouse	Vice President, Environmental and Energy Policy; TVA Chief Sustainability Officer, Tennessee Valley Authority
Kendra Abkowitz Brooks	Assistant Commissioner, Office of Policy and Sustainable Practices, Tennessee Department of Environment and Conservation
Chris Cox	Professor and Department Head, Civil and Environmental Engineering, Tickle College of Engineering, University of Tennessee, Knoxville
David White	Associate Dean for Research; Associate Director, Tennessee Agricultural Experiment Station, University of Tennessee Institute of Agriculture
Bill Dunne (as observer)	Associate Dean for Research & Facilities, Tickle College of Engineering, University of Tennessee, Knoxville

ISSE Faculty	
Mingzhou Jin	ISSE Director, Professor of Industrial & Systems Engineering and Civil & Environmental Engineering
Tim Ezzell	Director, Appalachian Leadership Institute, Assistant Research Professor
Terry Hazen	Director, Methane Center, Governor's Chair, Professor of Civil & Environmental Engineering
John Schwartz	Director, Tennessee Water Resources Research Center, Professor of Civil & Environmental Engineering
Yaoping Wang	Assistant Research Professor
Yulong Zhang	Assistant Research Professor

ISSE Affiliated Faculty	
Paul Armsworth	Ecology & Evolutionary Biology
Walker Forbes	Biosystems Engr & Soil Science
Joshua Fu	Civil & Environmental Engr
Jon Hathaway	Civil & Environmental Engr
Qiang He	Civil & Environmental Engr
Robert Jones	Sociology
Anahita Khojandi	Industrial & Systems Engr
Jiafu Mao	Industrial & Systems Engr
Sean Schaeffer	Biosystems Engr & Soil Science
Charles Sims	Baker Center for Public Policy, Department of Economics
Chris Wilson	Civil & Environmental Engr
Jie Zhuang	Biosystems Engr & Soil Science

ISSE Staff	
Virginia Salazar Buda	Drive Electric TN Coordinator
Kellie Caughorn	Senior Administrative Services Assistant, Tennessee Water Resources Research Center
Tim Gangaware	Research Director, Tennessee Water Resources Research Center
Lissa Gay	ISSE Communications Director
Ainsley Kelso	DET Digital Media Coordinator
Nawei Liu	ISSE Research Associate
Jonathan Overly	Director, East Tennessee Clean Fuels
Dylida Ries	ISSE Accounting Specialist
Sherry Russell	ISSE Business Manager
Rex Short	Program Manager, Technology Research and Development Program
Daniel Siksay	Coordinator, East Tennessee Clean Fuels
Katie Walberg	Research Specialist, Tennessee Water Resources Research Center
Sheila Webster	Director, Technology Research and Development Program
Catherine Wilt	ISSE Research Associate

Faculty Engaged in Sponsored Research

PI	Sponsor	Title	Start
Mingzhou Jin	US - NSF - National Science Foundation	2019 International Conference on Cleaner Production & Sustainability	9/4/19
Mingzhou Jin	US - NSF - National Science Foundation	Coupled FEWS-Sustain Global Crop US-China	7/1/19
Mingzhou Jin	DOE - ORNL - UT Battelle - Oak Ridge National Lab	Industrial Landfill Waste Management	7/30/19
Mingzhou Jin	DOE - ORNL - UT Battelle - Oak Ridge National Lab	Policy Study - Adoption of Alternative Fuel Vehicles	6/25/19
Mingzhou Jin	East Tennessee Clean Fuels Coalition	Administrative Support for East Tennessee Clean Fuels Mod 14	Continued
Timothy Ezzell	Appalachian Regional Commission	Appalachian Leadership Institute	1/1/19
Timothy Ezzell	Appalachian Regional Commission	Trends and Strategies for Tourism in Appalachia	Continued
Timothy Ezzell	East Tennessee State University	Increasing Economic and Entrepreneurial Opportunities by Promoting Outdoor Recreation Among Underrepresented Visitor Groups	8/15/19
Sheila Webster	National Partnership for Environmental Technology Education	National PETE DOE Worker Training	Continued
John Schwartz	Tennessee Dept of Environment and Conservation	TN Stream Quantification Tool Training	New
John Schwartz	National Park Service-Great Smoky Mountains	Improving the GRSM's understanding of its natural resources and processes thereby enhancing protection of the Park's resources	Continued
John Schwartz	National Park Service	Southern Appalachian Cooperative Ecosystems Studies Units, Characterizing Water and Soil Chemistry from the chimney tops to fire	Continued
John Schwartz Tim Gangaware	DOI - USGS - US Geological Survey	Tennessee Water Resources Research Center Program	Continued
Jon Hathaway	US - EPA - US Environmental Protection Agency	Restoring Floodplain Wetlands and Hydrologic Connectivity Using Regenerative Stormwater Conveyance	10/1/19
Jon Hathaway	Wood PLC	Assistance with Metro Nashville Stormwater Manual	5/6/19
Christopher Wilson	West Virginia University	Appalachian Community Technical Assistance and Training Program	3/3/20
Yaoping Wang	DOE - ORNL - UT Battelle - Oak Ridge National Lab	Data Analytics Support for Integrated Earth Model	3/13/19

US Geological Survey Active Projects

Project	PI	Co-PIs	Institution
<i>FY 2019 Water Resources Research Institute Program</i>			
Understanding Effluent Movement in Clayey Soils when using Subsurface Drip Dispersal to apply Domestic Wastewater	John Buchanan		University of Tennessee Institute of Agriculture
Investigate Industrial Facilities Storm Water Quality and SWPPP Performance	Maryam Salehi		University of Memphis
Harmful Algal Blooms in Critical Amphibian Habitats at Mammoth Cave National Park, Kentucky	Brittany Hogan	Tom Byl, faculty advisor	Tennessee State University
Real-Time Adaptive Detention Control Network: An Application in the Conner Creek Catchment	Aaron Akin	Jon Hathaway, faculty advisor	University of Tennessee, Knoxville
From the Plot to the Catchment Scale: Towards the Next Generation of Hydrodynamics Sediment Transport Models	Christos Giannopoulos	Chris Wilson, faculty advisor	University of Tennessee, Knoxville
Flood History from Paleoflood Deposits in Cut Bank Soil Profiles in Chickmaugua Reservoir, Tennessee River	Paula Perilla-Castillo	Larry McKay, faculty advisor	University of Tennessee, Knoxville
<i>FY 2020 Water Resources Research Institute Program</i>			
Sourcing Runoff and Chemical Origins in Urban Stormwater Runoff: An Application in Second Creek	Jon Hathaway	Anna Szykiewicz	University of Tennessee, Knoxville
Pollutant Sourcing Identification in Impaired Surface Waters	Qiang He	Shuai Li	University of Tennessee, Knoxville
Development of a Low-cost Real-time Water Quality Monitoring Network for Rural Watersheds	Alfred Kalyanapu	Tania Datta	Tennessee Tech University
Development of Lentic Periphytic Algal Indices of Trophic Status Needed to Assess and Monitor the Effects of Eutrophication in Littoral Habitats of Middle and East Tennessee	Jeff Lebkuecher		Austin Peay State University
Organic acid fate and behavior in the Great Smoky Mountains National Park	Jason R. Brown	John Schwartz, faculty advisor	University of Tennessee, Knoxville
Assessing Water Quality of Rivers Feeding Riparian Wetlands in Agroecosystems: Research Supporting the Evaluation of the USDA Wetlands Reserve Program	Robert Brown	Justin Murdock, faculty advisor	Tennessee Tech University
The use of Real-time Control in Bioretention Systems: An Investigation into the Microbial Communities of Actively Controlled Bioretention Systems	Padmini Persaud	Jon Hathaway, faculty advisor	University of Tennessee, Knoxville

New Faces & Goodbyes

ISSE Welcomes New Staff



Sherry Lynn Russell
ISSE Business Manager

Sherry comes to Knoxville having recently relocated to the area from Rockford, Illinois, where she spent 22 years as a Business Manager at the University of Illinois. Her responsibilities include financial management of the department, contracts and grants management, and human resource functions. She loves spending time reading and hiking to waterfalls.



Yulong (Mars) Zhang
Assistant Research Professor

Dr. Yulong Zhang is an assistant research professor in ISSE. He was a research scientist in the Laboratory of Environmental Model & Data Optima in Maryland. His post-doctoral research was in the Remote Sensing and Ecological Modeling Group in the Department of Geography at the University of North Carolina at Chapel Hill. His PhD is in Remote Sensing of Ecology from the University of the Chinese Academy of Sciences.



Virginia Salazar Buda
Drive Electric TN Coordinator

Virginia is the first line of communication for the Drive Electric TN (DET) program. Virginia coordinates and manages Tennessee statewide initiatives that advocate for the use and adoption of Electric Vehicles. DET is an initiative of East TN Clean Fuels and its partners. Virginia also advocates for the arts as a member of the Board of Directors of Tennesseans for the Arts.



Ainsley Kelso
DET Digital Media Coordinator

Ainsley is about to begin her senior year at UTK, majoring in Journalism and Electronic Media. From 2018-2020, Ainsley was writer and Editor-in-Chief at the Tennessee Journalist. She has considerable experience in digital media content creation, design, and management and is fluent in a wide variety of digital media platforms.

This past year, ISSE bid farewell to three people -

Sherry Redus, who was ISSE's communications coordinator, retired in April 2020.

Dr. Maria Campa Fernanda, a postdoctoral researcher at the Methane Center, has accepted a position as staff scientist at the National Nanotechnology Coordination Office in Washington DC.

Maddy Collins handled digital communications for the East Tennessee Clean Fuels Coalition, and she has taken a position at Ijams Nature Center here in Knoxville.

ISSE Student Highlights

Jason R. Brown is a Master's student in Biosystems Engineering and Soil Science. His current research examines the effects of acid rain deposition in the Great Smoky Mountains National Park, including wet and dry deposition of acidic compounds and metals to soils, the resulting addition to surface waters, and the fate and behavior of organic acids within surface waterways. Mr. Brown's research interests include pollutant introductions to natural ecosystems with an emphasis on waterways, the remediation of polluted soils and waters, and research and development of monitoring and sampling technology. Mr. Brown has produced general research articles for publication to the Great Smoky Mountains National Park Fisheries Department website in addition to being a regular contributor to their periodical newsletter. He intends to work toward his PhD in the UTIA Biosystems Engineering and Soil Science department.



Zhibo Cheng is a second-year Ph.D. student in the Department of Biosystems Engineering and Soil Science. Her current research focuses on the destructive removal of viruses from environmental systems using nanostructured metal oxides within the framework of the university's one health initiative. Her experimental research involves nucleic acid extraction, microbial culture, 16S sequencing, and characterization of reactive oxygen species. Zhibo employs multiple novel techniques to explore the interfacial mechanisms that determine the adsorption and inactivation of various viruses on nano-engineered surfaces, including epifluorescence microscopy, real-time quantitative PCR, atomic force microscopy, and interfacial process modeling. As co-author, Zhibo has published two research articles on plant mismatch repair genes under environmental stress conditions.



Wenquan Dong is a fourth-year Ph.D. student in the Department of Industrial and System Engineering at the University of Tennessee, Knoxville. Wenquan Dong received his Bachelor of Management in the College of Business from Hohai University, Nanjing, China, in 2016. His current research focuses on design and operation of smart warehouse, analysis of mass flow; last-mile delivery network with drones; food loss and waste (FLW), energy consumption and GHG emission along U.S. Food Supply Chain (FLW), and strategies of reducing FLW, energy consumption and GHG emission. Mr. Wenquan Dong's recent publications as a co-author and first author

focus on optimization of automated storage and retrieval system, drone delivery network, and assessment of FLW generation, energy consumption and GHG emission along U.S. FLW.



Zabrenna Griffiths is a third year Ph.D. student in Genome Science & Technology. Building on previous studies conducted by Dr. Hazen and members of his lab, Zabrenna is conducting a multiomics experiment to investigate the changes in deep ocean microbial community composition and oil-degrading genes after the addition of crude oil, both aerobically and anaerobically. She aims to increase the understanding of these biodegradation pathways to address water quality issues associated with the oil and gas industry. She plans to go between original science and science policy, motivated by environmental challenges in her native Jamaica. She has conducted guided research projects with the Sustainable Climate Risk Management Summer Scholars program at The Pennsylvania State University and the Great Lakes Bioenergy Research Center at Michigan State University.

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Zaher Jarrar is a Ph.D. student in the Department of Civil and Environmental Engineering. Jarrar received his Bachelor of Science in Civil Engineering from Birzeit University, West Bank, Palestinian Authorities in 2012, and he received his Master's from the Department of Civil and Environmental Engineering in 2018. His current research focuses on understanding underlying physical processes of the emergent phenomena during gas production from hydrate-bearing sediments. Such phenomena include fines migration, fines clogging, over-pressurization, and gas-driven fractures. Mr. Jarrar conducts

research in unique, in situ experiments that involve monitoring gas hydrate formation and dissociation in granular materials. His research outcomes help evaluate optimal conditions for the various gas production strategies from gas hydrate-bearing reservoirs.

Cheng-Pin Ku is a third-year Ph.D. student in the Department of Civil and Environmental Engineering at the University of Tennessee, Knoxville. Cheng-pin received his Bachelor of Science and Master of Science in the College of Public Health from National Taiwan University, Taiwan, in 2011 and 2013 respectively. The focus of Kuo's research works includes air quality modeling, machine learning, and exposure assessment. He had published 4 scientific articles in the international journals as first author (1 article) and co-author (3 articles), and he is preparing to submit 2 articles as well in this academic year.



His present research focuses on data fusion of air quality data and health data, and their applications on public health policies. His doctoral research will focus on real-time air quality forecasting models and the fusion of machine learning techniques and deterministic models.



Grace Long is a Master's student in the Department of Environmental Engineering at the University of Tennessee. She graduated from the University of Virginia in 2016, earning her Bachelor of Science in civil engineering. She then worked for three years in the Washington DC area for Dewberry in the Site/Civil department as an Engineer-In-Training. In 2019 she moved back to her hometown of Knoxville to attend UT and continue her education. Grace is interested in both sustainable stormwater management and stream restoration. She most enjoys field work assessing stream quality and inspecting stormwater management elements. She is currently assist-

ing Dr. Schwartz on the Beaver Creek Stream Restoration Project and assessing and suggesting modifications to the Tennessee Stream Quantification Tool.

Gillian Palino is a first-year civil and environmental engineering PhD graduate student at the University of Tennessee, Knoxville under the guidance of Dr. Jon Hathaway. She received her undergraduate degree at the University of Florida in Environmental Engineering with a minor in Soil and Water Science. In 2018 she co-wrote an extension publication describing the basics of using Quantum Geographic Information System (QGIS) to create maps and analyze data. Her thesis project focuses on the application of regenerative storm water conveyances as a method of improving hydrologic performance and water quality of urban storm water. Her interests include GIS and modeling techniques to better understand groundwater hydrology.





Padmini Persaud is a fourth-year Ph.D. student in the Department of Civil and Environmental Engineering at the University of Tennessee, Knoxville. Padmini received her Bachelor of Science in Environmental Engineering from the University of Florida in 2017. Her current research focuses on how the use of real-time control systems in bioretention practices affect microbial, hydrologic, and nutrient processing performance. Ms. Persaud employs multiple techniques to study microbial, hydrologic, and water quality changes, including ion chromatography, inductively coupled plasma mass spectrometry, and 16S

rRNA analysis. Ms. Persaud's research interests include smart stormwater treatment, green infrastructure design, and real-time control technology. Ms. Persaud's recent publication as first author focuses on comparisons between traditional and real-time controlled bioretention systems.

Dr. Scott Satinover is a recent Ph.D. graduate from the Bredesen Center, where he pursued a degree in Energy Science and Engineering. He worked with Dr. Abhijeet Borole and Dr. Terry Hazen on Microbial Electrolysis Cells (MECs). These should produce hydrogen with better energy efficiency than conventional water electrolysis, while also cleaning toxic effluents from industries. He tested these devices on complex wastes, including wastes from pyrolysis, fermentation effluent, hydrothermal liquefaction, and oil and gas wastewater. His dissertation explored how characteristics in feedstocks can impact MEC performance, which he hopes will aid in the acceleration of MEC technology towards commercialization. While a student, Scott published more than 30 articles in the Daily Beacon through the Ask a Scientist column and gave talks to the local chapter of Taste of Science. He is currently an engineering technical writer for MathWorks.



Kalina Scarbrough is an undergraduate researcher in Industrial & Systems Engineering who has been working on an ISSE seed project with Drs. Anahita Kojandi and Jon Hathaway. As part of this project, she has developed machine learning models to analyze sensor data. She recently won third place in the IISE Operations Research Division Undergraduate Student Research Dissemination Competition for her work titled Identifying a Minimal Set of Sensors to Predict Soil Moisture in Real-Time in Green Infrastructure that addresses green infrastructure (GI) inspection and maintenance. The

objective of this study is to identify a minimal set of sensors placed in bioretention areas that can accurately identify soil moisture trends in real-time, which may be used as an indicator of poor performance. Harnessing the possibilities of the Internet of Things (IOT) and sensor data-driven decision making can help inform and optimize green infrastructure inspection and maintenance.

Rongyun Tang is a third-year Ph.D. student in the Department of Industrial & System Engineering at the University of Tennessee, Knoxville. Rongyun received her bachelor's degree at Capital Normal University in 2015, and master's degree at Beijing Normal University in 2018. Rongyun, under the supervision of Dr. Jiafu Mao and Dr. Mingzhou Jin, is working on the responses and feedbacks of wildfire to environmental changes. Her major interests include modeling wildfire in the Earth System Model, exploring climate driving mechanism of wildfire by statistical analysis and machine learning methods, and assessing wildfire impact on the natural environment and human society. Her recent work, clarifying wildfire driving mechanism using DOE's Energy Exascale Earth System Model (E3SM) factorial experiments, has been published in the *Geography and Sustainability*.





Rui Zhou Rui Zhou is a first-year Ph.D. student in the Department of Industrial & Systems Engineering at the University of Tennessee, Knoxville. Rui Zhou received her Bachelor of Science in the College of Economics from Nanchang Hangkong University, Jianxi, China, in 2018, and her Master of Science in the Department of Industrial & Systems Engineering at the University of Tennessee, Knoxville, 2020. Her current research focuses on sustainable supply chain management under climate change, and techno-economic analysis of CO2 conversion to jet.

Alex Moore has been awarded the Appalachian Leadership Institute Fellowship from the Appalachian Regional Commission (ARC). From Bybee, Tennessee, Alex graduated this spring from the University of Tennessee with a bachelor's degree in political science; he is now a graduate student in the Master of Public Policy and Administration program at UT. Having previously interned with the cities of Morristown and Greeneville, Tennessee, he will now assist UT and ARC in hosting seven leadership sessions throughout ARC's 13-state region. These sessions will train professionals on how to improve local communities and bring jobs to the Appalachian region. After finishing his work with ARC and graduating with his Master's degree, Alex plans to work in local government in East Tennessee in either city planning or city administration.



right: Victoria Rexhausen checks up on a custom stream gauging station on Conner Creek. Image by Aaron Akin.



Research

FY 2019 Water Resources Research Institute (WRRIP) TNWRRC Proposals

March 1, 2019 – December 31, 2020
Federal funds: \$92,335
Non-Federal Match: \$184,670

FY 2019 WRRIP Administration: Dr. John Schwartz and Timothy Gangaware, Tennessee Water Resources Research Center, University of Tennessee, Knoxville

Faculty Proposals

Understanding Effluent Movement in Clayey Soils when using Subsurface Drip Dispersal to apply Domestic Wastewater

PI: Dr. John Buchanan, Department of Biosystems Engineering and Soil Science, University of Tennessee, Institute of Agriculture.

The primary objective of this project is to develop a comprehensive understanding of how effluent moves in the soil when using subsurface drip irrigation systems to disperse domestic wastewater in clayey soils within the Central Basin Physiographic Region. The Central Basin (sometimes called the Nashville Basin) includes Davidson County and the many bedroom communities that surround Nashville. There is a great demand for new housing in this area; however, the wastewater infrastructure is very limited. Instead of building new sewer systems that would feed into regional wastewater

treatment plants, many housing developments (subdivisions) in this region have constructed decentralized wastewater management systems. Within the subdivision, each home has a septic tank for primary treatment. Small diameter, pressurized sewers collect and transport the septic tank effluent to a small treatment system that provides secondary/tertiary level treatment. Once treated, the effluent is land-applied by subsurface drip irrigation within the subdivision. Using the Tennessee Department of Environment and Conservation's (TDEC) Dataviewer (TDEC, 2018), it was estimated that TDEC-Division of Water Resources has issued 174 operating permits to decentralized systems that utilize subsurface drip dispersal systems in the Central Basin. Most of these systems serve residential developments; however, a few of these systems serve schools, churches, and small businesses. The Central Basin is known for having shallow soils that are generally unsuitable for traditional septic systems. By using a decentralized strategy, more homes can be built in areas with unsuitable soils. This, of course, assumes that a sufficient area of suitable soils can be found close by to accept the treated effluent. In other words, there still has to be suitable soils, but the soil can be located separately from the homes.

A suitable site should have sufficient soil depth to provide additional treatment and be capable of deep drainage so that the effluent will move into the subsurface. In an attempt to quantify a suitable soil, the Tennessee Department of Environment and Conservation, Division of Water Resources (TDEC-DWR) requires soil evaluators to determine the depth, texture, and structure of the soil within potential effluent dispersal areas. Once evaluated, the results are compared to a table published in TDEC's design guidelines (TDEC, 2016) and a

hydraulic loading rate (HLR) is determined for that site. A typical HLR is 8 liters per day per square meter (0.2 gallons per day per square foot - gpd/ft²). So, for example, if a housing development is estimated to produce 114,000 L of wastewater per day (30,000 gpd), then 14,000 m² (150,000 ft²) is needed for the dispersal area. At issue is that clay and silty clay soils, that have weak blocky structure (within the top 51 cm or 20 inches), are not allowed for subsurface drip dispersal. Soils that match this description are common in the Central Basin and this regulatory restriction has limited new house construction.

Clay and silty clay soils with weak blocky structures are recognized as having low permeability. As such, the conservative approach taken by TDEC-DWR is fully justified. However, these soils have some permeability and can percolate effluent at a low rate. Research is needed to determine an appropriate HLR for these soils.

Investigate Industrial Facilities Storm Water Quality and Stormwater Pollution Prevention Plan (SWPPP) Performance

PI: Dr. Maryam Salehi, Department of Civil Engineering, University of Memphis

Storm runoff pollutants are among the major sources of surface water impairments in Tennessee. However, there are several guidance on storm water best management practices (BMPs) and pollution prevention plans, but there are many streams impaired by the runoff contaminant. In the West Tennessee, numerous streams and surface waters

have been assessed as impaired by nonpoint source pollutions. Urban nonpoint sources (NPS) are the substantial contributors to the surface water quality degradation. In some area the proportion of pollutants in urban storm water that originated from industrial activities have been reported to be significant compare to the other sources like residential or commercial landscapes, construction sites, roads and highways. There are multiple federal and state storm water regulations that require many types of industrial facilities taking steps toward protecting their storm water quality. But there are many cases where applied best management practices were not efficient in reducing the pollutant loadings below the recommended levels. Evaluation of storm water

management strategies is not possible without understanding the nonpoint source pollutants' loadings to the surface waters.

The project's goal is to better understand storm water quality at several industrial facilities to evaluate the sector pollutant discharge characteristics and examine pollution prevention practices effectiveness. Specific objectives are to (1) investigate the storm runoff constituents' concentrations and aggregate loadings for several industrial facilities, (2) examine the temporal and seasonal changes in storm water quality, and (3) identify the impacts of pollution prevention practices to reduce the contaminant loadings. This research will evaluate the

self-reported storm water quality data collected as a part of National Pollutant Discharge Elimination System (NPDES) permits by 12 Memphis Light, Gas and Water (MLGW) facilities during the last three years. These facilities reportedly exceeded the storm water quality levels recommended by Tennessee Department of Environment and Conservation (TDEC). To assess the data regarding to the regulatory interests, proportion of facilities exceeded storm water pollutant loadings over the time will be determined. Multivariate statistical approaches will be applied to assess seasonal correlations of storm water quality parameters. Water quality data will be examined to identify the temporal trend in pollutants discharge for different industrial facilities during the last three years. Storm water pollution prevention plans performance will be evaluated for two facilities with the greatest pollutant loadings.

This research highlights the importance of understanding storm water quality data, to encourage the industrial stakeholders taking serious actions to protect the storm water quality. Industrial facilities' operators are encouraged to understand their storm water quality data, detect the pollutants of concerns, potential problems in contaminating the storm runoff and implement the efficient BMPs. In addition, our findings will assist the state and federal regulatory decision makers recognize the impacts of industrial activities on local creek and streams. It will allow the regulators assess their progress toward managing the storm water quality at industrial sites, and protecting the watersheds to lower the aggregate pollutant discharge. This proposed research project will further the US Geological Survey's national mission to increase knowledge of water quality, evaluate how climate and landscape changes influence the water resources.



Graduate Student Supplemental Research Grant Proposals

Real-Time Adaptive Detention Control Network: An Application in the Conner Creek Watershed

Aaron Akin, Graduate Research Assistant; Dr. Jon Hathaway, Faculty Advisor, Department of Civil & Environmental Engineering, the University of Tennessee, Knoxville

This research has two objectives: (1) to implement a real-time network of sensors and smart adaptive control systems (ACS) on detention ponds to optimize their urban stormwater mitigation function, and (2) to monitor the hydrologic and geomorphic implications for the receiving waterbody, Conner Creek. A network of adaptive detention controls in a watershed presents a novel approach for stormwater management and streambank erosional control by controlling and mitigating for extreme flow or channel forming events. Each ACS will accomplish this by receiving external rainfall prediction data from the National Weather Service, processing these data to determine what, if any action, should be taken, and control the outlet of the system through an externally controlled valve. For instance, it may be desirable to draw down the water level in a pond to make room for runoff that is anticipated from an incoming storm event. The ACS will be informed by a detailed SWMM model of the system allowing extensive testing and scenario building.

right: Aaron Akin checks up on a custom stream gauging station on Conner Creek following a large rainstorm.



From the Plot to the Catchment Scale: Towards the Next Generation of Hydrodynamics – Sediment Transport Model

Christos Giannopoulos, Ph. D. Student; Dr. Christopher Wilson, Faculty Advisor, Department of Civil & Environmental Engineering, the University of Tennessee, Knoxville

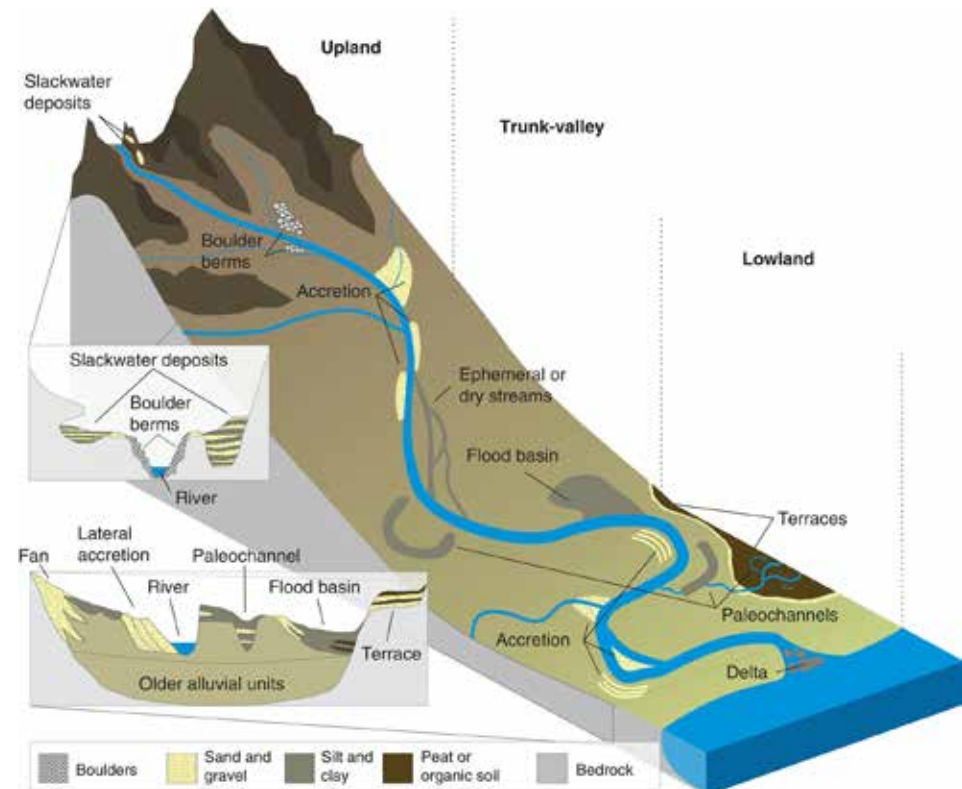
The overarching goal of this research is to assess the redistribution of mobilized soil through the drainage network of the watershed under a non-stationary climate and different management regimes. To do so, I am proposing a next-generation transport model that can resolve the hydrodynamics and sediment transport moving from the plot to the catchment scale. This model would address one of the biggest concerns of existing models, which is that they do not represent well the underlying processes at the floodplain-gully domain. The transport model will be incorporated into a coupled upland-instream modeling framework (Enhanced WEPP-3ST1D) for resolving gully erosion. It will first determine the gully initiation location and then resolve the advective and diffusive headcut retreat, gully bank failure due to fluvial and mass failure, and bed incision due to excess bed shear stress. In order to complete this model, I am requesting funding for trips to Oregon State University and Utah State University for one-week workshops. The trip to Oregon will be used to learn how to resolve floodplain topography and gully cross-sectional geometry in high detail. The trip to Utah will be to learn to develop and incorporate a geospatial tool and gully routine into the proposed modeling framework. The proposed model is a tool that can assess the relative effectiveness of BMPs regarding on-site and off-site

impacts of anthropogenic activities. The proposed hydrodynamics and sediment transport model can be utilized as a decision-making tool to inform water management, by replacing current models with limited reliability and applicability (e.g., empirically-based models).

Flood History from Paleoflood Deposits in Cut Bank Soil Profiles in Chickamauga Reservoir, Tennessee, River, U.S.A.

Paula J Perilla-Castillo, Ph. D. Student; Dr. Larry McKay, Faculty Advisor, Department of Earth & Planetary Sciences, the University of Tennessee, Knoxville

The objectives of the portion of the study described in this proposal are to evaluate the presence, preservation and frequency of PF deposits in floodplains of the Tennessee River in the upper portion of the Chickamauga Reservoir. My goal with this funding request is to obtain funds for radiocarbon dating that will allow me to fill the gap of knowledge of extreme flood events over the past several thousand years in the Tennessee River, and thus help improve hydrologic engineering, dam safety risk, and nuclear infrastructure safety. I hypothesize that the major flood events preserved at the six soil profiles can be distinguished and correlated between profiles. Correlation will allow for a better understanding of the flood history of the Tennessee River in different locations as well as flood frequency knowledge.





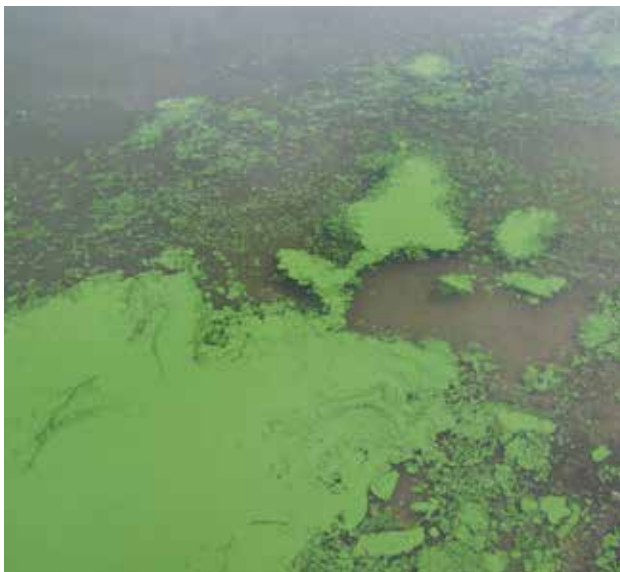
Harmful Algal Blooms in Surface Water in Amphibian Ponds and in the Green River at Mammoth Cave National Park, Kentucky

Brittaney Hogan, Graduate Research Assistant; Dr. Tom Byl, Faculty Advisor, Department of Biology, Tennessee State University

Harmful algal blooms are a growing concern at Mammoth Cave (MACA) National Park, Kentucky, because of the danger they pose to the tourists and sensitive ecosystems. MACA has ~650,000 annual visitors and was designated a Biosphere Reserve in 1990 because of the outstanding ecosystems on the surface and subsurface. It is home to over 70 threatened, endangered or State listed species (MACA NPS, 2014, 2017) and has declining amphibian populations. There is concern that cyanotoxins may be exacerbating pathogens such as chytrid fungus and renavirus. In December 2017, January and April of 2018, the USGS, in partnership with MACA and Tennessee State University, ran preliminary tests for the cyanotoxins microcystin and saxitoxin, and genetic tests for cyanobacterial presence in surface and cave waters. Microcystins were detected in surface waters and cave lampenflora at concentrations greater than 0.3 $\mu\text{g}/\text{L}$, the EPA advisory level for microcystin, and, established that cyanobacteria capable of producing cyanotoxin are present in cave and surface waters. These preliminary results validate concerns that harmful algal blooms are a danger to MACA's ecosystems and tourists.

left: Harmful algal blooms pose dangers to tourists and sensitive ecosystems at Mammoth Cave National Park, Kentucky.

The goal of this proposed research is to better understand the distribution and occurrence of cyanobacteria and toxins in critical amphibian habitats, such as the vernal ponds and illuminated cave passages of Mammoth Cave National Park. A census of the amphibians that use the ponds for breeding will be conducted to establish a connection between water chemistry and amphibian use. This information will help resource managers better predict, manage, and mitigate the occurrence of harmful algal blooms. A total of 100 environmental samples will be collected at four amphibian ponds, two Green River sites and six cave locations with lampenflora. Those samples will be analyzed for field parameters, nutrients, cyanotoxins, community structure, and cyanobacteria by molecular methods (Rintakanto et al, 2005; Graham et al, 2008). Depending on the molecular assay, either TaqMan Universal PCR Master Mix or SYBR Green PCR Master Mix (Applied Biosystems, Foster City, Calif.) will be used as described in Stelzer et al, (2013). In addition to distribution and occurrence, this research will provide data on the timing and conditions that lead to bloom development, the production of microcystin toxin, and the effects on amphibians.



FY 2020 USGS Water Resources Research Institute 104b TNWRRC Projects

March 1, 2020 – February 28, 2021

FY 2020 WRRIP Program Administration: Dr. John Schwartz and Tim Gangaware, Tennessee Water Resources Research Center, University of Tennessee, Knoxville.

Faculty Proposals

Sourcing Runoff and Chemical Origins in Urban Stormwater Runoff: An Application in Second Creek

PI: Dr. Jon Hathaway, Department of Civil & Environmental Engineering; Co-PI: Dr. Anna Szykiewicz, Department of Earth & Planetary Sciences, University of Tennessee, Knoxville.

Determining the source of stormwater runoff (and how sources change based on rainfall amounts and within event dynamics) is a critical need in urban hydrology to better site stormwater controls for hydrologic restoration, for better modeling pollutant transport in urban systems, and for more targeted pollutant reduction strategies. This study will use two approaches to perform source partitioning, a hydrologic method and via stable isotope analyses. Agreement between these approaches will suggest the validity of these partitioning techniques and allow insight into transport processes and pollutant origins in urban watersheds.

Objective: The objectives of this research are to: (1) better understand if source partitioning is possible in urban stormwater runoff using stable isotope tracers (nitrogen, sulfur, oxygen), and (2) determine how well source partitioning using stable isotope analyses of dissolved nitrate and sulfate matches hydrologic approaches to partitioning.

Pollutant Sourcing Identification in Impaired Surface Waters

PI: Dr. Qiang He, Department of Civil & Environmental Engineering; Co-PI: Dr. Shuai Li, Department of Civil & Environmental Engineering; University of Tennessee, Knoxville.

In the United States Environmental Protection Agency's most recent national water quality assessment, over half of the rivers and streams evaluated were determined to be impaired. Water quality impairment can result from a wide array of pollutant sources including sewage, stormwater runoff, and animal feces, to name a few. Section 303(d) of the Clean Water Act requires that total maximum daily loads (TMDL) be established for the impaired waters by states. Pollution control remedies (e.g. best management practices, BMPs) are required to address all the pollutant sources that contribute to the overall water quality impairment. In order to establish TMDL and corresponding pollution mitigation measures, it is essential to identify the pollutant sources to those impaired waters. However, effective methods for source identification of pollutants are lacking, making it very challenging to establish TMDL and develop targeted mitigation strategies.

Therefore, the primary objective of the proposed project is to evaluate the feasibility of microbial community composition as unique fingerprints to identify potential sources contributing to impaired surface waters. The general approach of the microbial community fingerprinting-based method is to compare the individual microbial community fingerprints of sources, such as stormwater samples, with those of impaired waters, to determine the potential contributions of various pollutant sources to the composite microbial community fingerprint of impaired waters.

Results from the proposed project are relevant to multiple areas of applications, including enhanced effectiveness of Stormwater Control Measures; surface water quality monitoring; advancing sensor technology and large dataset analyses; and watershed management strategies for reducing nutrients in surface waters. The proposed project also supports the US Geological Survey's national mission and objectives, including 1) Increasing knowledge of water quality and quantity as results from the proposed project will provide new perspectives into the pollutant sources that contributing to the impairment of surface water; and 2) Creating and delivering decision-making tools that support water management, as water quality impairment can result from a wide array of pollutant sources. The source identification tool to be developed in this project will provide a very useful decision-making tool for targeted pollution control and mitigation plans.

Development of a Low-cost Real-time Water Quality Monitoring Network for Rural Watersheds

PIs: Dr. Alfred Kalyanapu, and Dr. Tania Datta, Department of Civil & Environmental Engineering, Tennessee Tech University.

Continuous surface water quality monitoring is a cost-intensive venture that requires resources and close-coordination among federal and state government agencies. In the United States, surface water quality monitoring is typically a part of the real-time gaging network, maintained by the United States Geological Survey (USGS), under the auspices of the National Streamflow Information Program. Under this program, over 8,160 stream gages relay real-time data through satellite telemetry for the Federal Priority Stream (FPS) gages (Phillips and Melcher, 2006; USGS, 2019a). However, due to budget constraints and limited resources, USGS is always under pressure to discontinue stream gaging, and maintains a list of threatened and recently discontinued stream gages (USGS 2019b).

To address this challenge, there is a need for low-cost water level and quality sensors that can be deployed by state agencies and municipalities. We conducted a research project titled "Low-cost, real-time streamflow network for Falling Water River Watershed" in 2018, funded through the USGS 104b program.

This project enabled the development of low-cost water level network in the Falling Water River Watershed in the middle Tennessee region. The current proposed project is an extension of the ongoing

effort to include low-cost sensor network for water quality monitoring. We plan to include pH, dissolved oxygen (DO) and electrical conductivity as some of the water quality parameters.

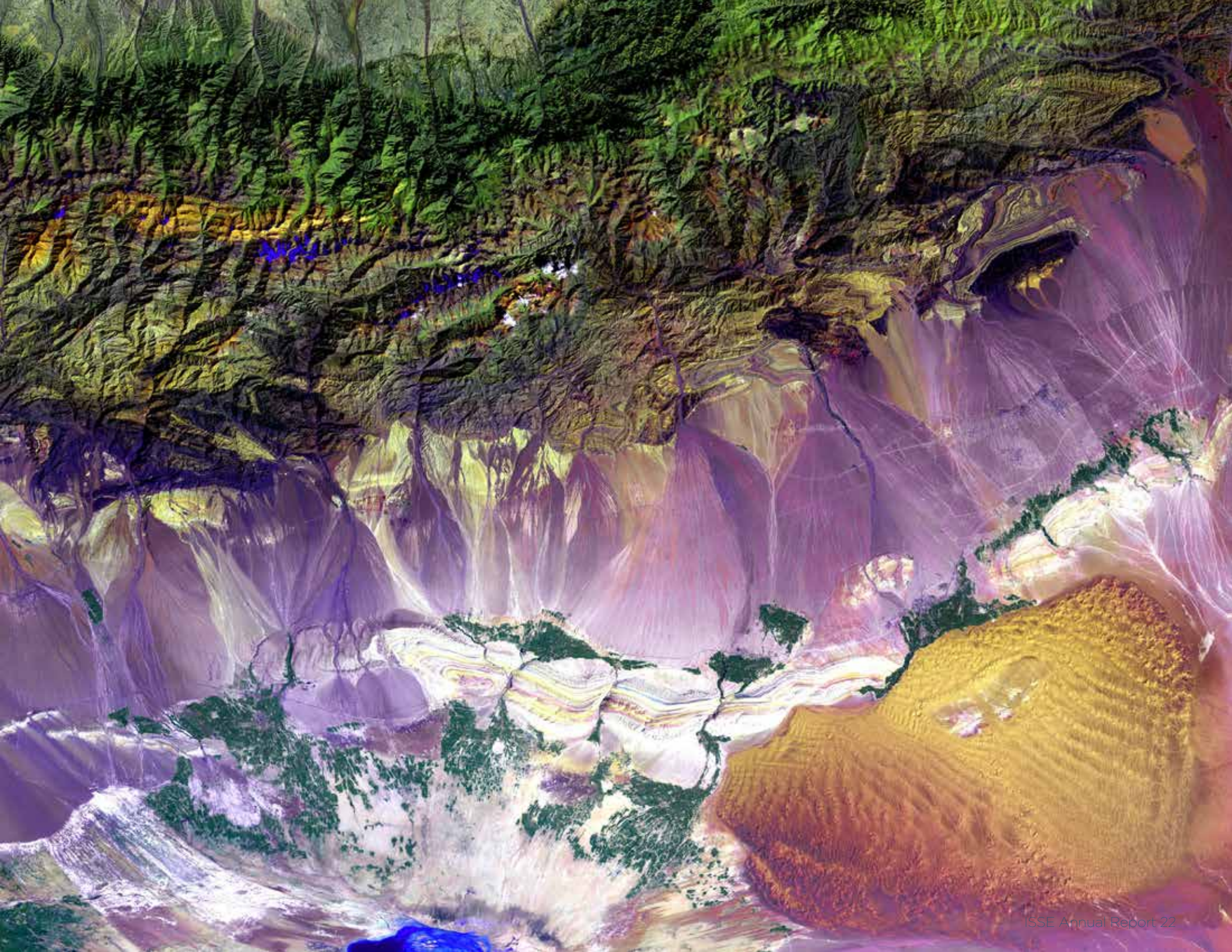
To achieve the project objectives, the following three tasks are proposed:

- Assemble a low-cost real-time water quality sensor
- Perform field-testing of the sensors
- Install sensors and monitor the sensor network.

The project study areas will include the Falling Water River Watershed and some river basins in the west Tennessee region. The Falling Water River Watershed (93 mi²) is HUC-10 classification watershed (HUC-0513010807), and a part of the Caney Fork watershed that drains into the Cumberland River in the Middle Tennessee region. It spans across White, Putnam, and Dekalb counties. This watershed is selected because it has already been instrumented with the low-cost water level sensors and therefore is an ideal candidate to extend it to monitor water quality.

The other study areas will be selected in coordination with the West Tennessee River Basin Authority (WTRBA) personnel (see letter of support). These locations will include river and lake systems in the western Tennessee region that are managed by the WTRBA.

Image source: US Geological Survey



Development of Lentic Periphytic Algal Indices of Trophic Status Needed to Assess and Monitor the Effects of Eutrophication in Littoral Habitats of Middle and East Tennessee

PI: Dr. Jeff Lebkuecher, Dept of Biology, Austin Peay State University

The relationships between nutrient concentration and abundance of lentic photoautotrophic periphyton are largely unknown which restricts their use as trophic-status indicators. The effects of eutrophication on algal assemblage structure cannot be evaluated without knowledge of the composition of healthy versus unhealthy assemblages. The objectives of this research are to: (1) document the richness and relative abundance of soft-algal and diatom taxa in littoral communities of Middle and East Tennessee lentic habitats, (2) correlate the relative abundance of each soft-algal and diatom taxon sampled to trophic status such that eutrophication-indicator species may be documented and trophic-status indicator values designated for each taxon, and (3) use the trophic-status indicator values to formulate the Lentic Periphytic Diatom Index of Trophic Status and the Lentic Periphytic Soft-Algal Index of Trophic Status.

Periphyton and water samples for determinations of total phosphorus and total nitrogen will be collected at ten upper littoral-zone sites ranging from oligotrophic to eutrophic in Middle and East Tennessee. The richness and relative abundance of diatom and soft-algal taxa will be documented and trophic-status indicator values assigned to each

taxon determined by abundance-weighted averages to the trophic status of the environments where taxa are present.

The relationship of trophic status to percent composition (relative abundance $\cdot 100$) of each taxon will be determined by calculating the abundance-weighted average (A-WA) for trophic status. A-WA of a characteristic (e.g., trophic status) for a taxon is the average value of a characteristic weighted by the abundance of the taxon at each site and will be calculated as: $A-WA_j = [\sum_{j=1}^n \text{taxon } n_j v] / N$ where: A-WA_j is the abundance-weighted average of a characteristic for taxon_j, n_j = number of taxon units j sampled at a site, v = value for the characteristic of a site, and N = total number of taxon units j at all of the sampling sites used to calculate A-WA_j.

Taxa more abundant at sites with greater values for trophic status will have a greater value for the A-WA and thus a greater trophic-indicator value. The values for the Lentic Periphytic Diatom Index of Trophic Status and the Lentic Periphytic Soft-Algal Index of Trophic Status will be calculated as: $\text{Index value} = [\sum_{j=1}^n \text{sp. } n_j t_j] / N$ where: n_j = number of individuals of taxon j , t_j = trophic-indicator value (A-WA) for taxon j , and N = total number of individuals tallied to calculate the index.

The indices will provide new tools that will enhance the ability of watershed managers to demonstrate the negative impacts of eutrophication and help managers illustrate to the public the importance of best management practices to improve water quality.

Graduate Student Supplemental Research Grant Proposals

Organic acid fate and behavior in the Great Smoky Mountains National Park

Jason Brown, GRA, Department of Biosystems Engineering & Soil Science; Faculty Advisor, Dr. John Schwartz, University of Tennessee, Knoxville.

Stream acidification has long been a concern to aquatic habitats, agricultural operations, and community water supply sources. The result of decades of pollution neglect, stream and soil acidification has inspired monitoring practices of atmospheric chemical deposition which has, in turn, played a role in the regulation of pollutants (Cai et al., 2010b). These improved regulations and advancements in technology function to manage and reduce outputs from certain point-source pollutants, such as power plants, although other known non-point levels of pollution are exceptionally difficult to suppress.

As a result, the reduced pollutant deposition has developed cause for concern over internally-produced acidic sources. Previously regarded as inconsequential due to large amounts of inorganic acid deposited across landscapes, organic acids have recently been suspected of playing a larger role in these internal soil and surface water chemical processes. As such, enhancements in the understanding of carbonic interactions will assist in remediation activities necessary to counteract this contamination. It is exceptionally important to define this knowledge to avoid future ecological and economic losses and other unforeseen consequences.

Given the aforementioned uncertainty, there is a need for further research of organic-C cycling and its relationship with acidic pollutants in GRSMNP. This concept will be addressed within this project by seeking answers to the following:

- What influences the activity of organic acids?
- What is organic acid's contribution to stream acidification?
- Can organic acid production be forecasted?
- How much is dissolved organic carbon affecting the toxicity of monomeric Al?

Assessing Water Quality of Rivers Feeding Riparian Wetlands in Agroecosystems: Research Supporting the Evaluation of the USDA Wetlands Reserve Program

Robert Brown, PhD candidate; Faculty Advisor, Dr. Justin Murdock, Department of Biology, Tennessee Technological University

Evaluation of nutrient retention capacity afforded by the USDA Natural Resources Conservation Service (NRCS) Wetlands Reserve Program (WRP) focuses on predicting nutrient retention rates based on floodplain soil characteristics, management practices, easement age, and frequency and duration of inundation. Nutrient uptake rates are calculated from water samples taken from flow-through incubations of soil cores collected from easements across west Tennessee and Kentucky. Uptake rates are then scaled to representative habitat areas to estimate

nutrient retention within easements. Incubation source water is made in the laboratory, and water chemistry parameters are held constant to allow more direct comparisons of soil uptake rates across all easements. Source water chemistry is derived from averaged historical data of water quality for rivers across the region. However, floodwater delivered to easements likely differs from historical averages in water quality characteristics. Floodwater characteristics may vary between river systems, and these differences can affect nutrient uptake rates. The proposed project will characterize floodwater quality of major rivers that feed WRP easements. Water will be collected from rivers at bankfull discharge and analyzed for total suspended solids, particulate and dissolved organic matter, and total and dissolved nutrients. NRCS funding requirements stipulate that all NRCS funds are spent on WRP easements. Therefore, additional funding is needed to collect off-easement samples from nearby rivers. Results of floodwater quality analyses from these rivers will inform ongoing research and provide natural resource managers with a more nuanced understanding of nutrient retention dynamics in WRP wetlands.

The use of Real-time Control in Bioretention Systems: An Investigation into the Microbial Communities of Actively Controlled Bioretention Systems

Padmini Persaud, Graduate Research Assistant; Dr. Jon Hathaway, Faculty Advisor, Department of Civil & Environmental Engineering, the University of Tennessee, Knoxville

Real-time control is a new technology for green infrastructure with largely unknown implications for water quality performance. This research aims to uncover the microbial processing that occurs within bioretention systems under both static and real-time control. In addition to building fundamental knowledge, the results will aid in optimizing real-time control in urban bioretention.

Bioretention is a green infrastructure practice used in mitigating peak stormwater flows and improving stormwater quality. Traditional bioretention involves the use of plants, engineered media, and drainage to replicate natural environmental processes (Glaister et al., 2017). A variation of bioretention involves creating an internal water storage (IWS) zone to allow discrete aerobic and anaerobic zones within bioretention cells. This may improve nitrogen processing, but can also limit storage space within the cell (Laurenson et al., 2013; Waller et al., 2018). Real-time control of bioretention systems has the potential to mitigate peak flows and further improve water quality, but the use of these systems in green infrastructure is relatively new. Preliminary research studied the effects of this technology on nitrogen processing and showed that actively controlled bioretention cells have the capacity to optimize nitrogen processing beyond that of traditional or IWS systems (Persaud et al., 2019). While overall water quality improvement has been studied, the specific microbial interactions within bioretention systems has not.

This research will focus on the microbial communities within bioretention systems that affect nitrogen processing and examine the difference in communities between traditional, IWS, and two real-time control bioretention systems.



Appalachian Regional Commission

Extending Our Welcome

Trends and Strategies for Tourism in Appalachia

Appalachian Regional Commission Tourism Study

Trends and Strategies for Tourism in Appalachia

PI: Dr. Tim Ezzell, ISSE

This report represents two years of work by a team of researchers from the University of Tennessee and Collective Impact, LLC. During this time, team members surveyed more than five hundred visitors to Appalachia and over seven hundred regional tourism stakeholders. Team members also visited more than a dozen communities across eight states.

The research team made considerable efforts to engage both visitors and stakeholders in the research process. This engagement was conducted both directly, through focus groups and interviews, and indirectly through open-ended survey questions.

Outsiders, and some insiders, sometimes view our region as poor. This study proves otherwise. Appalachia is a wealthy region – rich in resources, rich in history, rich in creativity, and rich in kindness, understanding, and hospitality. The Region has much to share and our visitors, we have found, gain much from their time here.

As Appalachia moves into the twenty-first century, the Region is embarking on a new chapter in its history, spurred on by a diverse population and an equally diverse economy. Tourism and travel, which have long been elements of the Region's life, are poised to become integral parts of this new economy. However, as Appalachian communities pursue various tourism strategies, they are confronted with a rapidly changing and highly competitive industry, and their ability to adapt to this ever-evolving landscape will be critical to their future success.



This study examines the state of tourism across the Appalachian Region. It evaluates both the opportunities for tourism in the Region, as well as the barriers and challenges communities may face. In particular, the study looks at the following wide range of questions:

- What common barriers (i.e., access to capital, perceptions of the local area, skills deficits, etc.) do communities and entrepreneurs face in their tourism development efforts?
- What resources and strategies can they use to overcome these barriers?
- What replicable best practices are being employed across the Region?
- What innovative new approaches are communities using to build their tourism sectors?
- How do successful businesses and communities leverage—and build on—local assets?
- What role do investments, including those by ARC, play in communities with successful tourism sectors?
- What leadership qualities are most important to local success stories?
- What emerging trends and markets hold the most potential for Appalachian entrepreneurs and communities?

- How are Appalachian communities and entrepreneurs using social media and digital technologies to promote their tourism development efforts?
- How can success in tourism be measured and evaluated?

By asking these questions, the research team and the Appalachian Regional Commission were able to accomplish several important goals. First and foremost, this study shows the current state of tourism across the region. Secondly, it provides community members, local leaders, and public officials with practical and proven strategies to improve and increase tourism. Lastly, it gives the ARC advice on how to measure tourism impacts and suggests areas where tourism investments can yield the best returns.

Bargain-hunting for Biodiversity: New Tool Pinpoints Conservation Targets

PI: Dr. Paul Armsworth, Ecology & Evolutionary Biology

The best bargains for conserving some of the world's most vulnerable salamanders and other vertebrate species can be found in Central Texas and the Appalachians, according to new conservation tools developed at the National Institute for Mathematical and Biological Synthesis (NIMBioS) at the University of Tennessee, Knoxville. The study involves a suite of computer algorithms that surfs across many different kinds of data to create maps of top priorities and projections of what species would benefit most from increases in conservation dollars.

An interdisciplinary team of computer programmers, biodiversity data scientists, conservation decision makers, economists, and others from around the globe convened at NIMBioS to develop the optimization tool, which was published in the journal *Ecological Applications*.

“The challenge for conservation practitioners is how to best combine many really disparate kinds of data and do so in a way that lets them compare possible options for protection—the goal being to find opportunities where conservation efforts offer the greatest bang for the buck,” said the study’s lead author, UT Professor of Ecology and Evolutionary Biology Paul Armsworth.

The algorithm considers data including land acquisition costs, future development patterns, budget allocations for conservation, and the presence of threatened species. The new approach could prove valuable to conservation and natural resource managers looking to optimize conservation dollars.



A new tool to help protect vulnerable species such as the *Eurycea sosorum* salamander (above), found near Austin, Texas, identifies some of the most cost-effective conservation bargains in the US.



Urban Floodplain Reconnection through Regenerative Stormwater Conveyances

PI: Dr. Jon M. Hathaway

In natural systems, stormwater moves to streams and river networks by way of floodplains, wetlands, and riparian forests which offer treatment and runoff detention. As watersheds are urbanized, these natural flow paths are short circuited by storm drains and pipes that bypass these ecosystem services. This causes increased peak flows in receiving waters with subsequent erosion, volume control, and pollutant problems.

Regenerative stormwater conveyances (RSCs) are an emerging design solution for urban runoff to decrease flow energy, increase infiltration rates, and remove pollutants. Positioned at the stormwater outfall, RSCs comprise an open channel step-pool system lined with vegetation and are sized to fully contain the 100-year storm. These pools are separated by riffle and weir boulder structures to safely convey water during large storm events.

The objectives of this project are to: (1) site, design, and create a floodplain wetland using RSC-style natural system design, (2) through surface and groundwater measurements, establish the quality and abundance of wetlands created by the Enhanced RSC installation, (3) develop design guidance for Enhanced RSCs being used to reconnect urban watersheds to floodplains / recreated wetlands, and a wetland functional tool to assess restoration outcomes, and (4) use a series of workshops and

*left: Nicholas Ross and Caleb Svensson install an access staircase on a stormwater pond.
Photo by Aaron Akin.*

webinars to educate regulators, designers, and other academics about the use of Enhanced RSCs for wetland restoration.

During this period, we selected the area beside Powell Branch Library as the project installation site. This area is managed by Legacy Parks, a non-profit organization in the Knoxville area. The stormwater outfall feeding the site has created a lot of erosion, short circuiting runoff to Beaver Creek in Knox County. Surveying was conducted to create a topographic map for the site's final design. We installed a tipping bucket and manual rain gage near the site to collect primary data. To pair with these rainfall data, pressure transducers were installed in the pipe feeding the site to get an initial estimate of the watershed's rainfall-runoff relationship.

We determined the watershed area using GIS and geospatial data for the location. Land use and soil type were then used to create sub-catchments of similar characteristic. Information on these catchments was entered into modeling software (HEC-HMS) to approximate flow through the RSC site under various size storm events. These initial calculations along with the topographic map will be used moving forward to begin designing the RSC.

Environmental Outputs and Outcomes: A survey of the site and watershed modeling allowed design of the RSC to begin. This data will be used to identify the location of the groundwater wells and monitoring equipment (in addition to sizing the RSC). Appropriate sizing of the RSC is critical for optimized stormwater treatment to address a substantial point of erosion where runoff enters Beaver Creek.

Scope of Work for “Assistance with Metro Nashville Stormwater Manual”

PI: Dr. Jon M. Hathaway

Specific Tasks and Deliverables:

- Assist Wood E&IS review revisions and updates to the 2016 Stormwater Management Manual, Volume 5 Low Impact Development. Specifically, six green infrastructure practices (GIPs): bioretention, urban bioretention, permeable pavement, infiltration, water quality swale, and extended detention pond. Deliverable: summarized review comments for each GIP and recommendations.
- Assist Wood E&IS with the research of technical specifications for the verification of bioretention media and soil cover composition as implemented in other stormwater manuals. Deliverable: a comparative table of verification processes and recommendations for local implementation.
- Assist Wood E&IS with the formalization of the technical specifications for the verification of bioretention media and soil cover composition currently under-development with Metro Water Services and the State of Tennessee. Deliverable: recommend revisions to bioretention GIP and document verification methodology.

Sponsored Projects

Methane Center NSF Hydraulic Fracturing Biocides Project

Sponsor: National Science Foundation

PI: Dr. Terry Hazen

For the second year of the NSF award, Impacts of Biocides Associated with Hydraulic Fracturing on Aquatic Microbial Communities, samples from stream in Pennsylvania were collected by undergraduate students from Juniata College, an undergraduate-only institution. Due to COVID-19 the undergraduate students were not able to travel to UTK for training but samples were sent to UTK for biogeochemical analyses. The students participated in weekly Zoom calls with former Methane Center Postdoc, Dr. Maria Fernanda Campa, where they discuss data analyses methods and wrote the results from summer 2019 sampling efforts. The manuscript is currently undergoing internal review prior to submission for publication.

This award is to study the environmental implications of biocides used in hydraulic fracturing, particularly antimicrobial resistance. The students collected water and sediment samples from 21 streams in Pennsylvania and completed the two summer field sampling events. These samples have now been processed for cell counts, ions, organic acids, and trace metals and will be processed for biocides and microbial community composition and function as well as for cultivation of biocide resistant strains.

What Is Driving the Global Wildfire Trend?

*Sponsor: ORNL Terrestrial Ecosystem Science Scientific Focus Area (TES SFA) project, funded by the US Department of Energy
PI: Rongyun Tang, Dr. Mingzhou Jin, faculty advisor*

Recent wildfires in California, Australia, and Tennessee cause the public wonder whether wildfires are more prevalent than before, and if so, what are the underlying reasons. Rongyun (Savannah) Tang, a PhD student at Industrial and Systems Engineering and a research assistant ISSE, is trying to answer those questions under the supervision of Dr. Jiafu Mao, an R&D staff member of the Climate Change Science Institute at the Oak Ridge National Lab, and Dr. Mingzhou Jin at UTK.

Preliminary results show that the satellite-derived burned areas for the past 20 years have declined, and this decreasing trend is consistent with what is simulated by the latest land component of DOE's Energy Exascale Earth System Model (ELM of E3SM). ELM factorial experiments further indicate that the changed fire activities at the global scale is mainly determined by the changing climate and land use and land cover change. Relevant regional analysis focusing on spatiotemporal dynamics of ecosystem fires in China over the past two decades has been accepted by Geography and Sustainability. Savannah is continuing the inter-comparisons among different sources of fire data and developing recommendations for potential mitigation of wildfire-induced damages.

Policy Study on the Adoption of Alternative Fuel Vehicles

*Sponsors: DOE - ORNL - UT-Battelle - Oak Ridge National Laboratory
PI: Dr. Mingzhou Jin*

For adoption analysis of Alternative Fuel Vehicles (AFVs), the total ownership cost of AFVs is the key element to consider to evaluate their relative competitiveness to conventional vehicles (CVs). Among all the aspects which affect the total ownership cost, the total fuel cost plays an indispensable role. Therefore, we collect two aspects of fuel cost to calculate the total fuel cost. One is the fuel economy of vehicles and the other is the fuel price of each technology. With extensive literature reviews, the team created a database on energy use for light-duty vehicles (LDVs) and medium- and heavy-duty vehicles (MHDVs) and energy price. All these data are stored in the form of excel spreadsheets. In total, the team identified 1,047 records for LDV energy use, 1,684 records for MHDV energy use, and 123 records for energy prices. Each record is distinguishable by vehicle type (e.g., powertrain, class, and use type), driving conditions (e.g., CS and CD), and reference source (i.e., different papers and reports). The team demonstrated example results as follows.

Figure 1 shows the fuel economy comparison between luxury and non-luxury LDVs for different powertrain technologies (CVs and AFVs). The weighted average fuel economies are calculated based on the harmonic means using vehicles sales and model-specific highway and urban combined fuel economies with the Wards data which are consistent with EPA rating. For electric vehicles (PHEVs and BEVs), MPG calculations are based

on EPA data. A full comparison in fuel economy is not made, with unavailable fuel economy data for several classes and technologies for luxury vehicles (e.g., fuel economy for luxury PHEVs). However, for available luxury vehicle data, luxury vehicles' fuel economies are generally higher than non-luxury vehicles due to potential better vehicle performances.

Another factor that contributes to different energy cost between luxury and non-luxury LDVs is the energy price. For CVs, premium gasoline prices are used which are expected to be higher than regular gasoline prices. However, a projection of future premium gasoline prices is not available compared to the gasoline prices which are projected by EIA. Therefore, the team managed to develop similar statistical relationship model to estimate the premium gasoline prices based on regular gasoline prices. Historical annual average gasoline prices from 1994 to 2020 are collected from the EIA data, and are used to fit the relationships.

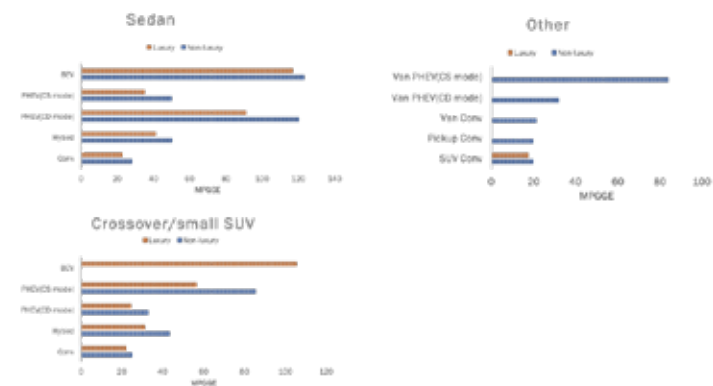


Figure 1. Comparisons in Weighted Average Fuel Economies between Luxury and Non-Luxury LDVs

Figure 2 shows two statistical models. The un-weighted model assumes that all historical data are treated equal, while the weighted model assigns higher weights to recent gasoline price data compared to older ones. The statistical relationship formulas are also present in the graph.

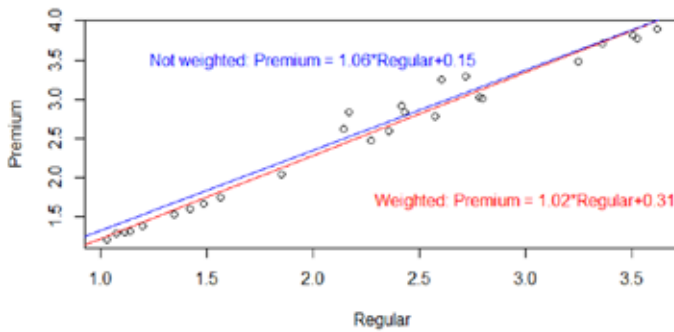


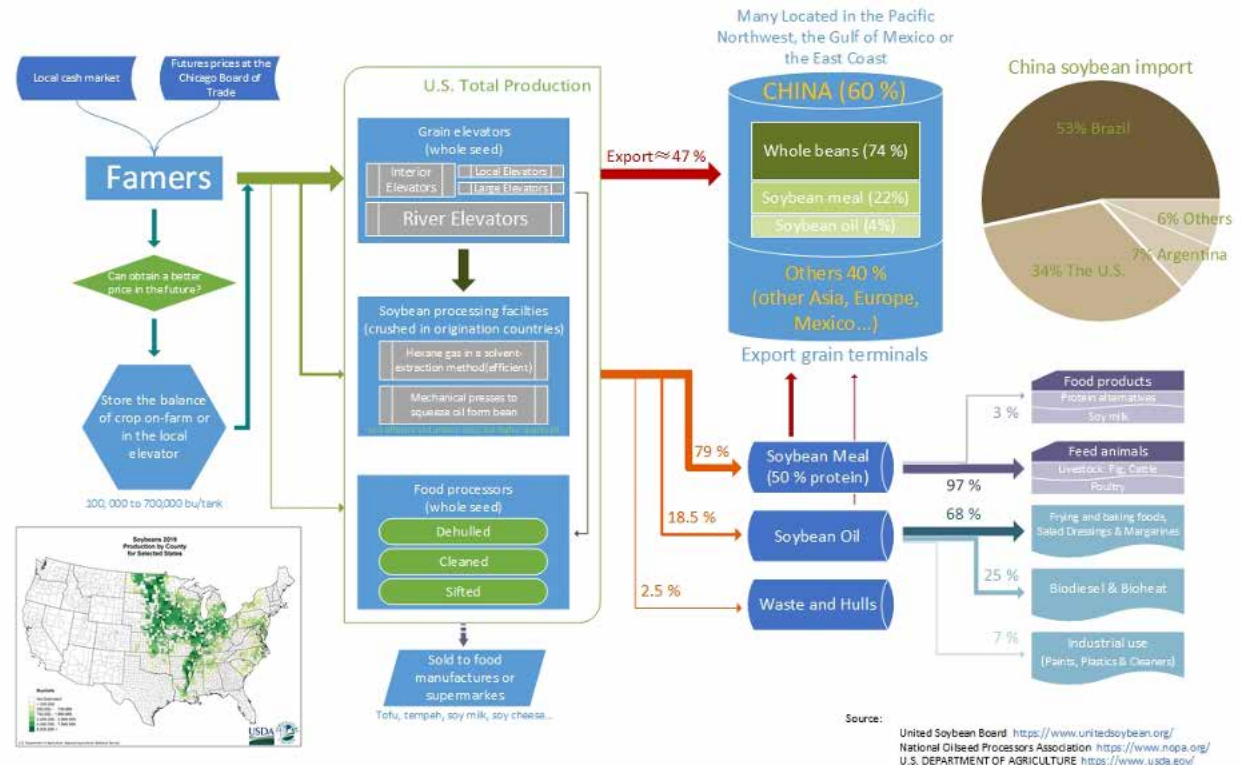
Figure 2. Relationship between Premium and Regular Gasoline Prices

NSF INFEWS: U.S.-China: Coupled FEWS Modeling for Sustainability of the Global Crop Supply Chain with a Focus on China - US Interactions: July 2019 ~ June 2020

Sponsor: National Science Foundation
PI: Dr. Mingzhou Jin

This NSF project is to advance FEWS systems modeling methodologies and enhance the understanding of the major interactions of the global crop Supply Chains (SC) by developing a framework for integrating climatic, economic, governmental, societal, and technological changes and using the SC formed by China and the US to identify technical, societal, and policy solutions to improve the sustainability and resilience of the global crop SC, especially soybean

SC. The team tries to understand how climatic, societal, governmental, economic and technological changes impact global crop supply, demand, and prices in a dynamic way. The project is trying to integrate various models with heterogeneous data and spatio-temporal resolutions via the idea of multi-scale modeling to connect the global environment and local issues. The implementation of this idea requires careful consideration of resolution selection and the interface between models with a tradeoff among system accuracy, solution relevance, model complexity, and computational burden. Through a stakeholder meeting in May 2020, the team has modeled the global soybean SC that considers interest of various stakeholders.



Source: United Soybean Board <https://www.unitedsoybean.org/>
National Oilseed Processors Association <https://www.nopa.org/>
U.S. DEPARTMENT OF AGRICULTURE <https://www.usda.gov/>

Quantifying Food Lost and Wasted Along U.S Food Supply Chain

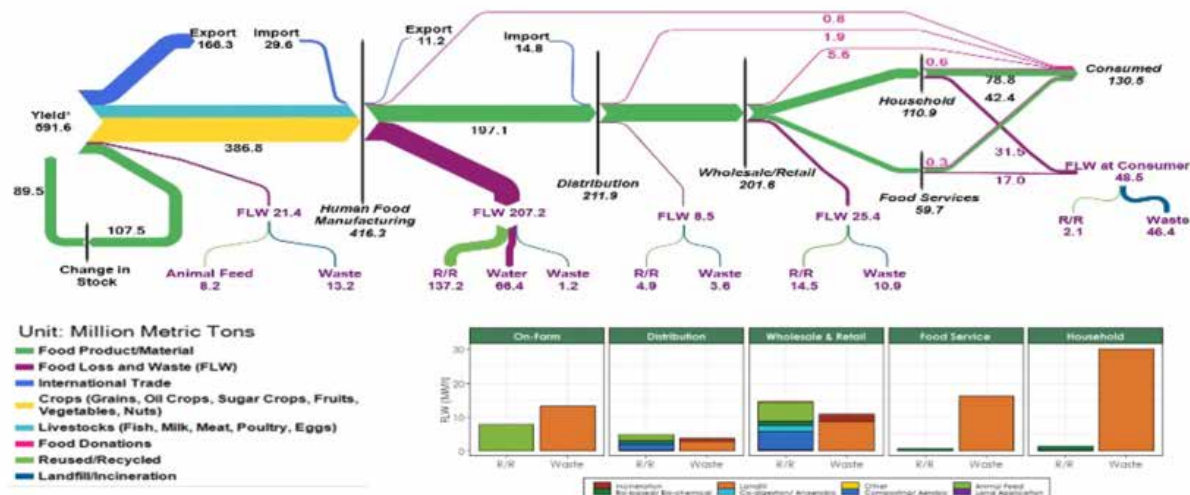
Sponsors: U.S. Department of Agriculture (USDA) and U.S. Environmental Protection Agency (EPA)
PI: Dr. Mingzhou Jin

USDA and EPA have set goals to reduce 50% of U.S food loss and waste (FLW) by the year 2030. In support of these goals, this collaborative study between ISSE and the Oak Ridge National Lab quantifies the food lost and wasted along the U.S food supply chain to establish a baseline of food loss and waste (FLW). The research team is led by Dr. Sachin Nimbalkar, the group leader for Energy Efficiency at ORNL and a joint associate professor at UT. The team also includes Wenquan Dong, an Industrial Engineering PhD student, Dr. Mingzhou Jin, ISSE director, and Ms. Kristina O. Armstrong, a post-masters research associate for energy efficiency at ORNL.

The study identifies the sectors and stages that contribute most to FLW, how FLW is disposed of in each sector, and the most effective ways to reuse and recycle the FLW generated in the U.S. food supply chain. Five major stages of on-farm production, manufacturing and packaging, distribution, wholesale and retail, and consumer stages were considered using data from USDA and other sources for the year 2016.

In 2016, approximately 311 million metric tons (MMTs), more than half of food harvested for human consumption, were wasted or lost, including

21.4 MMTs of food materials were harvested but not acceptable for buyers due to improper on-farm



production activities (e.g., harvesting and storage) and buyers' strict standards. It is also estimated that among on-farm FLW, 13.2 MMTs were sent to landfills, which is considered real waste, and 8.2 MMTs were used to feed animals.

Food manufacturing and packaging is the largest contributor to FLW, with a total of approximately 207.2 MMTs after food donation. However, most of this amount, 137.2 MMTs, was actually recycled for use in other industrial sectors, such as pet food and fertilizer. Water evaporation during food processing (e.g., dried fruit and vegetables) caused a loss of 66.4 MMTs. As a result, only 1.2 MMTs of food were actually disposed of via landfill, representing a high level of circular economy in the U.S. Food manufacturing sector.

Distribution generated the least FLW of 10.4 MMTs. The main cause was rejection due to food spoilage during shipment, which was low because of modern logistics technology and management (e.g., much more advanced cold chains than before).

Wholesale and retail (e.g., warehousing and grocery stores) contributed 25.4 MMTs of FLW for various reasons such as consumer rejection and overstocking. In general, U.S. food logistic service providers, wholesalers, and retailers have started to donate or recycle a large percentage of their FLW, mainly through composting and digestion. However, greater efforts can be made since around 40% of FLW in this stage are still disposed of in landfills.

Consumers (i.e., household and food services) are responsible for 48.5 MMTs of FLW. Consumers are the biggest contributors to landfills (46.3 MMTs). The consumer stage uses much less diversion, reuse, or recycling than other food supply chain stages. Therefore, more efforts should be made to prevent, recover, and recycle the FLW at the consumer stage.

Data Analytics Support for Integrated Earth Model

Sponsors: DOE, UT-Battelle & Oak Ridge National Laboratory

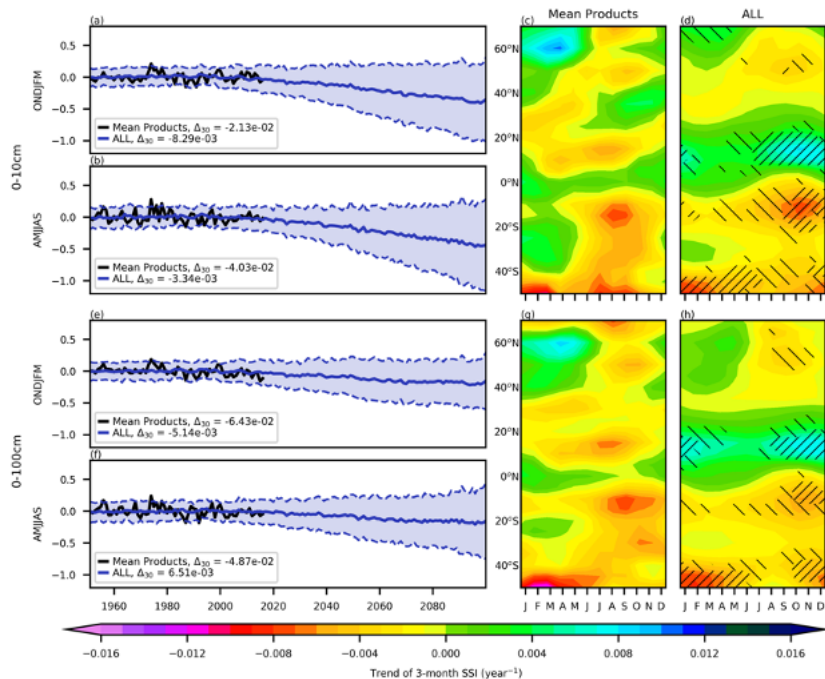
PIs: Yaoping Wang, Mingzhou Jin, University of Tennessee, Knoxville; Jiafu Mao, Oak Ridge National Laboratory

Background: Drought is a natural phenomenon that adversely impacts the productivity of natural and crop systems and the availability of water resources. Climate change is likely to cause intensification of global drought through the increasing atmospheric demand for evapotranspiration. Nonetheless, the pattern and degree of the impact are complicated by regionally heterogeneous changes in precipitation, and the differences between drought indices, seasons, and soil layers. Detection and attribution is

a genre of methods that can statistically quantify the impacts of human-related factors and natural climate variability on observed climate variables. For global drought, an appropriate climate variable for the detection and attribution can be soil moisture-based drought index, which is directly related to land-atmosphere interaction and the productivity of crops and natural plants. During the previous phase of the project, the team has developed several global, long-term soil moisture datasets that provide the foundation for such detection and attribution.

Goal: The project aims to conduct detection and attribution on global soil moisture drought for the historical period using a pattern-based method and previously developed datasets. The detection and attribution will be applied on latitudinally averaged standardized soil moisture index for each month of the year and two soil layers, 0-10cm and 0-100cm.

Progress to Date: The team has conducted the detection and attribution analysis and is finalizing the results for publication. The results indicate that significant human impacts ($p < 0.05$), mainly greenhouse gas emissions, existed in the historical trends of the latitudinally averaged soil moisture index. The spatial pattern of the impacts was characterized by wetting in the tropical region and in spring in the northern high latitudes, and drying, especially in summer, in the northern and southern midlatitudes. Future climate model projections suggest that the drying and wetting patterns will continue into the 21st century.



Historical changes in global average standardized soil moisture index (SSI), and latitudinally averaged SSI, in the historical soil moisture products (Mean NonCMIP) and the historical all-forcing simulations of the Coupled Model Intercomparison Project phase 6 (CMIP6) models (ALL). ONDJFM - October through March. AMJJAS - April through September. Δ_{30} refers to the difference between the average SSI values of the thirty-year period 1987-2016 and 1951-1980. Left hatches: 90% agreement on the sign of trend between the CMIP6 models. Right hatches: 80% agreement on the sign of trend between the CMIP6 models.



Seed Grants

Analyzing Strategies for Diverting and Managing Organic Waste Streams in Tennessee

PI: Dr. Christopher Clark, Agricultural & Resource Economics

Progress on the seed grant since the March 1 Progress Report has been hindered by the COVID-19 pandemic and the appointment of the PI to Head of the Department of Agricultural & Resource Economics. We have, however, responded to the shut-down of restaurants (the focal source of our organic waste efforts) and the disruption in food supply chains resulting from the pandemic in a couple of ways. First, Co-PI Chad Hellwinckel led the effort to submit the attached NSF proposal. Basically, when COVID disruptions hit, Chad seized the opportunity to look at home gardening and small-scale community composting as a response to the possibility of food supply chain disruptions. Should the NSF proposal be funded, we would broaden the work to include a number of other components of the original seed grant in a follow-up proposal. We are also investigating whether there is any overlap between the proposal Chad and his team submitted and some educational opportunities Seema Prasad our private partner is pursuing. However, given that Seema is a restaurateur in Nashville, her ability to participate in our work has been limited by her efforts to keep her restaurant afloat in these challenging times.

Chad is in the process of implementing obtaining IRB approval to conduct a survey of people who picked up compost at his community composting

centers, which we anticipate serving as the basis for a journal article (a deliverable of the seed grant). The PI and other Co-PIs will assist in designing and implementing the survey, as well as analyzing survey results and authoring a manuscript.

At the time of the order to work remotely was handed down, Chad and Brad Wilson were busy developing the rudiments of a siting model for facilities to process/compost organic wastes. That work has been on hold, pending Chad's composting efforts and Brad's work on a variety of COVID-related projects. Now that Chad's NSF proposal has been submitted, they are now restarting their work on the siting model, specifically by: including restaurants and institutions to go with their residential data, thinking about a second stage collection routing optimization routine (i.e., locate the facilities in the first stage and then solve for optimal collection routing given the locations), and considering not only waste sources but also nutrient sinks (e.g., farms, golf courses, etc). We hope to make the siting model (which is effectively composting technology neutral), perhaps coupled with "case study" composting technologies, as the basis for a grant proposal. The general idea is to develop a decision tool to help communities manage their organic waste.

We are also looking to integrate other work by Co-PI Shawn Hawkins on spatial nutrient imbalances associated with animal agriculture (i.e., excess of nutrients in chicken litter above crop intake in one county versus high ag demands for nutrients in other counties). Specifically, we are considering the creation of a spatially and temporally-explicit database of nutrient sources (i.e., organic municipal waste, biosolids, animal wastes, etc) and sinks (farms, golf courses, etc). Such a database would be

useful for thinking about the potential for, and the possible structure of, a recovered nutrient market. This effort could also easily lead to a journal article or Extension publication and might be a useful component of a grant program or Extension education program. We will investigate the possibility of State of Tennessee funding for such work.



Multi-Sensor Data-Driven Inspection/Maintenance of Green Infrastructure

PIs: Dr. Anahita Khojandi, Industrial & Systems Engineering, Dr. Jon Hathaway, Civil & Environmental Engineering

The goal of this work is to employ the Internet of Things to inform and optimize green infrastructure inspection and maintenance, an increasingly common burden for stormwater managers and utilities nationwide. Specifically, we aim to (Task 1) use laboratory experiments, low cost sensors, and real time monitoring to establish a baseline of bioretention performance under normal and impacted conditions, (Task 2) use machine learning algorithms to analyze sensor data for early identification of impacted bioretention.

As a reminder, data will be collected using a column study where we force poor performance on lab scale bioretention areas by introducing conditions that can lead to various maintenance requirements. This is critical, as within the timeline of this project it is improbable than any bioretention being monitored in the field (a potential alternative approach) would move from performing well to being in critical need of maintenance (for example, complete clogging of upper soil layers).

These photos presents the progress on column construction. The columns are composed of five distinct layers. From the bulkhead drain to the top of the column, there are 3-inches of gravel, a 3-inches of pea gravel, a 3- inches of sand, 3-feet of bioretention media, and 3-inches of mulch. Filling of the columns was completed in stages for each layer. For example, each of the nine columns were filled with the 3- inch drainage layer of gravel before moving onto the pea gravel layer. This process was used to allow the materials in each column to settle before applying the next layer. The depth of each layer was checked with a steel stream gauge before and after each



material was poured into the column to ensure consistency of each layer throughout all nine columns. Because the bioretention media was disturbed while filling, the columns were watered to promote any additional settling of materials before the final mulch layer was applied. While filling the bioretention media, extra care was taken to ensure that the soil moisture sensors were consistently installed 6- inches above the base and 6-inches below the surface of the bioretention media.

Seven sensors were installed on each column: two soil moisture sensors, an analog pressure transducer, a float switch, an ultrasonic sensor, and two discrete water depth sensors. The soil moisture sensors were installed within the bioretention media to monitor volumetric water content and temperature within the media. The ultrasonic sensor, one of the discrete water depth sensors, and the float switch were installed within a monitoring well attached to the side of each column to monitor ponded water depth. The second discrete water depth sensor and analog pressure transducer were mounted within a standpipe connected to the column at the same depth of the bottom of the bioretention media. Therefore, the water depth measurements within the standpipe are equivalent to the water depth within the bioretention media.

Task 2: Data analysis and machine learning models.

As reported in the past progress report, in anticipation of the data we will receive, we have used similar data from another column study to build machine learning models. Specifically, we have developed Neural Networks (NN) and Recurrent Neural Networks (RNN) where we use various data streams including the readings from a subset of sensors and

precipitation measurements to predict the readings from the remaining sensors at the same time epoch or at some point in the future.

The first part of this study was submitted as a conference paper to 2020 IISE Annual Conference. This study was recognized in Summer 2020 by IISE Operations Research Division as Third place, OR Undergraduate Student Research Dissemination Award.

External Funding and targeted publications

A pre-proposal was submitted to the Water Research Foundation (WRF) for the RFP: Unsolicited Research Program on March 30, 2020. The team was invited to submit a full-proposal, which is currently being finalized and will be submitted by the end of July.

The team is currently working on extending the conference paper and preparing a manuscript for submission to a peer-reviewed journal. We anticipate to submit this draft for review before the end of the Fall semester.

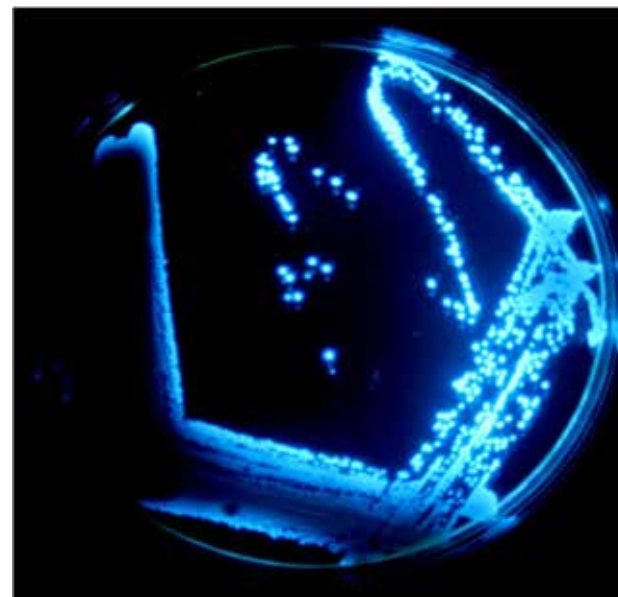
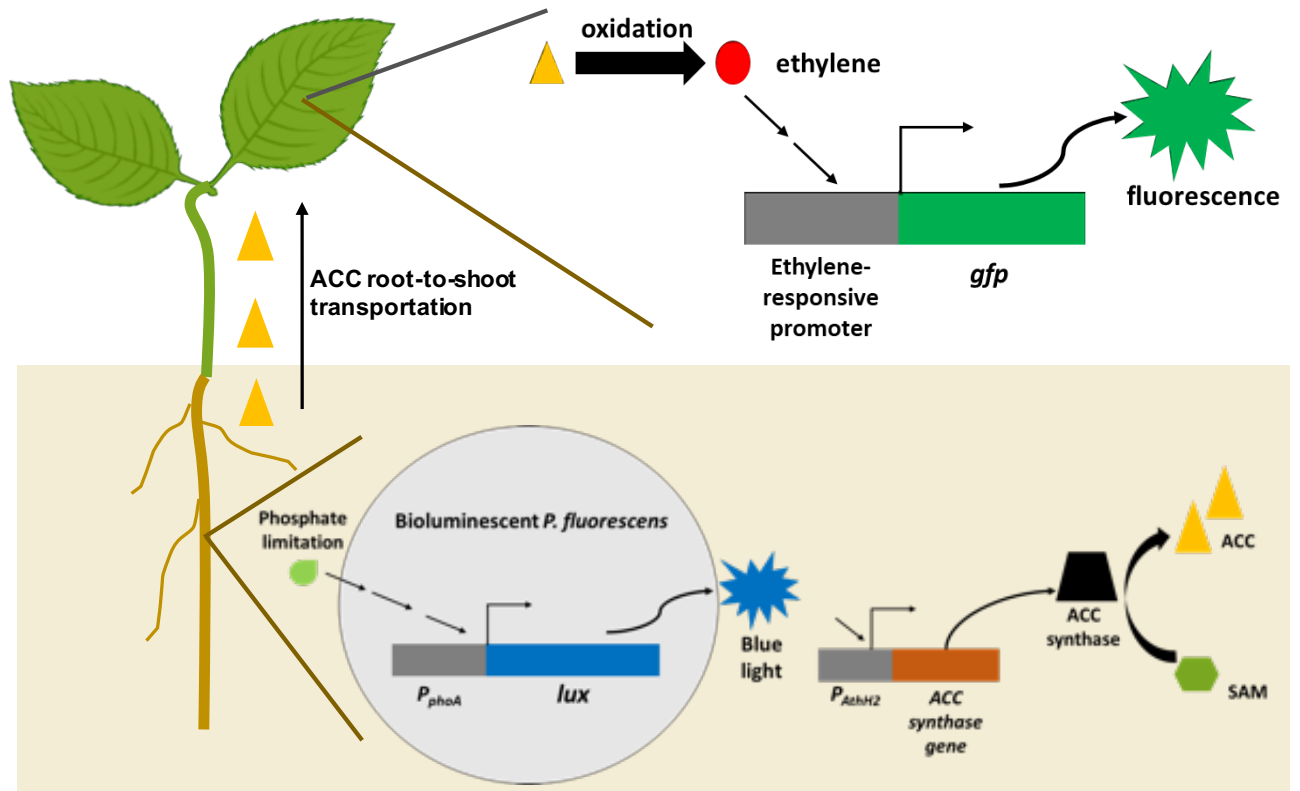


Emerging Synthetic Biology for Plant Phytosensing and Agricultural Sustainability

PIs: Dr. Steven Ripp, Center for Environmental Biotechnology; Dr. Sarah Werner (nee Lebeis), Microbiology; Dr. Scott Lenaghan, Food Science; Dr. Tingting Xu, Center for Environmental Biotechnology

The project goal is to develop a multi-organism signaling system consisting of rhizosphere bacteria and their plant host in order to sense and relay an underground soil signal to an easy-to-detect optical signal in plant leaves. To do so, the team will combine soil chemistry-responsive bacterial reporter systems and light-inducible plant promoter systems and take advantage of innate root-to-shoot plant transportation system to relay the signal to the canopy for ultimate detection. We will use bioluminescent rhizosphere bacterial bioreporters that are responsive to changes in soil conditions to induce the synthesis of plant signaling molecules in the root, and use the plant's vascular system to transfer the signaling molecules to the leaf canopy where they will trigger the production of the final optical signal for easy detection.

External proposals being developed: The team originally planned to develop a proposal to the NSF Signals in the Soil (SitS) program with a due date of May 20, 2020. However, the COVID19 pandemic-related slowdown in research activities made it impossible to meet this deadline. The plan now is to have a proposal submitted to the SitS program in 2021. If the SitS program is no longer available in 2021, our alternative plan is to apply to an NSF EAGER solicitation.



Bioluminescent bacteria



Training & Education

Appalachian Community Technical Assistance and Training (ACTAT) Program

*Sponsor: West Virginia University, funded by the Appalachian Regional Commission
PI: Dr. Christopher Wilson*

While many in Tennessee are fortunate to have adequate water supplies, there are those, predominantly in east Tennessee, who lack suitable water delivery and sewage disposal systems. Compounding the problem, several utilities in Tennessee have been sporadically maintained due to insufficient income. The resulting deterioration to manholes and sewage pipes has led to unrecoverable water loss, as well as

allowed rain and groundwater to leak into them (i.e., Infiltration & Inflow, I&I). With the state receiving 3-times more heavy precipitation events in the current decade as in the previous one, the added water overloads treatment plant pumps causing bacterial-laden raw sewage to back up into local streets and streams leading to fish kills, eutrophication, and other health problems. Roughly 20% of the small, public utilities in Tennessee are under moratoriums because of excess overflows.

Researchers from the Institute for a Secure and Sustainable Environment, along with colleagues from West Virginia University and the University of Kentucky, are part of the Appalachian Community Technical Assistance and Training Program

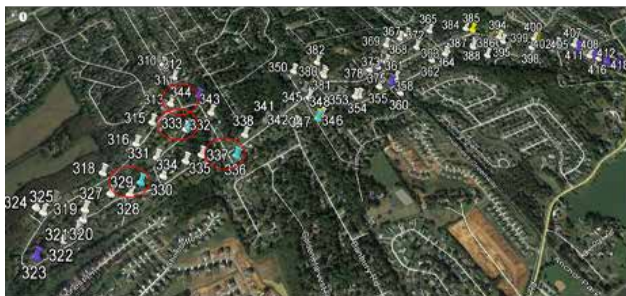
(ACTAT). ACTAT uses a land-grant university model program to provide free training sessions to community leaders and water utility service personnel in small Appalachian communities, and customized, face-to-face technical assistance.

Two training workshops have been held in the past year at the field office of the Tennessee Department of Environment & Conservation in Johnson City. Operators, who attended the training sessions from communities like Greeneville, Lakeview, and Carderview, are considering one-on-one assistance in developing and implementing Utility Management Improvement Plans to address their key concerns.

More training workshops are being planned in the Knoxville, Chattanooga, and Cookeville areas. However, in response to the COVID-19 pandemic, the workshops have been converted to two virtual ZOOM sessions. The first session focuses on conducting a managerial / operational self-assessment for each utility. The second involves a one-on-one session towards developing an action plan.

The Tennessee team offers additional assistance based on their strengths of infrastructure assessment, advanced monitoring instrumentation, and hydrologic/ hydraulic modeling. We are exploring ways to help the utilities identify economically recoverable water losses and estimate I&I

Figure (moving clockwise from top left): Thermal imagery inside a water distribution utility; An example of I&I through a degraded pipe; Satellite thermal imagery to identify potential areas of I&I; a Google Earth visual interface that can present asset notes as well as collected images and videos.



considering local geologic and topographic conditions. These include thermal imagery conducted both locally and via satellite and certain wastewater quality indicators (e.g., temperature, conductivity) which can also be more cost-effective for estimating I&I than dye or smoke tests.

Along the lines of outreach, we contributed information to the new ACTAT website (www.nesc.wvu.edu/actat), which is accessible through the West Virginia's National Environmental Services Center website. The website contains information related to Tennessee's water infrastructure, as well as an overview of the Tennessee team and how we can best assist the rural water/ wastewater utilities in the state. We plan to include video-taped testimonials from utilities who completed the ACTAT program. To guide these testimonials, we have developed short, but open-ended questions that allow the utility personnel to elaborate. The questions ask about their specific practices both before and after ACTAT.

The project has developed a website:
<https://www.nesc.wvu.edu/actat/tennessee>.



above: ACTAT provides free training sessions to community leaders and water utility service personnel in small Appalachian communities.

Appalachian Teaching Project

Increasing Economic and Entrepreneurial Opportunities by Promoting Outdoor Recreation Among Underrepresented Visitor Groups

In Fall 2019, Dr Ezzell led his eighteenth class as part of the Appalachian Teaching Project (ATP). The ATP, which is sponsored by the Appalachian Regional Commission, engages students at Appalachian colleges and universities across the region with communities to help address local or regional issues. UT Knoxville is one of fifteen institutions participating in the ATP. Dr. Ezzell's 2019 class research issues related to minority participation in outdoor recreation in Appalachia. They found that long-standing historical and cultural perceptions were a major barrier to outdoor recreation among underrepresented groups. A lack of representation in media also contributes to this trend. They also found, however, that interest in outdoor recreation is increasing, as younger populations seek to reclaim their connection to nature and their Appalachian identity. Using the Ocoee River Basin as a case study, the class formed recommendations that included increased representation in marketing media, welcoming signage, and programs to introduce minority colleges students to activities such as camping, hiking, and paddlesports.

right: Alex Moore, the 2019-2020 Appalachian Leadership Student Fellow, presenting UTK's project to the ARC leadership and staff at the annual ATP meeting in Washington, D.C.

National Institutes of Health & National Science Foundation STEM Programs

Dr. Ezzell continued his work with two innovation STEM programs, PIPES (Possibilities in Postsecondary Education and Science among Rural Appalachian Youth) and ASPIRE (Appalachian Students Promoting the Integration of Research in Education). The programs, sponsored by the National Institutes of Health (PIPES) and the National Science Foundation (ASPIRE), introduce and help prepare Appalachian youth for careers in the sciences and health sciences. Dr. Ezzell helps prepare and review project materials, helps address cultural barriers, and provides training for UT students and staff working in the project's Appalachian communities.





DOE Worker Training Program

Dr. Shelia Webster, ISSE research director, and training staff members were registered for the Emory University conference, Facilitating Workforce Protection for Biosafety and Biopreparedness when it was cancelled because of the Covid-19 Pandemic. Consequently, they participated in several days of virtual classroom presentations that included National Institute of Environmental Health and Sciences (NIEHS) Essential Worker Training for Train the Trainer.

Dr. Webster and her staff also attended a virtual grantee meeting with the Partnership for Environmental Technology Education (PETE). That webinar covered different plans to address Covid-19/Hazardous Waste Operations and Emergency Response (HAZWOPER) training. Other virtual meetings included Virtual Covid-19 Respiratory and Personal Protective Equipment Training and a Revised Covid-19 Biosafety and Infectious Disease Response Initiative.

Rex Short, Program Manager for HAZWOPER ONLINE, facilitates the collaboration between UCOR and UT. Currently, the HAZWOPER 24-hour and the 8-hour online refreshers have increased during the Covid-19 shutdown at UT and DOE facilities.

To bridge the field-to-lab studies of fundamental biological interactions, Dr. Dominique Joyner, certified trainer from Great EST Training and UT

left: Students from the Appalachian Teaching Project class evaluate the Ocoee Whitewater Center in the Cherokee National Forest.

Microbial Ecology and Lab Manager, will integrate ENIGMA (Ecosystems and Networks Integrated with Genes and Molecular Assemblies) research information into the HAZWOPER training. ENIGMA is a DOE funded project at ORNL, where field researchers are required to have 40-hour HAZWOPER and RAD Worker II level training.

UTK Participation in the National Partnership for Environmental Technology Education

Dr. Dominique Joyner in Civil & Environmental Engineering participated in CCCHST, the Community College Consortium for Health and Safety Training class in Davenport Iowa in June of 2019. CCCHST is one of twenty model worker training programs recognized and funded by the National Institute of Environmental Health Sciences (NIEHS). It consists of community colleges partnered with business and industry, universities, and community-based organizations and is administered by PETE, the Partnership for Environmental Technology Education.

The two-week teacher training course moves fast, with time only for training, homework, dinner, and then to bed. Week one is hazardous waste site remediation, and the second week is spill response. More than half of the class is spent in the field, observing the field site to generate HASP (Hazard Assessment and Signage Program) assessments, dressing out in Class A and B level gear, shown right, for sampling and running other practical drills to get the future trainers well versed in the scenarios they will teach. With this effort the University of Tennessee now has a qualified HAZWOPER trainer onsite.





TNWRRC Training

Since October 1, 2019, TNWRRC has offered seven different courses: Levels 1 and 2 of Tennessee Erosion Prevention and Sediment Control (TNEPSC) Training Program for Construction Sites plus a TNEPSC Recertification course; Levels 1 and 2 of Tennessee Hydrologic Determination Training and its corresponding Recertification course; and the Storm Water Control Measure Inspection and Maintenance Workshop.

TNWRRC has offered a total of 34 course sessions and trained 2,200 professionals in these workshops.

TNEPSC offers three training workshops for developers, contractors, engineers, and other professionals, inspection personnel, and enforcement officials responsible for all aspects of preparation and implementation of Storm Water Pollution Prevention Plans for preventing erosion and controlling sediment at construction sites one acre or more in size.

Tennessee Hydrologic Determination Training is a course for conducting hydrologic determinations. Successful completion of the training course is one of the requirements for certification as a Qualified Hydrologic Professional.

Storm Water Control Measure Inspection and Maintenance Workshops are available to design engineers and architects as well as plan reviewers and other local municipal program personnel. They provide insights on avoidance and minimization approaches to site layout, design guidance on specific permanent stormwater control measures, and experience using tools developed to assist designers and plan reviewers with implementation of runoff reduction and pollutant removal requirements.





Outreach & Collaboration

Appalachian Leadership Institute

Dr. Tim Ezzell, Assistant Research Professor, ISSE and Political Science; Cat Wilt, ISSE Research Associate; Dr. Katie Cahill, Associate Director, Baker Center for Public Policy

In October, the Appalachian Leadership Institute kicked off with its inaugural class of forty fellows representing thirteen Appalachian states. UT conducts the program in cooperation with the sponsor, the Appalachian Regional Commission and our team partners, Tuskegee University and Collective Impact, LLC, a consulting firm from Huntington, WV. The UT team includes Dr. Tim Ezzell and Cat Wilt from ISSE, and Dr. Katie Cahill, Associate Director of UT's Baker Center. The UT team includes a Appalachian Leadership Student Fellow who receives a full graduate assistantship in the UT MPPA Program. Our inaugural fellow was Alex Moore from Bybee, Tennessee.

This year's class of forty fellows attended multi-day sessions in Moorehead, Kentucky, Dalton Georgia, and Starkville, Mississippi. Travel restrictions related to COVID forced the team to adapt to online programming in the Spring, but the Institute continued to provide access to important information and skills development. Session topics included economic opportunities, workforce development, and leveraging natural and cultural assets. Along the way, fellows toured innovative communities, a workforce training site, and the nation's largest solar panel manufacturing facility.

right: ALI Fellows visited several innovative communities this year.



Demonstration Rain Garden Installation

In an effort to enhance local conservation efforts and help residents who live in a flood-prone area of the city, three UT faculty members will work with a group of homeowners to install rain gardens in the Edgewood Park neighborhood of Knoxville.

The faculty members—Lisa Reyes Mason, associate professor and PhD program director in the College of Social Work; Jon Hathaway, ISSE researcher and associate professor of civil and environmental engineering; and Andrea Ludwig, associate professor of ecological engineering—are overseeing the rain garden project. They've received a \$7,000 grant from the Alliance of Women Philanthropists and \$1,000 from UT's Office of Community Engagement and Outreach to fund the project.

A demonstration garden has been being built at the North Knoxville Branch of the Knox County Library in the Edgewood Park neighborhood. Interested neighborhood homeowners can apply to have a rain garden built on their property. Mason said funding



will pay for 10 gardens; residents will be responsible for their garden's upkeep once it's installed.

“Rain gardens are a form of green infrastructure increasingly used to sustainably manage urban storm water,” Mason said. “In residential areas, rain gardens fed by a home's downspout can reduce water damage on the homeowner's property, enhance quality of life through improved green space, and contribute to overall watershed health through reduced storm water runoff.”

The Hydrolunteers, a group of graduate students mentored by Hathaway and Ludwig who volunteer on water-related projects, created the concept for the demonstration garden at the library. They pitched it to Knox County and Knox County Storm water officials. After getting feedback and tweaking their plans, the students' designs were approved.

Now the researchers are calling for interested homeowners to apply to have rain gardens built on their property. The researchers hope the project will help them gauge urban interest in rain gardens. They will follow up with the residents involved to see if the gardens are helpful and manageable, and if there are ways the program could be improved.

If the results are positive, the project could encourage other cities to institute rain garden programs.

left: Padmini Persaud, a graduate research assistant in Civil and Environmental Engineering and a leader of the Hydrolunteers student organization, shovels dirt while helping build a rain garden at the North Knoxville Branch of the Knox County Public Library.

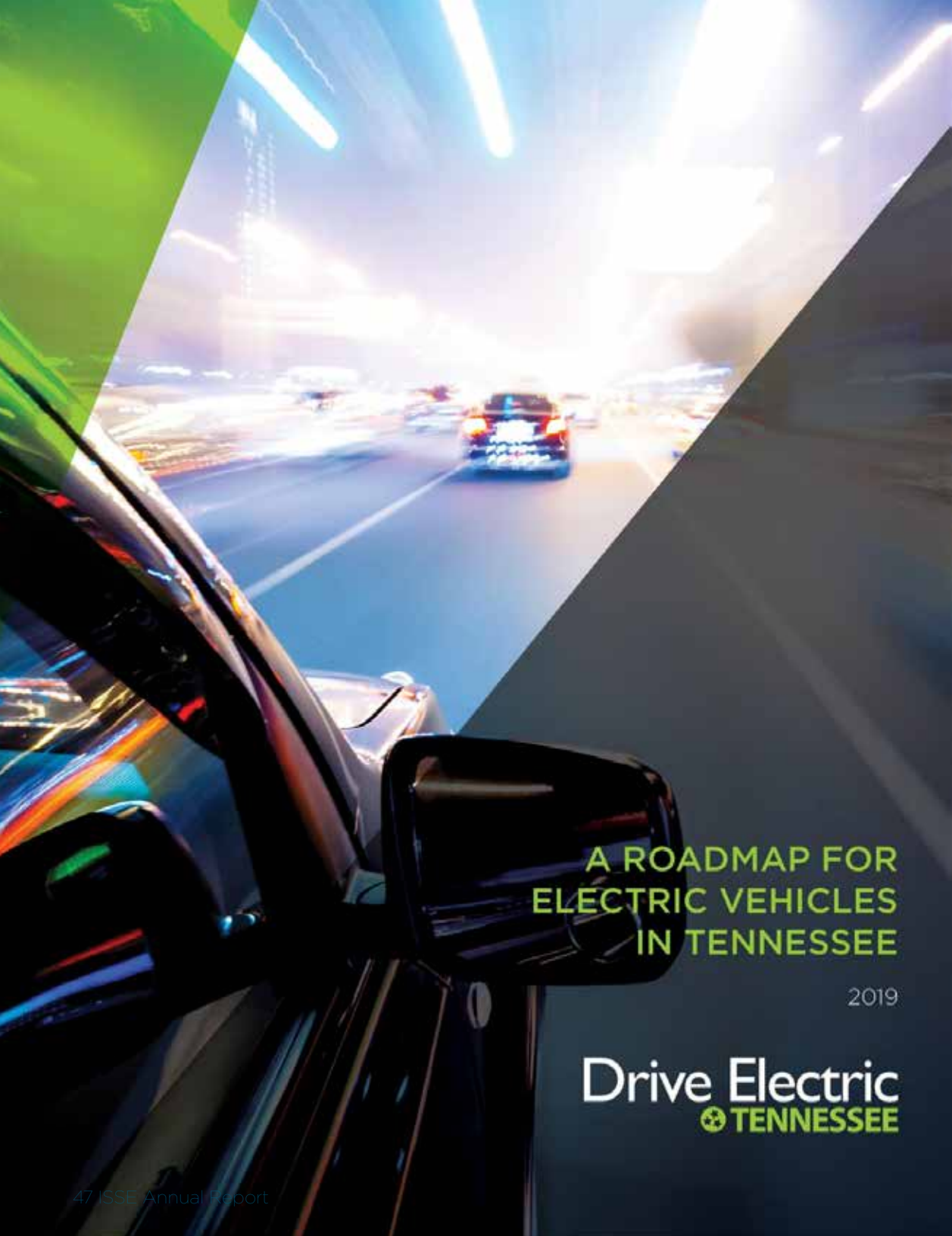


**FACULTY OF CIVIL
ENGINEERING
CTU IN PRAGUE**

TNWRRC Director John Schwartz
Conducts Research in Prague, Czech
Republic

Dr. John Schwartz, Tennessee Water Resources Research Center director, spent the 2019 Fall Semester in Prague as a Fulbright Fellow at the Czech Technical University. He worked with CTU faculty and graduate students on three projects:

- An experimental project related to sediment trapping efficiency on grassland treatments.
- A project related to soil erosion on agricultural land using the mini-jet tester Schwartz brought from the US. The mini-jet tester is a unique piece of equipment that measures streambank erosion. It was used to compare soil erosion estimates from CTU's rainfall simulator.
- The third project is a comparison study between stream revitalization practices and projects in the Czech Republic and stream restoration in the US.



A ROADMAP FOR ELECTRIC VEHICLES IN TENNESSEE

2019

Drive Electric
⊕ TENNESSEE

DriveElectric Tennessee

DriveElectricTN has a goal: get 200,000 EVs on Tennessee's roads by 2028.

A team of stakeholders, including TDEC and TDOT, electric utilities, electric vehicle manufacturers, businesses, and advocacy groups, has developed a vision for electric transportation in Tennessee. The group devised goals and guiding principles for increased electric vehicle adoption over the next five-to-ten years. Together, these stakeholders comprise Drive Electric Tennessee (DET).

DET's vision is straightforward—to advance the state of Tennessee as the electric transportation leader in the Southeast. DET works at the local, state, and regional levels to nurture and develop relationships with a broad audience. We recognize that other Southeastern states are advancing their own Electric Vehicle (EV) initiatives, and we value their willingness to work with us as a unified regional front.

In 2019, DET released the first edition of its Electric Vehicle Roadmap for the state. The Roadmap established a goal to increase electric vehicle adoption to 200,000 EVs by 2028 and identifies projects and initiatives for local stakeholder implementation that will increase EV adoption across multiple Tennessee use cases and sectors. These initiatives address charging infrastructure, consumer awareness, vehicle availability, and supportive programs and policies.

DET benefits from the leadership and dedication of numerous partners: Tennessee Valley Authority, Tennessee Department of Environment and Conservation, Office of Energy Programs, Seven States Power Corporation, EPB in Chattanooga, East Tennessee Clean Fuels and Middle West Tennessee Clean Fuels, and the Tickle College of Engineering's Institute for a Secure & Sustainable Environment at the University of Tennessee, Knoxville.

East TN Clean Fuels Launched its Southeastern Corridor Council

ETCleanFuels is a co-leader in the development of the Southeastern Corridor Council. Coalition staff from 10 states are sharing ideas to address several different types of alt-fuel signage and filling in gaps in alt-fuel corridors. On April 16, the council hosted more than 25 state DOTs and other state departments on a webinar to talk about the existing issues and barriers and work to secure their partnership going forward. ETCF started the SCC and is a co-chair.

DriveElectricTN Hosts Ride & Drive at 2020 Knox News Auto Show

In February 2020, DriveElectricTN staffers and volunteers held an electric vehicles (EV) Ride & Drive at the Knox News Auto Show. This included 35 student volunteers from UTK. Attendees could test drive five different EV models over the three-day event held at the Knoxville Convention Center. The DriveElectricTN EV Experience™ at this year's show was principally organized by Virginia Salazar Buda, Coordinator of the East Tennessee Clean Fuels Coalition's DriveElectricTN program.

“Even the most electric-skeptical folks have changed their minds about electric cars when they actually get behind the wheel and drive one,” says Buda. “This program is geared towards folks who haven't experienced the thrill of driving an EV before. Lots of people believe that EVs are underpowered go-karts; they're not. Once they drive an EV, they're surprised at how fast they are, and how fun driving can be again.”

The EV Experience™ is a “Ride & Drive” initiative, one of over 20 EV-related projects that DriveElectricTN is spearheading, that connects event attendees with local EV owners and auto dealers who offer new and used EVs in their stock. Participants can ask questions of real-life EV owners, learn about charging options, explore the different types and models available, discover how much money they can save on fuel and maintenance costs, and then test drive one or more EVs to experience the fun of driving electric themselves.

“Our Knox News Auto Show event was our most successful event to date,” says Daniel Siksay, EV owner and Co-Coordinator for ETCleanFuels. Over 8,000 people attend the three-day event. “I engaged with hundreds of people and offered dozens of test drives to folks. It felt great to share my passion with them and show Knoxville that EVs are viable options for them and their families.”



Publications, Presentations, Media Recognition & Awards

2019-2020 Publications

- A. Chen*, R. Tang[1], J. Mao*, C.Yue, X. Li, M. Gao, X. Shi, M. Jin, D. Ricciuto, S. Rabin, P. Ciais, S. Piao, “Spatiotemporal dynamics of ecosystem fires and biomass burning-induced carbon emissions in China over the past two decades”, *Geography and Sustainability*, 1(1), 47-58, 2020.
- A. Chen*, R. Tang[1], J. Mao*, C.Yue, X. Li, M. Gao, X. Shi, M. Jin, D. Ricciuto, S. Rabin, P. Ciais, S. Piao, “Spatiotemporal dynamics of ecosystem fires and biomass burning-induced carbon emissions in China over the past two decades”, Accepted by *Geography and Sustainability*, 2020.
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2019-2020 Presentations

- T. Cokyasar, W. Dong, M. Jin, Network Optimization For Hybrid Last-mile Delivery With Trucks and Automated Drones, INFORMS 2019, Seattle, WA.
- M. Jin, W. Dong, Y. Wang, Scheduling For Order Picking in 3D AS/RS, INFORMS 2019, Seattle, WA.
- H. Kose, M. Jin, Quality and Productivity Trade-off in Powder-bed Additive Manufacturing, , INFORMS 2019, Seattle, WA.
- Y. Wang, M. Jin, A. Muhammad, J. Mao, Y. Zhu, L. Tang, L. Liu, B. Liu, X. Zhang, A Scalable Modeling Framework for the Sustainability of the Global Crop Supply Chain focusing on U.S.-China Interactions, AGU 2019, San Francisco, CA.
- N. Liu, Z. Lin, F. Xie, and M. Jin “Evaluating National Hydrogen Refueling Infrastructure Requirement and Economic Competitiveness of Fuel Cell Electric Long-Haul Trucks”, TRB 2020, Washington, DC.
- M. Jin, “Strategic Adoption Decision of Additive Manufacturing for Low-Volume Demand”, Seminar at City University of Hong Kong, November 2019, Hong Kong.
- M. Jin, “Strategic Adoption Decision of Additive Manufacturing for Low-Volume Demand”, Seminar at University of Texas, Austin, October 2019, Austin, TX.
- W. Dong and M. Jin, “Food Waste and Loss in the US”, November, 2019, Hong Kong.
- M. Jin, “Data Revolution to Fill The Global-Global FEWS Gap”, 13th Annual US – China, Eco-Environmental Symposium, October, 2019, Seattle, WA.
- M. Jin, “Coupled FEWS Modeling for Sustainability of the Global Crop Supply Chain”, 13th Annual US – China, Eco-Environmental Symposium, October, 2019, Seattle, WA.
- J. Hathaway, “Stormwater Research Update ‘Smart’ Stormwater,” presented to Tennessee Stormwater Association - September 2020
- J. Hathaway, “Tree Function in Stormwater Biofilters: The Green in Green Infrastructure, presented to the University of Minnesota stormwater seminar series, January 2020
- J. Hathaway, “Rainfall Interception of Urban Trees in the Knoxville Area,” presented to the USFS Urban Forest Connections Webinar, August 2019
- J. Hathaway, “Stormwater Goes Green? Investigating the Benefit and Health of Urban Trees in Green Infrastructure,” presented as Guest Lecture at University of Georgia, October 2019
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- Jonathan Overly, East TN Clean Fuels, Drive Electric TN*
- Washington County Cuts Ribbon on 5 New Propane School Buses
- <http://www.tncleanfuels.org/2020/08/31/washington-county-cuts-ribbon-on-five-new-propane-school-buses-alternative-fuels-program/>
 - [https://ngtnews.com/washington-county-schools-adds-propane-buses-to-fleet-\(national\)](https://ngtnews.com/washington-county-schools-adds-propane-buses-to-fleet-(national))
 - [https://www.wjhl.com/news/local/washington-county-tenn-schools-unveils-five-new-propane-buses/\(local\)](https://www.wjhl.com/news/local/washington-county-tenn-schools-unveils-five-new-propane-buses/(local))
- UT researchers perform surveillance testing to track, contain spread of COVID-19, September

Panel Discussion on Research Opportunities for Cleaner Production and Sustainability

The main goals of the 2019 International Conference on Cleaner Production and Sustainability (CPS 2019) were to provide an opportunity for researchers and practitioners, from different regions and with diverse backgrounds and expertise, to discuss environmental and sustainability issues in corporations, governments, academic institutions, regions, and societies, and to share their novel research ideas, experience, and potential solutions for cleaner production and circular economy.

The NSF funding was to facilitate a panel on November 1st during 2019 CPS to discuss the research gaps and future directions of cleaner production and circular economy based on the presentations.

About thirty international researchers joined the discussion, including 10 US researchers from Purdue, University of Miami, University of Florida, Michigan Tech, Clemson, and University of Tennessee. Travels of five faculty members and three students were sponsored by this NSF conference project.

The discussion focused on sustainable urban systems and circular economy through cleaner production and sustainability. The panel identified research gaps in the integration and coordination between cities and their surrounding rural areas.

The environmental and social sustainability can be achieved only through systems modeling on the interactions among many human and natural systems. A circular economy perspective can facilitate cleaner production beyond the production stage by incorporating the distribution, consumption, and recycling/reuse stages. To make any technical and societal solutions work in real-world, researchers need to fully engage stakeholders who may have different interest and could be geographic distributed, even far away from each other. The panelists also mentioned that heterogeneity in culture and behaviors have not been fully modeled in global assessment model.



The panel, shown above, discussed sustainable urban systems and circular economies through cleaner production and sustainability. They identified research gaps in integration and coordination between cities and surrounding rural areas.

Awards & Honors

Mingzhou Jin

Professor Mingzhou Jin, Industrial & Systems Engineering, received the 2020 Chancellor's Research and Creative Achievement Award, which recognizes tenured faculty members who have received national and international recognition in their field. Dr. Jin was also honored with the 2020 Tickle College of Engineering Research Achievement Award. His research focuses on operations research and its application in sustainability, transportation and logistics, supply chain, additive and smart manufacturing, and climate science. Jin's research is supported by a broad spectrum of federal, local government agencies, and corporations including NSF, DOE, ORNL, Y12, Argonne, TDOT, America Makes, FedEx, Nissan, and the Material Handling Industry, among others.

Joshua S. Fu

Joshua S. Fu is the John D. Tickle Professor in the Department of Civil and Environmental Engineering. This year he was named a Board Certified Environmental Engineering Member, American Academy of Environmental Engineers & Scientists; Vice Chair of the Scientific Leadership Team and Steering Committee, Measurement-Model Fusion for Global Total Atmospheric Deposition (MMF-GTAD) Initiative, World Meteorological Organization (WMO), Geneva, Switzerland; Advisor to the Advanced R&D Advisory Committee for the President's Office, Industrial Technology Research Institute, Taiwan; and Member, Distinguished Lecturer Committee, Association of Environmental Engineering and Science Professors (AEESP).

Terry Hazen

Terry Hazen is one of 16 honored by the 2021 American Society for Microbiology (ASM), which recently announced recipients of awards in research, education, and leadership. Hazen was recognized for the ASM Award for Environmental Research, which honors an outstanding scientist with distinguished research achievements that have improved our understanding of microbes in the environment, including aquatic, terrestrial, and atmospheric settings.

Jon Hathaway

Jon Hathaway is the newest associate editor for the *Journal of Environmental Engineering*. The journal, published by the American Society of Civil Engineering, shares research news in environmental engineering science, systems engineering, and sanitation. Also, Hathaway will contribute his expertise in urban hydrology and green infrastructure. Hathaway's recent paper, "Establishing a Framework for the Spatial Identification of Effective Impervious Areas in Gauged Basins: Review and Case Study," in the *Journal of Sustainable Water in the Built Environment*, was awarded Best Case Study by the journal. The paper reviews existing methods to quantify and identify the impervious areas in a watershed that are most detrimental to stream health—Effective Impervious Areas (EIA)—and proposes a new model framework that builds on these methodologies to offer an automated and objective way to spatially identify the most probable impervious areas comprising the EIA.

right: A member of the Hazen Lab group draws a wastewater sample from one of several sites on campus. Once collected, the samples are taken back to the lab for processing.



UT Researchers Perform Surveillance Testing to Track, Contain Spread of COVID-19

Connor Holt, Daily Beacon Staff Writer

Since the spring semester, the University of Tennessee administration, in collaboration with various officials and expert researchers, has been exploring every possible avenue for preventing the spread of COVID-19 on campus come the fall semester.

Dr. Terry Hazen, governor's chair for Environmental Biotechnology, is one of the primary researchers involved in this preventive effort. One of the methods agreed upon by him and the university was performing surveillance testing on the buildings lived in by student residents. This form of testing is entirely anonymous, and doesn't identify any single individual in order to protect student anonymity.

Researchers wearing disposable Tyvek suits will be led by Facilities Services either to a valve in the low part of the building, or in some cases to a manhole on the street, where they will collect three wastewater samples for testing. These samples could be as small as 500 milliliters. They will then clean the sample, seal it and put it in a secondary container before bringing it back to their approved Biological Safety Level 2 Plus laboratory, where it will be immediately pasteurized in a 60-degree Celsius water bath for two hours.

After running the three pasteurized samples through a centrifuge, filtering them and then performing reverse centrifugation, they will prepare it for real time QPCR/quantitative preliminary chain reaction

to identify a specific marker in the COVID-19 genome. Such tests are designed to allow the team to identify how many virus particles there are in the waste-water at a given period of time, and potentially how many people in the building are giving off those viruses.

"We will also probably sequence the genome using sequencers at Oak Ridge to try and identify different strains -- and the potential dominant strain -- in particular buildings," Hazen, who has an extensive history in performing this kind of research, said.

If all three tests turn up positive, they will report their findings to the Student Health Center Director Dr. Spencer Gregg and to the Chancellor's Cabinet. They will also immediately notify their other surveillance lab run by Dr. Frank Loeffler, Governor's Chair for Microbiology and Civil and Environmental Engineering and Dr. Albrecht von Arnim, professor and associate head for Biochemistry & Cellular and Microbiology.

Loeffler and von Arnim's surveillance lab will perform an anonymous testing method called pooled saliva testing. According to Loeffler, their current plan is to test up to 500 students per day. The laboratory will not have any personal student information and will receive tubes with barcodes. The pooled saliva testing will combine five individual samples into a combined sample, which will then be analyzed. The results will be reported daily to the Student Health Center. It's important to note that to protect student anonymity, only the Student Health Center can decode the pooled samples and connect the test results with specific individuals. It is only Dr. Gregg's team at the Student Health Center who will contact these students for individual testing.

If the team's goal of 500 samples per day is reached, the laboratory will be able to operate with only two lab technicians and a surveillance laboratory supervisor. However, if asked, the lab has the capability to increase their daily output to 1,000 samples. If that happens, they would be required to increase their number of lab technicians to four.

Once Hazen identifies a building, Loeffler and von Arnim's group will immediately call up everyone in that building, and will by floor have them spit into a collection tube. The pooled samples will help them find which floor has infected people. After that they will notify Gregg's group and they will perform clinical laboratory industrial action certified testing on everyone living on the positive-tested floor to figure out specifically who is infected.

"That potentially should save us time and money, and that's why they're doing this. Waste-water and saliva testing will hopefully keep us ahead of the virus in terms of asymptomatic cases and things like that," Hazen said.

With all the moving parts, it became apparent that they would require a specialized software to assist them in making sure everything runs as designed.

"We received excellent support from the OIT applications group to build a computer interface that integrates the different steps of process while maintaining sample anonymity," Loeffler said.

For the time being, however, this software is still under testing to make sure it will run as smoothly as possible.

Director's Goals for 2020-21

ISSE will continue to implement its five-year strategic plan to increase the research, educational, and outreach activities at the University of Tennessee. ISSE will promote the development of policies, technologies, and educational programs that will address and help remedy critical environmental issues around the world.

As a State Center of Excellence, ISSE will expand its outreach, education, and applied research for the State of Tennessee and further increase our engagement with state agencies such as Tennessee Department of Environment & Conservation, Tennessee Department of Transportation, and Tennessee Department of Agriculture; with municipal and county local governments; and with local industries such as Tennessee Valley Authority and Eastman. New training and outreach programs, such as the new Tennessee Stream Quantification Tool Training and Drive Electric Tennessee. ISSE will also improve the economic and environmental sustainability of the Appalachian area through its continuous support to the Appalachian Leadership Institute.

ISSE will continue building its research strength through its own inhouse capability and interdisciplinary collaboration with other academic and research units on campus. ISSE will fund seed grant proposals and strategically support six or seven key affiliated faculty members annually. The funding will be concentrated around the integration of global systems models and locally-relevant engineering solutions. The seed grants and strategic investment will emphasize societal impacts and promote externally funded research. Besides financial support, ISSE will grow as a platform to help faculty

and research staff pursue larger grants, to conduct convergent research, and to facilitate more collaboration with Oak Ridge National Laboratory and other research institutes. ISSE will lead efforts in applying for larger centers, such as DOE Industrial Assessment Center, NSF Engineering Research Center, and others.

In addition, ISSE will continue its supports of graduate and undergraduate students to prepare a quality workforce that can handle our national environmental issues. A research conference is planned to provide a forum for students who are interested in sustainability issues to share their research ideas and findings.

ISSE will support the newly funded NSF International Research Coordination Network (iRCN) for Creating Transdisciplinary Nodes of Food-Energy-Water to Support Sustainable Urban Systems (FEWSUS). The iRCN will bridge existing international and domestic FEW-systems and relevant networks and partnerships in an effort to identify and refine urban FEW challenges, harmonize perspectives, generate opportunities for collaboration, and realize synergies of currently siloed and uncoordinated work for advancing a FEW-focused global agenda of sustainable urban development. FEWSUS and other international collaboration will enhance ISSE and UT's international visibility in sustainability research and education.

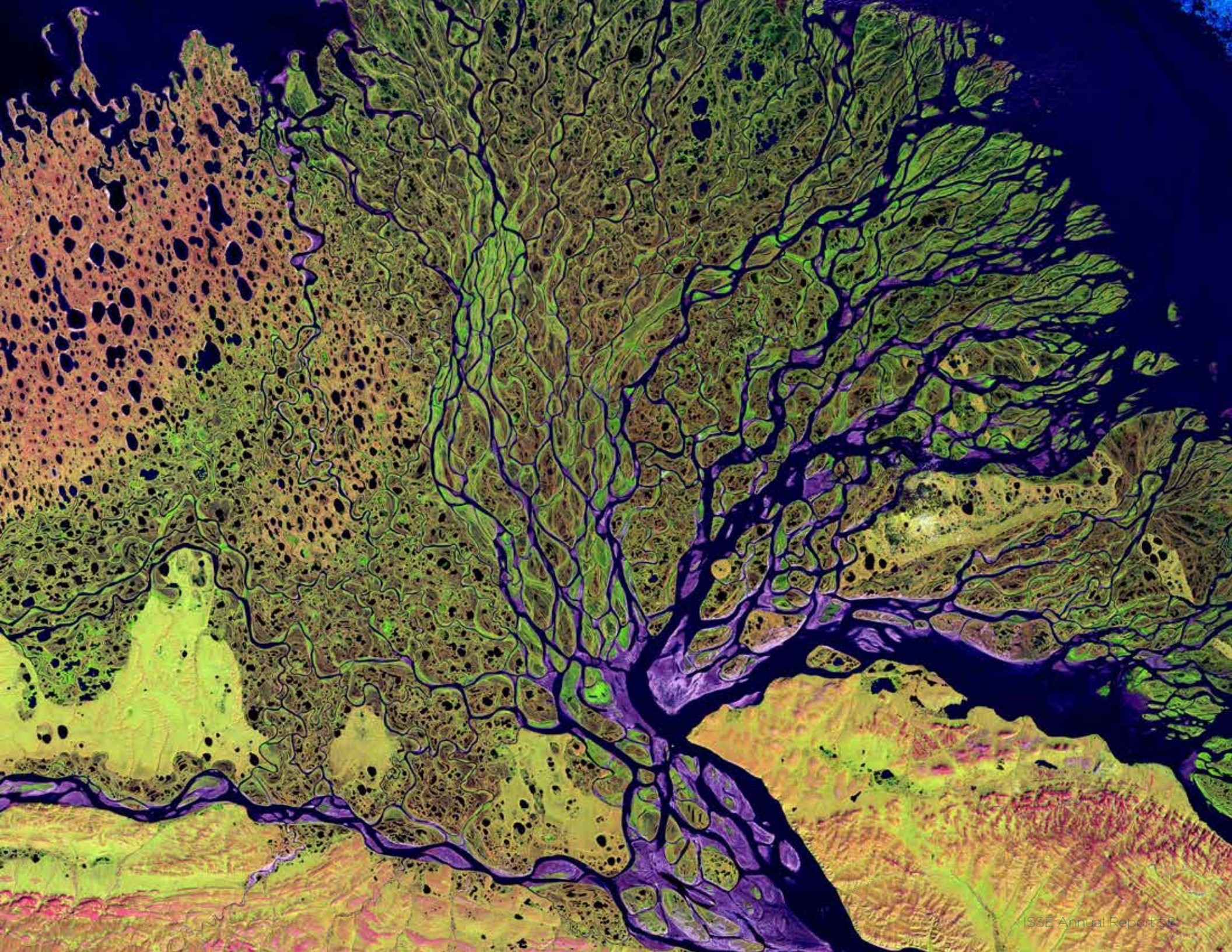
The Integrated Earth Model team will finalize and submit its final paper on Soil Moisture Dataset within this year. During the next academic year, the team will incorporate the developed soil moisture datasets and evaluation methods into the

International Land Model Benchmarking Project (ILAMB) Python package, and will explore the implication of climate change-induced soil moisture changes on the terrestrial carbon cycle.

For the coming year, the Methane Center will continue its goal to form a transdisciplinary-multi institution NSF Engineering Research Center (ERC). After getting a NSF ERC planning grant in 2019 to support team building and idea maturation, we have submitted an ERC preproposal titled ERC for Protecting and Advancing Water, Environment, and Sustainability dealing with integrating wastewater biosensors with machine learning to track contaminants and pathogens in real time. We will continue to gather data and publish in various methane related research topics to strengthen our understanding and leadership in the field.

The ISSE researchers involved with the Appalachian Community Technical Assistance and Training (ACTAT) Program are expanding their horizons and targeting rural water and wastewater utilities in the Cookeville and Chattanooga regions. Continuing to work with the Tennessee Department of Environment & Conservation, we will hold at least one Workshop-In-A-Box training session in both regions. Stemming from these workshops we help at least one utility in both regions to develop an action plan that will address their management areas in need of improvement.

Image source: US Geological Survey





THE UNIVERSITY OF
TENNESSEE
KNOXVILLE

INSTITUTE FOR A SECURE &
SUSTAINABLE ENVIRONMENT

Schedule 7

Centers of Excellence Actual, Proposed, and Requested Budget

Institution: University of Tennessee, Knoxville
Center: Institute for a Secure & Sustainable Environment

Expenditures	FY 2019-20 Actual			FY 2020-21 Proposed			FY 2021-22 Requested		
	Matching	Appopr.	Total	Matching	Appopr.	Total	Matching	Appopr.	Total
Salaries									
Faculty	\$ 177,182	\$ 118,783	\$ 295,965	\$ 177,182	\$ 197,887	\$ 375,069	\$ 177,182	\$ 119,496	\$ 296,678
Other Professional	404,236	131,390	535,626	404,236	139,934	544,170	404,236	132,179	536,415
Clerical/ Supporting	93,442	74,289	167,731	93,442	74,512	167,954	93,442	74,736	168,178
Assistantships	128,362	136,170	264,532	128,362	144,718	273,079	128,362	145,152	273,514
Total Salaries	\$ 803,221	\$ 460,632	\$ 1,263,853	\$ 803,221	\$ 557,051	\$ 1,360,272	\$ 803,221	\$ 471,563	\$ 1,274,784
Longevity (Excluded from Salaries)	\$ 5,293	\$ 4,191	\$ 9,484	\$ 5,293	\$ 4,317	\$ 9,610	\$ 5,293	\$ 4,330	\$ 9,622
Fringe Benefits	179,648	120,455	300,103	179,648	152,806	332,455	179,648	120,816	300,464
Total Personnel	\$ 988,162	\$ 585,278	\$ 1,573,440	\$ 988,162	\$ 714,174	\$ 1,702,336	\$ 988,162	\$ 596,708	\$ 1,584,871
Non-Personnel									
Travel	\$ 78,654	\$ 357	\$ 79,011	\$ 78,654	\$ 414	\$ 79,067	\$ 78,654	\$ 414	\$ 79,068
Other Supplies	63,635	24,250	87,885	63,635	39,315	102,949	63,635	24,347	87,982
Maintenance	430	17	447	430	17	447	430	17	447
Consultants	39,183	-	39,183	39,183	-	39,183	39,183	-	39,183
Other (Specify):									
Media Processing	5,007	3,235	8,242	5,007	3,241	8,248	5,007	3,248	8,255
Gasoline & Diesel	2,379	-	2,379	2,379	-	2,379	2,379	-	2,379
Communication	5,464	7,530	12,994	5,464	8,310	13,774	5,464	8,326	13,790
Subscriptions & Memberships	3,315	-	3,315	3,315	-	3,315	3,315	-	3,315
Computer Services	1,738	5,856	7,593	1,738	5,867	7,605	1,738	5,879	7,617
Student Fees	49,408	71,321	120,729	49,408	76,156	125,564	49,408	71,607	121,015
Contractual and Special Services	92,187	2,950	95,137	92,187	2,956	95,143	92,187	2,962	95,149
Awards	-	5,734	5,734	-	5,745	5,745	-	5,757	5,757
Food and Housing - Conferences	114,297	-	114,297	114,297	-	114,297	114,297	-	114,297
Direct Cost Sharing	148,035	41,643	189,677	148,035	129,324	277,359	148,035	66,899	214,933
Total Non-Personnel	\$ 603,731	\$ 162,892	\$ 766,623	\$ 603,731	\$ 271,345	\$ 875,076	\$ 603,731	\$ 189,456	\$ 793,187
GRAND TOTAL	\$ 1,591,893	\$ 748,170	\$ 2,340,063	\$ 1,591,893	\$ 985,519	\$ 2,577,412	\$ 1,591,893	\$ 786,165	\$ 2,378,058
Revenue									
New State Appropriation		\$ 747,278	\$ 747,278		\$ 748,729	\$ 748,729		\$ 786,165	\$ 786,165
Carryover State Appropriation		237,682	237,682		236,790	236,790			-
New Matching Funds	\$ 1,591,893		1,591,893	\$ 1,591,893		1,591,893	\$ 1,591,893		1,591,893
Carryover from Previous Matching Funds	-		-	-		-	-		-
Total Revenue	\$ 1,591,893	\$ 984,960	\$ 2,576,853	\$ 1,591,893	\$ 985,519	\$ 2,577,412	\$ 1,591,893	\$ 786,165	\$ 2,378,058