Purdue Fundamental and Applied Research and Extension Showcase

Bringing World-Class Education, Life-Changing Research to Rural and Urban Communities

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Photos: Purdue University, College of Agriculture

PURDUE UNIVERSITY | Extension

Contents

Forward

Each year, we compile a large report about the impacts of Purdue fundamental and applied research and Extension accomplishments, outcomes, and activities which we submit to the USDA.

These impact stories demonstrate the measures taken to bring Purdue's world-class innovation and expertise to the urban, suburban, and rural areas where they're needed most. To show the breadth and scope of our outreach, we collected all of these stories to share with a broader audience. Here are just some of our examples:

- Advancing soybean production through soil fertility and plant nutrition
- Identifying and classifying foodborne pathogens to prevent economic loss
- Harnessing chemical ecology to address pests and protect pollinators
- Interactions of diet, flavor, and saliva for eating healthy
- Addressing animal welfare issues
- Increasing sustainability of turf
- Regulation of photosynthetic processes related to drought stress

In Extension, our specialists and educators deliver educational programs and researched-based knowledge that help our families, individuals, and communities survive in these uncertain times. Here are some of our activities:

- Offering grant writing courses to local governments, nonprofits, and individuals
- Providing youth experiences to address global issues of poverty and hunger
- Teaching safe home preservation practices
- Increasing the skills of tomorrow's workforce
- Building organic farming in Indiana
- Creating notification systems to protect bees, crops, horses, and other vulnerable populations from chemical applications
- Rainscaping to prevent polluted runoff

Our combined efforts meet the changing needs of residents in every Indiana county. We hope you'll find this compilation interesting and helpful as you communicate with stakeholders about potential collaborations.

Thanks to all of you who shared your work and assisted us in the process of crafting this document. Together, we do great things and we appreciate every single individual's help in this effort.

Jason Henderson, Senior Associate Dean, Director of Purdue Extension, Purdue University
Bernie Engel, Associate Dean and Director of Agricultural Research and Graduate Education, Purdue University

Acknowledgements

Purdue Agriculture, Veterinary Medicine, and Health and Human Sciences engage in groundbreaking, multidisciplinary research that addresses society's most pressing challenges. Our efforts bring vital information and resources from the laboratory and classroom to the cities and towns of Indiana, across our nation and around the world.

In this report, you'll learn about our work to understand global change and the challenges of sustainably feeding a growing planet; analyze residuals and reclaimed water for their impact on soil and human health; monitor regulation of phenylpropanoid metabolism in plants; assess antibiotic resistance in livestock; determine best practices for water quality protection at the watershed scale, and much more.

You'll also learn how we address mental health issues that affect our families and workplaces; build youth skills in STEM; equip tomorrow's workforce; facilitate natural resources conservation and leadership for sustainable communities, and offer produce safety training to help growers comply with regulations.

All of these activities contribute to our shared mission as a land-grant research institution to build a sustainable future for our local communities, our state and beyond.

I thank Jason Henderson, Senior Associate Dean and Director of Purdue Extension, and Bernie Engel, Associate Dean and Director of Agricultural Research and Graduate Education for their leadership in this effort, and all of the faculty, researchers, specialists, educators, and volunteers who tirelessly discover and deliver unbiased information and resources.

Karen Plaut, Glenn W. Sample Dean of Agriculture, Purdue University

Purdue Extension plays a fundamental role in helping our university put science into practice. Our faculty, specialists and educators work closely with communities and stakeholders to build lasting collaborations and partnerships aimed at addressing their most important opportunities and concerns.

Extension is a trusted advocate for Indiana residents and collaborates locally to provide life-changing education, knowledge and support. The COVID-19 pandemic has made this a difficult year for many Hoosiers – some are struggling with job security or mental health issues. Some are concerned with how to keep food supplies safe and accessible to all community members. And, with or without a pandemic, challenges such as soil and water quality continue to demand attention.

These are the times when our outreach is of the greatest value to our state. This showcase of accomplishments demonstrates the collective ways we contribute to the people of our state, delivering the knowledge and skills they need to be successful. We are proud that today's Extension uses 21st century tools to meet the people of our state where they live, and equip them with the knowledge they need to thrive during these uncertain times.

The best part is that the benefits are available to all. You just need to be an Indiana resident willing to learn. When you read these stories, I think you'll find them to be powerful examples of how we help our communities become healthier and stronger, and enhance the lives and livelihoods of people throughout the state.

Jay T. Akridge, Provost and Executive Vice President for Academic Affairs and Diversity, Purdue University

Impact Highlights

Extension and Research stories are organized into these categories:

- Agriculture (Crops and Livestock)
- Horticulture and Natural Resources
- Food, Nutrition, Families and Health
- Youth Development
- Community and Business Development

Agriculture

CROPS

Advancing soybean production through soil fertility and plant nutrition research

Since most of the fertility recommendations for soybean and nutrient allocation were based on research from the 1970's, maximizing the yield potential of soybeans demands an updated investigation in nutrient uptake and allocation. Fertilizer application improves soybean yield, but is also costly for the grower. Improving the efficiency of the soybean's ability to utilize nutrients could improve profitability and also reduce the environmental impact in surface waters.

The goal of this research is to advance soybean yields by establishing solid foundations in soil fertility and fine-tuning plant nutrition. Specific objectives were to identify changes in critical fertility for modern soybean production, determine optimal fertilization approaches to improve plant nutrition and yield through methods, timings, and nutrient sources/formulations.

Soybean yields in 2017, 2018, and 2019 did not differ near Lafayette regardless of the historical potassium application. Soybean yields near Butlerville showed little variation from historical application of potassium. Incremental fertilizer potassium rates were applied in 2019 and will be repeated across other Purdue Agricultural Centers.

Since 2015, soybeans near LaCrosse in northwest Indiana have increased yield from sulfur applications. The greatest and most consistent yield response has been to ammonium sulfate (AMS) broadcast-applied prior to soybean emergence in 2016, 2017, and 2018. This same treatment also increased soybean yield near Vincennes in southwest Indiana in 2016.

In the same sulfur-deficient fields, foliar applications of spray-grade AMS was promising in 2016, but mixed yield results in 2017. Crop injury was noted in later season applications where temperatures were higher and leaf recovery was minimal. The positive yield response to the foliar application was still less than the standard pre-emergence application.

The most interesting finding in 2018 was the influence of planting date on sulfur responsiveness. Soybean planted early were very responsive to various sulfur applications compared to the same variety and treatments applied during the first week of June. The soil

temperature and moisture effects on mineralization of organic matter and nodulation were likely the underlying source of responsiveness to sulfur applications.

In-furrow evaluation of orthophosphate was embedded in several trials in 2018 and 2019 at Wanatah and West Lafayette. Orthophosphate increased soybean yield across two locations in 2018, but did not affect yield in 2019.

A new foliar delivery system was evaluated in 2017 and 2019 to determine the effectiveness of applying sulfur or manganese in the middle of the soybean canopy versus the traditional over-the-top. The source was the main driver for yield with response to foliar protection, or all together. Delivery method was mixed in terms of yield response, but nutrient concentrations were typically higher with the over-the-top method. These ongoing efforts in evaluating nutrient uptake and allocation help determine new ways to increase soybean yield potentials with regard to economic viability, environmental stewardship, and social responsibility.

Building organic farming in Indiana

Demand for organic grains continues to grow, yet domestic production in the U.S. fails to meet consumer needs. While organic crop production has increased, Indiana still remains far behind the production of neighboring states, necessitating educational programs and resources for farmers exploring the possibility of transitioning into organic farming.

Purdue Extension addressed this issue by creating a multi-pronged effort to provide educational events and networking opportunities for interested organic growers, growers in transition, growers starting organic production, and crop consultants.

Extension partnered with Jasper County Soil and Water Conservation District (SWCD) and the IDEA Farm Network to host the first Indiana Organic Grain Farmer Meeting – a two-day event with marketing information and networking opportunities. First day topics included organic transition financials, organic inspection and recordkeeping, and developing transition strategies and best practices. Day two offered attendees advanced production and marketing presentations on diversified crop rotations, value-added small grain production and marketing, organic hay production and marketing, nitrogen management, weed management, grain market update and buyer panel discussion, and organic crop insurance options.

The trade show facilitated networking among attendees and industry representatives. More than 200 attended, with about 80 percent from Indiana and the remainder traveling from Illinois, Kentucky, Michigan, Ohio and Wisconsin. Half of those were farmers, with the remainder from other agriculture professions. Follow up revealed that nearly 100 percent of attendees improved their understanding of organic transition strategies as well as the certification process. For those operating a farm, nearly the same amount indicated plans to use knowledge gained in their farm's transition and a willingness to share information with colleagues and peers.

The Organic Agriculture Summer Series also showcased existing organics practices, featuring three Indiana farming operations. Host farms delivered presentations about their operations, and a representative from the Office of Indiana State Chemist discussed Fertilizer Application Rules. Nearly 200 participants attended during the two days, with more than 80 percent indicating plans to apply ideas learned to their farm operation or business or organization. More than 90 percent of farm operators said they would make changes to their existing transition plan or current organic production.

Extension also addressed the lack of service providers for organic production. This led to the establishment of the Organic Agronomy Training Service (OATS), a collaboratively managed, science-based train-the-trainer program for agricultural professions with organic (or transitioning) producers to increase knowledge among Extension staff, crop consultants, agronomists, and technical service providers about organic production systems and USDA National Organic Program (NOP) regulatory compliance. Nearly 50 individuals attended the pilot program offered in Indiana. Post evaluations yielded positive feedback, with nearly all indicating plans to update or alter their current plan or production.

Extension continues to build organic farming in Indiana, expanding on these efforts and creating educational opportunities and networking events, like the Indiana Organic Roundtable Meetings, which foster dialogue with like-minded producers. As the organic industry in Indiana continues to grow, so too will Extension's commitment to provide resources and support in the coming years.

DriftWatch™: Purdue Extension responds to save lives, horses, crops and bees

A potentially dire situation was developing in August of 2019 when horses and mosquitoes from Elkhart County tested positive for Eastern Equine Encephalitis (EEE) virus. In late September 2019, horses began dying of EEE in northern Indiana and southwestern Michigan. LaGrange and Elkhart counties have a combined population of 25,000 horses. When cases of EEE appear in horses, human cases will follow. The mortality rate for horses infected with EEE is nearly 90% in horses and 33% for humans who are bitten by an infected mosquito. By this time, four people in Michigan had already died, and three people in Elkhart County were hospitalized. The Indiana State Board of Health approached county commissioners about spraying the infected mosquitoes to stop the spread of EEE to horses and people. This solution posed negative consequences for organic farmers and beekeepers – including loss of organic certification and bee hives.

The Indiana State Department of Health (ISDH) issued an alert that the virus activity was detected in Northern Indiana. Local health departments and the Centers for Disease Control (CDC) agreed to initiate aerial spraying to reduce mosquito populations in LaGrange, Elkhart and Noble counties within a 5-mile radius of EEE-positive horses and mosquitoes. Purdue Extension responded and worked with Elkhart County Commissioners to notify organic farmers and local beekeepers including the Michiana Beekeepers Association whose president forwarded messages to their membership and posted them on the website about the scheduled spraying. Purdue Extension specialists provided information on which insecticide should be used with information about how to protect bees, and an opt-out of spraying option for organic farmers. More than 315 organic Amish farms in and near the spray zones were notified through in-person visits.

Purdue Extension assisted in registering organic acreage and beehives on DriftWatch™, a specialty crop and beehive registry and mapping program created by Purdue's College of Agriculture. Beth Carter, Office of Indiana State Chemist, was instrumental in getting new entries into DriftWatch™ and BeeCheck™. Carter was approving entries right up until spraying was conducted, so many beekeepers were posted in time.

Commercial pesticide applicators accessed DriftWatch™ to identify at-risk acres, then uploaded maps that stopped spraying over registered fields and beehives. Extension educators assisted individuals in registering organic fields and beehives, conducted television and local newspaper interviews, and responded to hundreds of phone calls from concerned residents. Every beehive

in the spray zones was identified, and Purdue Extension sent updates on the status of the spraying of 11,000 acres, as it occurred.

Purdue Extension efforts resulted in 470 enrolled hives, and over 50 new organic farms. These measures set a precedent, instituting safety measures for insecticide applications for organic and beekeeper operations, including ongoing education and registration to prevent future incidents.

Indiana Small Farm Conference: Building capacity, networking for small-scale farmers

Small farms in Indiana represent 71% of all farms across the state. In the last 30 years, Indiana farms have decreased significantly from 70,506 in 1987 to 56,649 in 2017. During this time, many Indiana farms expanded to remain profitable – not an option for many small-scale or future farmers. The 2017 census found 23,262 producers identify as new, or beginning. These numbers indicate a market for small-scale agriculture production, prompting Purdue Extension to establish the Indiana Small Farm Conference to provide education and opportunities for small-scale and beginning farms lacking resources.

Since the inaugural Indiana Small Farm Conference in 2013, it has served as an annual educational and farmer-to-farmer networking event for the small-scale and diversified farming community. Topics presented in 2019 focused on crop and livestock production, business planning, sustainable agriculture, marketing, food safety, urban agriculture, and exploring options for diversifying farm operations. Surveys from attendees reported learning and adopting sustainable practices and technologies, diversified farming topics, business planning, finances, marketing, crop production, and livestock production. More than two-thirds of participants said they learned about assistance and technical support from organizations like Purdue Extension and USDA, as well as numerous networks, coalitions, and co-ops. Nearly everyone who participated acknowledged the role of diversified agriculture in a local food system and expressed appreciation for the networking opportunities with experienced farmers and producers.

The “Trade Show Passport” was a tool used to encourage more interactions between attendees and exhibitors, resulting in 250 interactions among participants. Feedback indicated most planned to adopt recommended practices in farming, crop production, livestock, and sustainable practices and technologies, including: crop planning; growing mushrooms; fruit orchards; livestock; soil health; greenhouses; fungal/ecosystem integration; cover crops; seed saving; lean farming; and cucumber grafting. More than half indicated plans to complete a business plan for their operation and to adopt recommended marketing practices in the areas of business planning, social media, market analysis and strategies. Others indicated the intention to write or revise an existing plan, with 20 percent planning to start a new business within the next year. Purdue Extension organizes and hosts the Indiana Small Farm Conference to bring research-based knowledge and best practices to small-scale farming operators and enthusiasts across the state.

Industrial hemp production, processing and marketing

Purdue research and Extension became actively engaged in the agricultural pilot program regarding the research and production of industrial hemp in 2014, after it was legalized under the U.S. Farm Bill and approved by the Indiana Legislature. The state bill authorized industrial hemp production limited to "purposes of research conducted under an agricultural pilot program or other agricultural or academic research." Extension increased capacity and research-based knowledge to assist farmers interested in learning, and potentially growing, this emerging crop.

Since then, Purdue has applied for and received a federal permit to transport hemp from Canada and Europe and launched many efforts in the area of industrial hemp, including the development of a team of faculty and Extension educators from across the state and college. At the end of August 2015, the first field day was held in Indiana to provide information on hemp to experienced farmers, new farmers, organic farmers, law enforcement, Purdue Extension educators and the general public. Two subsequent hemp production fields were offered. During this time, two Purdue students have graduated who worked collaboratively with hemp research leading to upcoming publications. The changes under Hemp Farming Act of 2018 led to hiring the first Extension hemp specialist. She is helping growers set up their production programs and begin collaboration with 30 companies to start the process of establishing hemp as a commodity for Indiana. Extension also assisted more than 100 farmers in developing their licensing packages for large scale productions.

Purdue also conducted research on Midwest agronomic practices to determine effects on grain, fiber, and dual-purpose productivity as functions in the establishment of practices, soils, and planting dates and best practices to maximize yield and profits pose ongoing challenges with industrial hemp. Purdue Extension also assisted the public with industrial hemp, including field trials to address nutrient levels, harvest issues, disease and insect pressure, and fiber production. Previous work within the group showed few to non-existent peer-reviewed studies on hemp, with only three studies addressing weed management dating back to 1900.

Research was conducted to characterize the growth and phenology of hemp cultivars and determine the impact of delayed planting on the phenology and growth of seed, with regard to fiber hemp varieties in the Midwest. Initial findings also showed delayed planting generally reduced the onset and duration of female flowering and the time to first mature seed formation, but the magnitude of these effects varied among cultivars. Purdue research and Extension continue to lead efforts in providing more industrial hemp research-based knowledge and education to meet the public need.

Produce safety training helps growers comply with regulations

The Food Safety Modernization Act was signed into law in 2011. One of seven regulations from the Act, the Produce Safety Rule, became law in 2016, marking the first time the produce industry was exposed to industry-wide regulation. Among other requirements, the rule mandated that one person from each covered produce farm must receive food safety training using an FDA-approved curriculum. The Produce Safety Alliance (PSA) is the only FDA approved curriculum, and only certified trainers and lead trainers may teach the classes.

Purdue Extension began preparing for these new regulations in 2014, when funding was secured to train educators in the FDA-recognized curriculum. FDA approval took an extended length of time, causing a delay in the delivery of training. The team currently consists of nine trainers, three of whom have lead trainer status that allows them to conduct trainings throughout the nation. Extension has partnered with trainers from the National Farmers Union (Indiana chapter) to expand the number of trainers available for offering classes. Partnerships with the Indiana State Department of Health and Indiana State Department of Agriculture have resulted in the Safe Produce Indiana collaboration under which all trainings are offered.

The PSA curriculum was made nationally available in the Fall 2016. Since then, Extension has offered statewide trainings. During 2016–2017, nine 8-hour workshops were conducted, and 142 vegetable growers obtained training certificates, making them compliant with training requirements of the Produce Safety Rule. During 2017-2018, 13 more trainings were conducted, and 114 individuals received their certificates. In 2018-2019, 15 trainings were conducted with

195 individuals receiving certificates. The three-year totals include 37 events that reached 451 participants. Within the first year, an estimated 50 percent of the produce acreage in Indiana was impacted by this safety training. For cantaloupe, it is estimated that this training has affected at least 90 percent of total acreage in Indiana. One-year follow up surveys of the 2017-2018 programs indicated that 100 percent had made some sort of change to their farm to improve food safety practices, since attending the training. Some 50 percent added or modified on-farm infrastructure or equipment to improve food safety practices, including changes to packing areas, addition of hand washing stations, and switching to hard plastic harvest containers.

Indiana has offered more trainings to growers than most states in the north central region and conducted more trainings than several larger vegetable-producing states like Texas, Georgia, North Carolina, South Carolina and Arizona. These trainings contribute to regulation compliance and safer production for Indiana produce growers.

Professionals and hobbyists prepared for safe and legal use of UAV's

Unmanned Aerial Vehicles (UAV) technology has become increasingly popular for commercial uses in agriculture, marketing, surveying, real estate and hobbyists. Many UAV operators or potential operators do not have proper understanding of required certifications for use. Others have the equipment, but they are unsure of potential applications to their operation. Equally concerning is the need for safe and legal operation of any purpose.

To address this, Purdue Extension developed a new program to help participants engage in safe and lawful operation of UAVs (drones) for personal and professional applications. The 16-hour UAV Training series provides device maintenance, meteorology, data management and the development of flight plans. The first half of the series reviews material for the FAA Part 107 Remote Pilot Knowledge Test. The second half includes hands-on flight and applications. A total of 54 participants attended one of the three series offered in 2019. Most participants were farmers or state regulators. More than half of the participants indicated they were responsible for management decisions for an agricultural operation, with seventy-five percent managing more than 1,000 acres.

As a result of the training, all respondents reported being more aware of the legalities and safety protocols of UAVs and gained a better understanding of applications associated with UAV technology and troubleshooting techniques. Nearly all participants indicated feeling better prepared to take the FAA Remote Pilot Knowledge Test, required for legal operation, and three-quarters of those planned to pursue test completion and application filing to become a Drone Pilot. The remainder said they would consider taking the test at some future point. Most participants indicated plans to use UAV technology in their professional capacities, which included farming and regulatory inspections related to farming. Many of the respondents planned to invest in UAV technology, noting the technology would save time in scouting fields, faster identification of problem areas in their fields, and knowing where to follow up with in-person inspection of potential problem areas.

After completing the series, more than half of participants have contacted Extension with news that they passed the FAA Remote Pilot Knowledge Test, with feedback that the UAV training series was a valuable investment for the fees they paid. Client satisfaction was considered excellent, with overwhelmingly positive responses stating the training was a "great program" and a "valuable program at an appropriate time" in addition to being fun and informative.

One year after the program, participants completed a follow-up survey. Half of the respondents had taken and passed the FAA's Remote Pilot Knowledge Test and obtained certification.

Respondents were comfortable using UAV technology and have conducted safe flights. Over half indicated they had adopted practices taught during the UAV program, including adding an observer/spotter/line of sight with flights, checking field cover crops and standing water, using the logbook for flights, checking the B4UFLY app, and talking with airport. And, for the first time ever, an Extension program was taken into the classroom at Purdue University. During spring semester 2020, the UAV Signature program was delivered to 31 students on the West Lafayette campus.

By offering this training, Extension reached new audiences, including emergency responders, architects, engineers, construction companies, forestry and wildlife experts, videographers, urban planners, county commissioners, insurance adjusters, and many others in the education of safe and legal uses of UAVs.

Regulation of photosynthetic processes research

Photosynthesis is the process by which sunlight and carbon dioxide are converted by plants into energy used by almost all life on Earth. Plant biomass, including foods, fuels and wood products, is primarily generated by photosynthesis. A large multistate project aimed to understand and improve the regulation of photosynthetic productivity is currently underway, with a focus on understanding the developmental and environmental limitations of photosynthetic productivity.

Research efforts seek to gain a better understanding of the stomatal regulation of photosynthesis. Stomata are adjustable pores on the surface of leaves that act as the gateways for the exchange of gases between the leaf and the atmosphere. Stomata are the primary means by which land plants limit photosynthetic productivity in response to environmental signals. Experiments have been focused on using methods that measure stomatal movements, with the main goal of gaining new knowledge on how stomata regulate photosynthesis. This knowledge will provide key genetic and physiological targets for plant breeders to improve photosynthesis through altering stomatal behavior and to predict the plant productivity responses to environmental conditions.

Current efforts are underway to develop strategies to overcome limitations to photosynthetic productivity caused by developmental and environmental factors. Initial results have shown that stomatal aperture places one of the greatest limitations on carbon exchange and photosynthesis. The nature of stomatal responses in ferns and the role of leaf anatomy and hydraulics in regulating gas exchange (in early vascular plants) was investigated to gain insights about the ancestral mechanisms of stomatal regulation. It was determined that ancestral stomatal regulation in vascular plants is a very simple process regulated by leaf hydraulics. Further, hydraulic function and embolism resistance in individual leaves is critical for determining leaf survival and the capacity to recover from drought stress.

Research, identification and classification of foodborne pathogens

Foodborne pathogens cause significant economic losses across all levels of industry and society, and many pathogens are deadly. Even pathogens that cause no significant stress to normal healthy individuals can result in death for individuals who are immunocompromised, very young, or elderly. Thus, maintaining the integrity of the food chain is a critical part of a well-developed agricultural system. While there are tools and technologies available for testing foods for pathogens, many tests are time consuming and expensive. Some can only be performed within high-technology environments, and some cannot be adapted to all types of samples. Designing and implementing test systems that are low cost and easy to perform can provide a huge return of investment– a necessity for many countries that cannot afford current technologies.

Purdue research has led this effort with the creation of a proposed technology that greatly reduces the cost of pathogen detection and is inexpensive to manufacture. As the technology matures, low-cost versions will become available in resource-poor environments. Microbial identification is essential in biosecurity, food safety, and the clinical environment relevant to this technology, which could include monitoring and preventing hospital infections. To achieve this, three steps are needed to deliver correct identification of a species and include sample acquisition/preparation, microbe detection and microbe identification. Most efforts in instrument development using optical technology have focused on the development of a colony counter, which is a simple detection device that requires further testing for the identification of organisms. Morphological methods that observe the characteristics of the bacterial colony through visual inspection are widely studied in the identification and classification of bacterial colonies. The objectives of this research project are to provide low-cost, reagent-free pathogen-identification technologies that enhance all aspects of food safety, offer a low-cost method for monitoring microbial species in a variety of situations, and develop a series of software suites that allow direct and rapid analysis of the results. This research will develop the technology, expand the software for advanced classifications, and build a database of known organisms that can be used to track and identify species from different locations.

Receiving a patent based on an alternative approach to lateral flow assay development has been a key accomplishment in the current cycle. This new technology could be highly advantageous for future multiplexed assessments, and key in detecting toxins and pathogens through laser spectroscopy. In time, this equipment could allow detection to move to the field, with hand-held instruments, using low cost tests.

Research on global change and the challenges of sustainably feeding a growing planet

Since the 2007/2008 commodity crisis, there has been a resurgence of interest in the sustainability of the world's food system, efforts to feed the world's population and ensuring the environmental sustainability of the planet. Global agriculture has managed to offer a growing population an improved diet. Yet signs of slowing yield growth for key staple crops, combined with public opposition to genetically modified crops, have slowed biotechnology developments in some areas of the world. Uncertainty of climate change may affect the productivity of farming in regions where poverty and malnutrition are most prevalent, leading to a vulnerability for the world's poorest populations.

The broad objective of this project is to improve our understanding of the interplay between population and income growth, biofuels policy and production, international trade, climate impacts and climate policy in determining future food security, land use change and greenhouse gas (GHG) emissions at global and regional scales. Land-based GHG emissions account for about one-quarter of GHG emissions, and could offer up to 50 percent of abatement potential at modest carbon prices. Yet current predictions of land use change and GHG emissions over the coming century are uncertain and often ignore the dynamic interplay between these forces. Four objectives have been identified in improving current knowledge and policies: understanding and quantifying drivers of global changes in land use and GHG emissions and formulating policy responses to these changes; evaluating impact of uncertainty in climate impacts, climate change mitigation policies and energy prices on both optimal and observed land use at a global scale over time; assessing impact of future water shortages on global food production relative to trade and land use; and evaluating impacts of these global changes on world food prices, food security, and poverty in developing countries.

The terms of trade impacts (changing export prices, relative to import prices) are cut in half when the spatial variation in climate impacts are removed. When biophysical impacts of climate change on crop production are allowed to vary across an empirically estimated uncertainty range, the welfare consequences are highly asymmetric, with much larger losses at the low end of the yield distribution. Impact of policies aimed at curbing GHG emissions from conversion of tropical forests to palm oil production in Malaysia and Indonesia was evaluated. The demand for palm oil has contributed to record levels of deforestation, carbon emissions and biodiversity loss. Sustainability certification schemes fall short and lead to calls for more aggressive measures. Evaluation of alternative conservation policies in a global economic framework showed market-mediated responses confounded efficacy and distributional impacts. Limiting palm oil production or consumption is unlikely to halt deforestation, therefore, domestic action will be necessary to maintain economic solvency, rather than outside intervention.

Research on harnessing chemical ecology to address agricultural pest and pollinator priorities

Organic agriculture continues to grow in both demand and production and is particularly reliant on developing holistic, ecology-based systems. Agricultural crops are valuable to the culture and economy with principal crops valued at more than $5.32 billion and a vegetable harvest of more than $700 million. The value of agriculture is indisputable. Still, these systems rely on pesticides to ensure profit despite the growing trend to explore alternative, non-pesticidal strategies that unite several disciplines and lead to sustainable solutions to reduce the impacts of insect pests while protecting valuable pollinators.

In light of this, research is developing chemical ecology tools and information to support sustainable agriculture by reducing damage from pests in crops such as potatoes, brassicas, cucurbits, apples, blueberries, and sweet corn, while maintaining pollinator health. The goals of this effort include generating awareness of science-based chemical ecology tools to support sustainable production and facilitating adoption of these methods. Projects studying the effects of volatile chemicals, emitted from cucurbit flowers or aggregation pheromones on the attraction of striped cucumber beetles (SCB), is one of these efforts designed to provide organic control options for this species, which is one of the biggest insect pests in organic systems.

During the summers of 2018 and 2019, the effects of floral volatiles for mass trap-and-kill was observed. Thirty-six traps were placed in zucchini plots at two locations in northwest Indiana – a commercial organic farm and the Purdue University specialty crops farm. The traps were made of plastic gallon jugs drilled with small holes with soapy water inside to drown the captured beetles who entered. Jugs contained lures with three floral scents known to be attractive to the beetles. These traps killed thousands of SCB per field over their early- and late-season generations with floral lures dramatically enhancing the attractivity of traps to the pest. Currently, floral volatiles are being tested with a synthetic version of the beetle's aggregation pheromone to determine whether these natural volatiles synergize, creating a potent stimulus to "pull" beetles off of neighboring plants and protect the crop from damage.

Because cucurbits are highly dependent on pollinators for yield, other projects in the lab are focused on how cucumber beetle pest management using pesticides affects pollinator health, including honey bees, wild bees, and monarch butterflies. This four-year project compared an integrated pest management (IPM) vs. conventional corn/melon system at five sites around Indiana. Data were collected on pest population dynamics, crop yield, bee health and abundance, and pesticide residues on leaves, soil, pollen, hive products. The results from the summer of 2019 are consistent with 2018, showing that in IPM plots, pest populations rarely or

never crossed their economic threshold and, therefore, chemical interventions were largely unnecessary. As a result, IPM fields had equivalent or higher yields and better performance of pollinators.

Research on the regulation of phenylpropanoid metabolism in plants

The sun is the principle source of energy for our planet, and photosynthesis is the primary mechanism by which that energy is captured and stored in the form of reduced carbon. An outcome of these biochemical events is that plants represent a quantitatively important, sustainable and carbon-neutral source of energy for humans. To maximize the utility of plants, it is important to gain control of processes associated with energy capture and storage, including molecular mechanisms that allocate fixed carbon to the myriad biochemical pathways in plants.

One most significant pathway is the phenylpropanoid biosynthetic pathway that leads to the deposition of lignin. Lignin is a cross-linked phenolic polymer that makes the cell walls of specialized plant cells more rigid. Its synthesis represents the single largest metabolic sink for phenylalanine in the biosphere and represents a huge metabolic commitment for plant metabolism. Lignin is also a significant barrier to using crops for livestock feed, pulp and paper production, and generating cellulosic biofuels. There is great need to understand lignin biosynthesis while simultaneously improving the ability to engineer plant metabolism to be modified for improvement of agriculture.

Two novel, plant-specific proteins (REF4 and RFR1) appear to control the amount of lignin a plant produces. REF4 and RFR1 are components of Mediator, a large multi-protein complex that facilitates interactions between DNA-bound transcription factors and RNA polymerase II to activate or repress expression of downstream genes. To determine how REF4 and RFR1 function as components of Mediator, a set of experimental approaches including immunoprecipitation methods were used to determine proteins with which REF4 and RFR1 interact in the Mediator complex. These experiments establish which proteins are relevant to regulation of phenylpropanoid accumulation in plants and simultaneously identify additional proteins relevant to this process. We determined the functional differences between REF4 and RFR1 by altering relative expression levels in different tissues, and are learning how to coordinate the transcription of genes required for lignin deposition to gain insights for manipulating this pathway for human energy needs.

LIVESTOCK

Addressing animal welfare

Issues related to animal welfare are under heightened public scrutiny. Research plays an important role in understanding the animal's experience by developing novel behavioral and physiological indicators to determine optimal animal welfare and provide a scientific basis for assessment and audit programs as well as breeding strategies for increased resilience.

Heat stress has significant negative repercussions to health and productivity, across species, due to heat waves increasing globally. Current research efforts to understand heat stress and determine how to improve welfare that includes evaluation of heat stress and disease in turkeys, in addition to the behavior of chickens raised for meat, during a heat stress event. Developing welfare indicators in swine is also part of the effort, noting how thermal stress results in lost

productivity, increases incidence of illness and morbidity and negatively impacts welfare. The USDA funding for this effort in 2018 helped re-define the range of thermal comfort for sows of various parities and reproductive stages, evaluate temporal pattern of physiological response of sows to heat stress, and create a decision support tool for farmers. Pig heat stress is being approached from a genomic angle, as the progress made is permanent and cumulative over generations.

While heat stress is a major focus, understanding when and how behavioral changes can indicate welfare issues, such as parasite infestations in laying hens, is also an avenue of investigation. Basic understanding of abnormal behaviors, such as feather picking behavior in domestic ducks, can help develop methods to mitigate the behavior and improve duck welfare. Further, the genetic selection of desired behaviors, such as docility in Angus cattle, can be used to maximize efficiency, since temperament traits have a profound effect on the long-term sustainability related to welfare, safety, longevity, and management practices.

Based on research conducted to date, temperature preference of sows falls at the low end of the Guide for the Care and Use of Agricultural Animals in Research and Teaching range with late gestation sows choosing cooler temperatures. This work is important for current decisions about heat stress management in sows. Various genomic regions and candidate genes associated with important biological functions were identified in various pig chromosomes, noting that heat tolerance is a heritable trait and can be used in breeding schemes. Results compiled from poultry research examined effects of heat stress on chickens raised for meat, which change their behavior during times of heat stress, spending less time preening. Cattle findings determined that docility in American Angus is a heritable trait and can be improved through genetic selection. This research helps provide a better understanding of the underlying genomic mechanisms for various behavioral indicator traits in cattle, pigs, and sheep, which will be used to help improve animal welfare and overall productivity.

Analyzing welfare attributes for cattle: Supply and demand for livestock production process

Today's meat and dairy product shoppers are increasingly sensitive to processes employed in the production of livestock products. Marketers are appealing to consumers by selling how a product was produced, as demonstrated by product labels on supermarket shelves, in restaurants, and advertisements. Livestock products evoke consumer sentiment regarding the treatment and welfare of animals in the production processes for meat and milk products. Beyond animal welfare, the public is increasingly interested in the treatment of employees, impacts on environment, and other externalities that production processes may produce. Market pressures have produced changes in practices on farms as consumer groups have a growing influence on issues related to animal handling. Research connecting consumer demand with producer willingness is needed to assist with on-farm decisions and whether to adopt these changes, which result in new practices and production systems.

Previously published research explored consumer preferences for pig and dairy cattle handling and treatment practices. Building upon past findings, the primary goal of this project by Purdue Extension is to understand the impacts potential animal welfare changes in dairy and beef cattle rearing systems will have on the supply and demand of beef and dairy products. Practices such as tail docking and dehorning dairy cattle are under scrutiny, in addition to non-conventional housing systems in modern beef production facilities.

Researchers hypothesize that consumers' perceptions of the welfare of beef cattle associated with various practices are significantly different than those associated with dairy cattle.

Objectives in this area include comparisons of beef and dairy products to previously completed work that explores the reasons for variation in consumer and producer preferences regarding animal handling and treatment. Specific objectives include estimating how consumer demand for beef and dairy products is affected by the perception of the animals' welfare. This research will help determine the potential supply-side impacts in adopting welfare attributes and investing in production systems under current use in livestock production and in proposed new systems.

Initial findings varied by animal species and the specific food produced, when responses were evaluated from consumers across the nation. Positive and significant differences were reflected in the willingness to pay extra for cheddar cheeses raised under conditions with perceived humane welfare practices. Pasture access for dairy cattle was another important factor identified, which varied by demographics like gender, household income, and region of residence.

Antimicrobial resistance research

Resistance of bacterial pathogens to antimicrobial therapies represents a critical concern in livestock production and human health. Foundational knowledge of disease ecology and mechanisms of antimicrobial resistance (AMR) remains limited. Methods to rapidly identify AMR pathogens are vital in protecting farms from disease outbreaks.

A network of multi-disciplinary scientists conduct comprehensive and integrated risk-based research and outreach to improve safety of food from farm to fork. They are seeking to understand prevalence and frequencies of pathogens and antimicrobial resistance within the environment, food products and food production processing, distributions and consumer systems. Efforts are focused on comparative and comprehensive multiple pathogens linked to antimicrobial resistance (AMR), multiple animal species susceptible to AMR microorganisms, and its integrative approach.

Purdue research is investigating alternatives to feed antibiotics that include a cocktail of pathogenic bacteria including Salmonella and E. coli in live animals and food matrices. Research is linked with robust Extension programming to facilitate the findings into educational programming and applications, including the online course, Diversity in Veterinary Medicine, for students and faculty at veterinary colleges across the nation.

Two of the main objectives in this project include determining the ecology and mechanisms involved in resistance and transmission of AMR, and then creating and delivering programs on antibiotic stewardship in food production systems through education and outreach. Progress includes enhanced surveillance and monitoring of antibiotic resistance and development of improved diagnostic tests. Purdue engineers, veterinarians and the animal diagnostic lab created a rapid diagnostic test to diagnose and recommend treatment for bovine respiratory disease (BRD). This test provides veterinarians a tool to aid in the antibiotic prescription decision-making process and increase antibiotic stewardship to decrease resistance. Determining the ecology and mechanisms involved in resistance and transmission of resistance are important factors in doing this. Researchers sampled dairy and swine manure (and stored manure) prior to manure application at the Purdue University farm, in addition to samples from farms in Michigan and New York. This resulted in a better understanding of soil manuring and the environmental fate of antibiotic resistance genes on the animal microbiome and resistome.

The impact of animal management practices depends on quantifying and understanding the horizontal transfer of resistance plasmids – a novel method to study the ecology of antibiotic

resistance genes. Research efforts help develop and evaluate interventions (including alternatives to antibiotics) that reduce antimicrobial resistance in food production systems. Analysis is still underway, testing marketed alternatives for their selective pressure for antibiotic resistance genes – a key factor in assisting producers with their antimicrobial stewardship.

Horticulture and Natural Resources

A multidisciplinary approach to increase the sustainability of turf areas

In Indiana, production and maintenance of turf is approximately a $2 billion industry that includes golf courses, athletic fields, sod farms, commercial lawns and residential turf. Turf is maintained under a range of environmental regimes with diverse budgets and expectations by individuals ranging from seasoned professionals to inexperienced homeowners. Decisions regarding irrigation, fertilizer use, pesticide application and maintenance require daily attention, carry significant economic costs, raise environmental concerns, and influence the long-term vigor of the turf sward.

To assist with these issues, Purdue Extension engaged with land managers, providing fact-based information on how to preserve and protect the environment by using fewer chemicals and yet maximizing appearance. This five-year research effort focused on two main objectives – identifying turf species and cultivars that require less upkeep than currently used systems, then refining practices for those species for maintenance and pest management practices to minimize care and maximize outcomes.

Combined research and Extension efforts provide the public and turfgrass managers with science-based recommendations for sound pest management and the development of environmentally sustainable, next-generation pest management tools useful for managing turfgrass pests. For example, chemical ecology work with billbugs is opening the door to exploiting chemical communication to manage this important pest complex. Efforts to understand biogeochemical dimensions of white grub larval ecology are providing new insights into factors driving ecology of soil insects. For herbicide resistant weed management, the research team continued studying geographically distinct populations of buckhorn plantain and presented research on non-chemical control options. Research on the whole-plant response to drought, heat, salinity and flooding stresses is providing insight on how to improve turfgrasses.

Helping turf managers be efficient with use of water in landscape was also part of the effort. A combined approach of molecular and applied research identified specific plant enzymes, closely associated with drought tolerance traits in wild grass species. The team evaluated germplasm (species and cultivars) for turf species (both warm and cool-season) that may be adapted and persist in this cool-humid/transitional climate. This is achieved through active participation in testing programs like the National Turfgrass Evaluation Program, the Turfgrass Water Conservation Alliance, and co-operation/collaboration with various turfgrass breeders across the United States. Replicated field plots were established to increase capacity to better assess chronic drought stress at different mowing heights, and the supplemental irrigation needs of common lawn species. Findings on the ecology of weeds prevalent in non-irrigated turfgrass helped learn more about weed management in non-irrigated turf from mowing and fertilization practices.

Extension's research and education in the area of turf is part of an ongoing effort to maximize efficacy and minimize pesticide applications – better for the manager and better for the environment.

Invasive plant control for woodland owners

Approximately 85,000 residents of Indiana own property that includes 10 or more acres of woodlands. Most of these individuals are unaware that their properties are potentially infested with invasive plants that threaten the health and survival of their woodlands. Education and

training regarding the management of these private woodlands are necessary to maintain the health and beauty of the ecosystems and their productivity for hardwood timber and wildlife habitat for current landowners and future generations.

The Southern Indiana Purdue Agricultural Center (SIPAC) is an active research and training center nestled on 1320 acres with 635 of that as wooded forest, about 160 miles from Purdue's West Lafayette campus. For more than 55 years, Extension foresters with Purdue's Department of Forestry and Natural Resources, based at SIPAC, have been helping southern Indiana landowners manage their woodlands.

In September 2019, Extension educators conducted Invasive Plant Control Training for Landowners – a day-and-a-half program at SIPAC, where attendees engaged in practical, demonstration-based training by foresters and natural resource professionals. Topics of instruction included assessing the owner's invasive plant problem (species, size, and amount), and learning the three pillars of invasive management – prevention, early detection, and strategic management of existing infestations. In a collaborative partnership with the Invasive Species Awareness Coalition of Dubois County, the Four Rivers Forestry Committee, the Orange County Invasives Partnership, and the Indiana Department of Natural Resources speakers and instructors worked together to help property owners learn about their invasive plant control options and how to decide which methods were best for their situation. This also included proper herbicide application, how to seek funding and technical assistance, putting a plan into place for long term restoration and enhancement, and information on when to hire a contractor.

Results from the training survey represented 31 participants who have 4189 acres of land in Indiana. Participants were asked to rate their level of knowledge before and after training with most reporting very little knowledge of the "three pillars" of invasive species plant management at the beginning. At the conclusion of training, participants reported: great improvements in knowledge levels of understanding why invasive plants are considered a threat; how to get help with managing invasive vegetation on their property; how to assess the invasive species; and how to make and prioritize a plan to address the infestation. A significant 90% of those who participated reported great satisfaction with the training in their surveys, indicating the new knowledge would help them make future decisions and take actions to manage invasive species on their property, within the next 12 months.

Natural resources conservation through collaborative community leadership

Natural resource management and land use planning decisions made by conservation professionals, government and community leaders, and private landowners impact the quality of Indiana's environment. Natural resource challenges cross all disciplines and audience groups that Purdue Extension serves.

Extension sought to address this need with the creation of Conservation through Community Leadership (CCL), a statewide natural resource program to enhance decision-making for community implementation. This curriculum has best practices from leadership training and community development frameworks to facilitate community decision-making, leadership development, and action planning for complex natural resource management and land use planning. CCL is a roadmap for communities to identify issues, assess community conditions and resources, create a shared vision, and then develop an action plan for implementing strategies. This can take two years, and involves convening community leaders as a local working group meeting four times with Extension facilitators supporting community visioning, sharing innovative management strategies, and coaching them through action plan development.

Results include a local or regional action plan and implementation project strategies for working groups, county or municipal comprehensive plan updates, watershed management plans, or fundraising initiatives. In the past three years, CCL was initiated in Union Township, Kosciusko, Gibson, Dearborn, Pulaski, and Owen counties, and Pendleton, Indiana – each tailored for local issues.

Examples include Kosciusko and Pendleton, areas that focused on integrating natural resource elements into comprehensive plans. Gibson convened to support a watershed management plan, while Dearborn supported a community garden initiative. Owen and Pulaski developed invasive species activities, and Pulaski worked with their soil and water conservation district to produce a 36-page action plan to guide formation of the Cooperative Invasive Species Management Area (CISMA). Residents from Dearborn County Soil and Water Conservation District worked with the Purdue Master Gardener State Coordinator and other gardeners to produce an action plan for expanding county-wide community gardening. Owen County Soil and Water Conservation District launched a Cooperative Invasive Species Management Area (CISMA) effort from their CCL experience. Feedback revealed nearly all participants gained a better understanding of natural resource issues and learned how to apply the new knowledge and tools they had gained.

CCL supports development of high-quality local and regional action plans and strategies for implementation in Indiana communities. Group planning can lead to a more collaborative process with the inclusion of multiple perspectives. Action plans addressed watersheds, community comprehensive plan updates, invasive species council guidelines and plan commission recommendations for improvements in Indiana's communities.

Rainscaping to prevent polluted runoff

There is a need for education on sustainable landscape practices to prevent polluted runoff. Landscape practices such as rain gardens, which direct storm water to be absorbed by plants and soils, are of increasing interest among Purdue Extension clientele and conservation partners.

Rainscaping is a combination of sustainable landscape design and management practices that prevent polluted runoff from reaching water bodies, directing stormwater to be absorbed by plants and soils. This work builds on the highly successful Extension Master Gardener (EMG) program model, to form the Purdue Rainscaping Education Team. Curriculum materials, instructional videos, marketing materials, and a local host guide were created for statewide use. Instruction using a flipped classroom model introduces participants to rainscaping and rain gardens through at-home learning using videos and reading assignments. In-class discussion and activities cover the topics of rain garden site selection, plant selection, garden design, installation, maintenance, and community engagement. Additionally, participants attend local tours of rain gardens and construct a demonstration rain garden.

Results from these efforts have yielded participation from many counties that have initiated rainscaping projects and established partnerships with the Purdue EMG Program. One project, a collaboration of Johnson and Marion counties, installed a rain garden on the Johnson County Extension office property. Additional efforts include Posey County's work with the Soil and Water Conservation District and EMG volunteers to update a demonstration rain garden in Mt. Vernon Riverfront Park. Steuben, Lake, Boone and Warrick counties have installed demonstration rain gardens and interpretive signage. Purdue EMG volunteers in Steuben County worked with Pokagon State Park to install a rain garden at the park. Lake County worked with the Soil and Water Conservation District to create a demonstration rain garden on county

government grounds. Purdue EMG volunteers in Boone County collaborated with a local church to install a rain garden next to the public community gardens. Warrick County assisted the County Soil and Water Conservation District and Purdue EMGs to install a rain garden in Friedman Park.

Post-surveys indicated nearly 100 percent of participants have increased their ability to plan and install a rain garden, with nearly the same amount intending to directly apply information learned within the year. Many respondents also noted plans to educate others who want to build rain gardens and to create several rainscaping methods to leverage as education opportunities.

Demonstration rain gardens installed from 2017-2019 have the capacity to reduce runoff by 760,720 gallons each year, which can greatly improve water quality in Indiana communities. Custom designed interpretive signs have been installed to promote education. Participants are encouraged to unite as community teams implement public education programs and provide technical assistance for homeowners and public projects.

Research of beneficial reuse of residuals and reclaimed water: Impact on soil ecosystem and human health

Beneficial use of biosolids to enhance soil quality and soil fertility is constantly challenged by concerns of chemical constituents with potential to remain after wastewater treatment processes. The presence of trace organic chemicals (TOrCs) in municipal biosolids has garnered much attention from the public and regulatory community. Sound science is needed to properly evaluate risks to the ecosystem and human health so biosolids may continue to serve a beneficial purpose rather than be destined for landfills.

The primary goal of this research is to provide needed data for properly assessing risk protective of human and environmental health while supporting optimal use of municipal biosolid for land reclamation. The concentrations of TOrCs in biosolids and composted city wastes, which include yard trimmings, food packaging and other paper wastes among other compostable materials used in both agricultural and urban settings, are helpful in ecological risk assessments. Currently, the TOrC concentrations of greatest concern are perfluoroalkyl substances (PFASs), particularly the perfluoroalkyl acids (PFAAs), which cannot be degraded biologically, are mobile, and for which minimum allowable concentrations in water are in the low parts per trillion. PFAAs were detected in all composts and biosolid-based fertilizers. Analysis of a limited number of more recent biosolid-based fertilizers reflected a substantial decrease in total PFAAs especially of the longer chain PFAAs that have been phased out for most applications. Increasingly lower allowable concentrations of PFAAs in groundwater and surface water by some states is raising additional concerns regarding the contribution of land-applied biosolids to PFAA contamination of groundwater. However, in most cases, the PFAA loads in biosolid-based products and composts are relatively low compared to other exposure routes except when industrial inputs have resulted in elevated PFAA loads in biosolids.

The research team completed greenhouse studies evaluating uptake of both PFAAs and a subset of other trace organics by kale, turnips and radishes in Miracle Grow supplemented with a 2016 biosolid-based fertilizer product at 0, 1 and 4 times the recommended rate. Long-chain PFAAs remained primarily in the growing media with some on the roots and the root vegetable peels. Some shorter chain PFAAs were detected in kale leaves. PFAAs in root vegetables and in leaves increased with increased application rates. Most of the PFAAs remained in the growing media and not associated with the plant. Ongoing Purdue-led research will continue to study the relative contributions and subsequent mitigation of PFAAs to groundwater from land-applied biosolids and treated wastewater irrigation in agricultural operations. Research projects like this

help develop an understanding of the processes that govern environmental fate and remediation of contaminants and assist in selecting guidelines for industrial and agricultural settings.

Research on best practices for water quality protection at the watershed scale

A standardized methodology is necessary to accurately predict Best Management Practice (BMP) performance effectiveness across a range of scales for water quality protection. Conducted on a multi-state level, this approach can lead to cost-effective and informed decision-making process when making watershed management decisions.

Current research includes monitoring water quality from a variety of watersheds with a range of conditions including differing land use and associated implemented BMPs, varying geographic and geologic conditions, and evaluating models for predicting BMP performance and water quality at the field and watershed-scales when considering climate change. This research studied pollutant loads from two representative watersheds draining to Lake Michigan based on resident groups of urban, suburban, rural, and agricultural areas to determine the willingness of resident groups to adopt conservation and management practices and to aggregate potential pollutant reductions based on willingness scenarios with the various stakeholders. The team conducted a survey to explore residents' awareness of and attitudes toward water quality improvement practices, their likelihood of adopting these practices, and factors that influence that likelihood. Respondents valued improved environmental quality and reduced flash flood risk as benefits of adopting water quality improvement practices, and identified not knowing about specific conservation practices, which were identified as main barriers to adoption. Survey results were analyzed to assess knowledge and the likelihood of implementation. For rain barrels, a high adoption and knowledge is present, yet with limited environmental impact since they represent a fraction of potential runoff. A higher knowledge of cover crops was revealed, but the likelihood of adoption is much smaller, suggesting other hurdles exist.

Assessment also was made about ecosystem services of urban rain gardens to determine how this impairs water quality and ecological health of nearby streams and rivers. Stormwater control measures (SCMs) to disconnect surfaces from receiving waters also were implemented, reducing flood impacts and increasing pollutant removal – critical in regulating ecosystem services. The team conducted a multi-city comparison of ecosystem services provided by SCMs in Charlotte, NC, a large metropolitan region with a progressive stormwater utility and West Lafayette, IN, a small city with a developing stormwater utility and active community-based watershed stewardship. The focus was on commonly used rain gardens, ecologically based and scalable to provide multiple ecosystem services throughout urban landscape. Water quality was measured for runoff and soil water in three rain gardens in each city from January 2017 through May 2018. All sites were on public lands (schools, parks) in neighborhoods with varying socioeconomic factors.

Our overall objective for this project was to assess the environmental tradeoffs between water quality and climate regulation when best management practices (BMPs) are implemented in agricultural watersheds. Findings show soil testing during the early stages of a project can help identify those sites best-suited for management, while also understanding the role of community stewardship in delivering ecosystem services in urban landscapes.

Research on spatial linkages of soil and water resources for sustainable agronomic production in Indiana

Water, its availability and our access to it, is essential to the health of many ecosystems. Access is complicated by community needs and environmental factors like rainfall, severe weather, and climate variability, all which make planning difficult. Significant quantities of data detail the

subsurface of hundreds of aquifers across the nation, but much isn't available in geodatabases for regional analysis. They are sometimes available as data layers for individual states, but they are truncated at political boundaries that do not represent aquifer boundaries. A seamless dataset is proposed to analyze what's been compiled, so land managers and producers can gain a greater understanding of water management.

The long-term goal of this project is to quantify the water storage capacity in the soils and aquifers of Indiana and note how future changes in the quantity and timing of water supply and demand will affect agronomic production. This effort includes development of spatial and temporal databases, field studies, remote sensing observations and hydrologic and crop simulation modeling at multiple scales to predict the sustainability of agronomic production in the state. Objectives include quantifying the subsurface water storage capacity in Indiana soils and groundwater aquifers, evaluating agricultural water use in Indiana in relationship to climatic extremes and projections of future climate change and water demand, and integrating findings to on-line spatial databases for use in research, Extension and teaching.

Compilation of a database of soil, vegetation, wetlands and open water and forcing data to start running model simulations at a spatial resolution is nearing completion. Efforts include using a version of the VIC model (a large-scale, hydrological that solves water and energy balances) incorporating all Purdue-based code updates for groundwater, agricultural drainage, and surface inundation. The VIC-CropSyst model, a coupling of the VIC land surface model with the CropSyst crop production model, has been applied to all of Indiana as part of the Indiana Climate Change Impact Assessment (INCCIA). The model has been updated to include representations developed at Purdue for subsurface drainage and urban areas. Field experiments quantified variations in biomass and yield development by water availability. This data will be used to improve the representation of crop growth under conditions of water stress.

These efforts resulted in a new app published to Google Play, and Final Dominant Soil Parent Materials (DSPM) maps placed on the Soil Explorer website for Iowa and Michigan, along with a draft map for Arkansas, and soil orders, moisture regimes, and features maps for the Arequipa Region of Peru.

Food, Nutrition, Families and Health

Increased knowledge of safe home food preservation practices in the North Central Region

Home food preservation is a process that, when done correctly, can produce a bounty of food. However, when home food preservation practices are performed incorrectly, undesired food safety issues can result in illness and possibly death. Since many residents of Indiana preserve foods throughout the year, it is critical to provide the most recent, research-based home food preservation information.

North Central Region (NCR) Extension educators worked on a food safety program for consumers across the region that included Indiana, Iowa, Kansas, Michigan, Missouri, North Dakota, South Dakota and Wisconsin. This NCR food safety team developed and delivered food safety education and implemented evaluation tools and analysis, based on home food preservation starting in 2017, then expanded in 2018 to include produce safety for food pantries. Food preservation topics included boiling water bath, dehydration, fermentation, freezing, pickling, pressure canning, steam canning, and sweet spreads. Programs were presented on multiple platforms, including lectures, demonstrations, hands-on events, and more.

These efforts attracted more than 1600 individuals who participated in the 2017 classes. Nearly all workshop participants reported learning information that was new to them, while more than half attested they had changed their food preservation practices. An overwhelming majority said they have implemented safe home food preservation practices and have shared their knowledge and resources with others. Additional feedback showed confidence in the ability to preserve food safely from the training. From 2017-2018, more than 3,300 NCR attendees completed a revised, end-of-session evaluation. Nearly 100 percent said they would recommend the educational program for others. Many noted plans to share the resources provided, along with an eagerness to preserve food at home more often and make sure their home resources were up-to-date.

Feedback from Indiana participants who completed the 2019 evaluations indicated about one third had been preserving food at home for less than one year before the training. Roughly the same amount reported they had been preserving food for 10 years or more. All said they would recommend this program to others, expressing confidence their preservation techniques had improved, along with the knowledge of where to get safe, research tested recipes for preserving food, and how to implement these best practices in a home environment. Nearly 90 percent said they plan to use the food preservation resources and follow directions provided by Extension and USDA. Encouraging comments said the workshops were "very informative" and that they were "going to try new recipes and canning methods." The Home Food Preservation workshops deliver knowledge and provide resources that contribute to the food safety of Indiana residents and the North Central Region.

Interactions of diet, flavor, and saliva for eating healthy foods research

"Good medicine tastes bitter" is a saying that dates back to Confucius. The idea is that things that are good for your health are unpleasant to consume. This phenomenon is more than psychology, as many of the chemical compounds in drugs and foods that are "good for you" have unpleasant flavors. The same properties that make chemicals unpleasant are also the properties that may drive the contributions to health. Many bitter compounds in vegetables are the exact same chemical compounds that could fight cancer, reduce risk of diabetes, or protect against

obesity. This reality results in a fundamental problem for human nutrition: foods we should eat are the same foods our mouths tell us are unacceptable.

This research sought to improve healthy food flavor through modification of saliva. The research uses oral sensations (taste, smell, spiciness) and secretions (spit) to improve foods for health. Whether making healthy foods more palatable, easier to consume, or increasing absorption of key nutrients, the goal is that food should taste good—even if it's healthy for you, and even if you are not healthy.

Preliminary data indicate saliva influences flavor perception for specific, healthy food compounds (unsaturated fat, spicy compounds, polyphenols), and may be useful for making unpleasant sensations less intense. Research objectives included determining salivary protein changes before and after adding target flavor compounds to the diet with regard to whether flavor perception is altered by changes in salivary proteins, in addition to determining changes in salivary proteins during dietary interventions, like low sodium diets, non-nutritive sweetener diets. Experiments were conducted on those with no food allergies who tasted beverages containing bioactive flavors like unsaturated fat, spicy compounds, bitter polyphenols, food-based flavors, and no flavors. Participants provided baseline saliva, then tasted three beverages. Researchers identified high and low sensitivity to the flavor of interest, and high and low expression of the salivary protein. Next, a six-week intervention was completed to assess flavor sensitivity and the expression of salivary proteins, with ratings collected from participants who were given different sets of beverages to sample each week.

One study demonstrated exposure to polyphenols (the bitter stuff in cocoa products) in a chocolate milk mixture caused saliva to change, which could reduce the bitterness intensity of chocolate. A second study looked at bitter compounds from green tea and whether those also alter saliva and change the bitterness intensity that people experience. This work initially confirmed saliva adapts to reduce the bitterness of certain foods. Knowing diet changes saliva in ways that influence the flavor of that diet is critical in understanding why people find certain foods bitter and palatable and others do not. Changing to a healthier diet is hard, especially if people don't like the flavor of the healthy diet (often associated with bitter flavors). Results will help those trying to switch to a healthier diet, to stick with it and the body will adapt to like the flavors better. Once patterns between saliva and diet are defined, then salivary profiles could be useful in further research to verify diet records or dietary compliance in the field of nutrition. Research is identifying human salivary proteins modifiable by diet which can ultimately impact diets of healthy foods for weight management and disease prevention.

Mental health first aid

Mental health and substance use issues create widespread concern across the nation, and are often perceived differently than other physical health conditions. This attitude can perpetuate shame and stigma, which may discourage individuals from seeking or accepting help. Evidence shows that education to reduce the stigma in communities greatly improves an individual's chances of successful recovery. The stigma surrounding mental health and substance use is not only harmful to the individual, but also to their family and community. Community members can gain skills to support one another, similar to a CPR or medical First Aid certification, to prevent distress and promote engagement in effective treatment. In the age of the opioid crisis, every resource available is valuable and holds potential to save lives.

Purdue Extension provides Mental Health First Aid (MHFA) courses to adults about assessing signs and symptoms of mental health and substance use issues, as well as acquiring tools for

first-aid assistance to someone experiencing a crisis. MHFA is an eight-hour, in-person course. The target audience is any adult interested in learning more about mental health issues. Topics include anxiety, depression, substance use (including opioids), trauma, and deliberate self-harm. During MHFA, participants learn how to be a resource to and support for those at risk for mental health and substance use issues. MHFA was presented 15 times during 2018-2019, reaching 414 individuals. There were 381 who completed the post-evaluation, with more than a 90 percent response rate, and of those about three-quarters identified as female, 24 years or older and Caucasian.

Post-evaluation results showed that MHFA was well-received by and beneficial to participants. Nearly everyone agreed or strongly agreed in their confidence to recognize signs that someone may be having a mental health problem, substance use challenge or crisis. About the same amount indicated the improved ability to reach out to someone having a mental health problem, substance use challenge or crisis, and that they could now recognize and correct misconceptions about mental health, substance use and mental illness. More than 90 percent also showed confidence in asking a person whether they are considering killing themselves. One individual noted, "This is a course that would benefit all people." Another identified, "What I enjoyed most about this class was how the different types of mental illnesses were discussed and how to handle the situations." The program's ability to provide a starting point in mental health education was evident in one of the comments indicating its helpfulness to those new to the topic. This feedback and continued demand for additional programs affirms its value in providing mental wellness and first aid training for communities and residents across Indiana.

Co-parenting for successful kids

Abrupt or involuntary disruptions in a child's life can affect a child's feelings of security and stability and lead to negative impacts on physical, emotional and cognitive development. In Indiana, when a family is going through a divorce or custody proceeding, judges have the discretion to require co-parenting education. With the national average of about half of all marriages ending in divorce, this situation affects a great number of the state's children.

Purdue Extension provides the Co-Parenting for Successful Kids (CPSK) program to meet the statewide need of co-parenting education, easing the adjustment for children experiencing a family divorce. This four-hour program emphasizes the importance of keeping children out of the middle of adult conflicts, along with many topics like identifying the stages of grief, and adjusting to one another's parenting styles. A total of 544 parents completed the online course or attended the onsite class. Online course participants received feedback about their journal submissions from trained facilitators.

In the program evaluation, nearly 100 percent of parents reported learning ways to keep children out of the middle of adult conflicts between the co-parents, with nearly the same amount developing a child-focused co-parenting plan with the other parent. Nearly all indicated they learned positive communication methods with co-parents by using "I" messages, and helping their children adjust to the divorce or custody modification based upon the children's ages and stages of development. All parents said they intended to use the strategies they learned to help their children adjust to the new co-parenting arrangements.

Other key feedback indicated how parents learned to stop criticizing each other in front of their children, along with the importance of not asking children to relay messages to the other co-parent. Parents also reported learning ways of disciplining relative to the child's age group, including positive ways of communicating to reduce family stress. Many indicated their former

methods of parenting were not “the right way” based on what they learned in the program, including how the new the material helped them carefully think through the divorce process.

Extension helps parents learn that when co-parents are responsive, responsible, and especially respectful to the children and each other, conflict between co-parents is reduced, and the overall well-being of children is improved.

Research on school readiness disparities and the role of region, family, community and preschool experiences

Less than half of children living in poverty start kindergarten ready for school. Compared to their more affluent peers, these children begin school with poorer pre-academic skills like letter recognition, early math, social-emotional health and self-regulation. Early school readiness skills influence more than just kindergarten academic outcomes. Children with strong school readiness, measured between ages four and five, are more likely to have academic success in elementary, middle, and high school, and more likely to graduate college by age 25. School readiness is linked to earned income in adulthood and considered a necessary benchmark for entry into middle class. Gaps in school readiness have important long-term implications for educational and economic success.

Geographic region is a unique, yet understudied, context for development of school readiness. Striking variability exists along urban-rural continuum of kin networks, access to resources, and educational opportunities. Disparities across urban-rural continuum in academic achievement for young, elementary school children are beginning to emerge. Recent analyses suggest elementary school age children living in rural communities are less proficient in their early literacy skills and 60 percent more likely to be placed in special education services, compared to their urban counterparts. Scant research has been dedicated to understanding whether geographic region plays a role in children's development before kindergarten entry, and if it impacts school readiness.

Purdue researchers set out to identify differences between family, community, and preschool experiences of low-income children across the urban-rural continuum. The additional objective included exploring differences in three aspects of children's school readiness (pre-academic skills, social-emotional health, and executive function) across the urban-rural continuum. Results from the first two objectives will inform an investigation about whether aspects of children's family, community and preschool experiences act as mechanisms linking geographic region and school readiness.

Data for the objectives has now been collected and analyses have been completed with results disseminated. One of the key findings showed children from rural communities and small cities are more demographically at-risk relative to children living in urban communities due to factors like lower parental education and family income. Additionally, children from rural communities experience slightly higher preschool classroom quality compared to their urban counterparts. While there are few differences in children's school readiness across the urban-rural continuum, teachers rated children from rural communities as having higher social competence than children in urban communities. Children who live in rural communities and small cities, benefit more from high preschool classroom quality in terms of their social-emotional competence relative to children who reside in large urban communities. These research findings are important in understanding how we can work to eliminate the disparities that prevent a child’s school readiness and bring these factors to light, hopefully leading to the creation of new, educational strategies, so all children can be successful.

Youth Development

4-H adult volunteer positive impacts on Indiana youth and communities

Adult volunteers are highly utilized to deliver positive 4-H Youth Development program experiences. Significant staff and financial resources are expended in developing volunteers to work with various aspects of the 4-H program. Are these volunteers effective? What types of impact does their service provide? The North Central Region 4-H Volunteer Impact study provided these answers.

There are vast opportunities for adult volunteers from leading a club or one-time event to helping with an afterschool program to serving as a judge for 4-H project exhibits, to name a few. This impact study was conducted with adult volunteers in 12 states to better understand the value of being a 4-H volunteer. A total of 1,000 volunteers from each state were randomly selected and asked to reply to an electronic survey.

A total of 255 Indiana 4-H adult volunteers responded and noted their top reasons for volunteering included helping others, making a difference and supporting a child in 4-H. Nearly half reported having a tenure of at least 11 years, 25 percent had been volunteering 2-5 years, and roughly the same amount for 6 - 10 years. Nearly two-thirds of the volunteers were 4-H members as youth. On average, each volunteer gives nearly 10 hours per month – more than a $2000 value to the community. Indiana adult volunteers personally benefit from their 4-H involvement, with nearly everyone indicating they had built new relationships with youth. One volunteer stated, "Impacting the youth's experience and assisting them with preparation for the future, I genuinely enjoy just having the opportunity to meet these young individuals and get to know them while seeing their growth over time."

The 4-H program benefits from 4-H volunteers who contribute their skills in after-school mentoring programs in challenging neighborhoods, achieving great success with disadvantaged students. Nearly 80 percent also indicated learning to think from different perspectives and gaining a better understanding of working with children with special needs. Those who recruited new youth mentioned how 4-H crosses all economic and social lines. 4-H volunteers also strengthen public value by increasing civic involvement in community affairs and politics.

This study lends the supportive data to confirm what we always believed – the 4-H program would not be possible without volunteers. Through their training and service, adult volunteers grow personally, enrich the 4-H program, help youth build skills, and make Indiana communities stronger.

INWork: INnovate, INvest, INspire: Skills for tomorrow's workforce

The Indiana Workforce Department estimates that there will be one million jobs by 2025. The current statistics of Indiana's unemployment rate of 3.5% in comparison to the nation's 3.7% rate illustrates that Indiana is facing a worker shortage. In 2007 the report, "Every Promise, Every Child: Turning Failure into Action," youth defined their success as having a good job, yet lack the needed skills.

Purdue Extension developed and implemented INWork – INnovate, INvest, INspire: Skills for Tomorrow's Workforce which teaches high school youth life skills for the working world. To increase the number of qualified applicants for Indiana jobs, Extension joined forces with local educational institutions to offer INWork throughout Indiana. There were 180 youth who completed the program offered in 10 counties. Youth participated in hands-on career readiness

activities. Sessions included: SMART goal setting, decision making, personal accountability, professional dress, teamwork, problem solving, conflict resolution, time management, safe and professional social media, fiscal literacy, career exploration, preparing resumes and cover letters, and interviewing.

As a result of INWork, 100 percent of high school youth recognized the importance of being on time to work, doing their job well, with 99 percent recognizing the importance of being trusted by their employer and respecting others in the workplace. Nearly all who participated acknowledge the importance of having a professional image on social media. More than 80 percent identified a career they would like to pursue, after successfully exploring career options. Looking beyond high school, more than 75 percent indicated plans to attend a 4-year university the year after high school or immediately jump into the workforce -- others were planning to attend a community or vocational college. By completing INWork, these youth showed positive development preparing them to work after high school with skills that will help them succeed. In the future, the INWork curriculum will be updated and rebranded as Work Ready and available for workforce development programming across the U.S.

Youth experiences at the Heifer Ranch increase understanding of global hunger and poverty

In 2016, the United Nations Food and Agriculture Organization estimated 815 million people – roughly 10 percent of the world's 7.6 billion population – suffer from chronic undernourishment. In Indiana, one out of six children and one out of seven adults struggle with hunger. While the world produces enough food to feed everyone, many people do not have enough income to purchase or land to grow nutritious food.

In an effort to educate and heighten awareness of these issues, 11 Indiana county teams, traveled to Heifer International in Perryville, Ark., to participate in the Global Gateway Experience. The 44 youth and 11 adults were immersed in team-building activities and experiences meant to provide a greater understanding of global hunger. Participants experienced what's referred to as the Global Village, where they saw re-creations of urban slums, bamboo huts, shanties, and refugee camps. Each participant was assigned to a village where they would spend the night and prepare a meal with limited resources. This opportunity exposed participants to the struggles of managing inadequate shelter, food, water or cooking fuel. After returning to Indiana, each team implemented an action plan to provide others with a better understanding of global hunger issues and to address those issues in their communities.

After participating in the Global Gateway Experience, youth shared new perspectives, noting the importance of livestock as a resource for ending hunger and poverty. Nearly everyone indicated they felt like they could help end world hunger and poverty and mentioned learning the difference between malnutrition and starvation. Participants also reported developing a curiosity about international affairs on TV, the internet, and other media. Participants agreed that because of this experience, they became more accepting of different cultures. Ninety-five percent said they would work to encourage others to volunteer in their community, and the majority said this exposure would lead them to participate in (or lead) a community service project. Feedback noted an appreciation for being able to spend the night in the village, which gave them insights as to what extreme poverty would feel like. Participants provided comments like, "Being able to camp in the villages really gave me a perspective and an unforgettable experience" and "I liked to learn how people in different places in poverty live, and I liked it when we worked together."

Results from the Global Gateway Experience demonstrate how Purdue Extension contributes to positive youth development by heightening the need for community awareness, service, and leadership in the effort to prevent and end poverty and hunger.

Community and Business Development

Enhancing the value of public spaces: Creating healthy communities

In Indiana, community leaders make decisions about public spaces like parks, trails, farmers' markets, schools, and Main Streets that affect the health and wellness of the community. Many communities face significant challenges to quality of life and economic development, indicated by low state rankings for health outcomes and poverty rates.

Enhancing the Value of Public Spaces: Creating Healthy Communities (CHC) was developed for Indiana communities by a comprehensive, multidisciplinary team of Purdue Extension professionals from Health and Human Sciences, Nutrition Education Program, Community Development, Agriculture and Natural Resources and Illinois-Indiana Sea Grant. This team created a curriculum, marketing flyers, promotional videos, podcasts and a series of instructional training videos. CHC combines data collection and analysis with inclusive public deliberation to design high-quality action plans toward meaningful, sustainable improvements for public spaces focused on community health. This is achieved through community design coupled with information resources, case studies, and strategies to enhance food access and active living via community-based programs and improvements to public spaces.

In the town of Gaston a public spaces action plan for a new community center, trails, and community wellness activities was created. In Terre Haute, an updated parks and recreation master plan was developed. The focus in Connersville was to integrate health and wellness into community initiatives. The project included downtown public space revitalization and strategy recommendations for the community's comprehensive plan. On a post-survey, completed by Terre Haute participants, findings revealed expectations were met or exceeded for the presentation of information, facilitation of activities and encouragement of discussion, opportunities for learning about public spaces, and building connections to resources. Both Gaston and Connersville participants indicated they felt engaged in activities, the discussion was meaningful, the workshop was informational, and their knowledge about how to create healthy communities had increased. Respondents also indicated being more likely to use information from CHC for future public spaces planning. For Fayette County and Connersville, their two-year process engaged more than 153 community members and generated 482 volunteer hours, valued at $11,631. In addition, because of the EVPS: CHC program, city government in Connersville secured $100,000 to support additional healthy eating and active living efforts.

CHC is a valuable effort led by Extension that helps communities working to develop high-quality public spaces action plans that improve the quality of the environment, bolster economic development, and create healthier living places for individuals and families.

Beginner's Guide to Grant Writing benefits Indiana communities

Competitive grant proposals are an increasing revenue source for nonprofits, educational institutions and local governmental units. Many people working in nonprofits and local governments find themselves in positions in which they need or want to write grants, but they have little or no training. Writers who understand the grant writing process and can communicate their ideas clearly to potential funders can leverage funding to improve the quality of life in Indiana communities.

To help communities, Purdue Extension delivers the Beginner's Guide to Grant Writing program (BGGW). Each workshop is hosted by an Educator and taught by a team of two trainers. Two full days of instruction and activities are geared toward novice grant writers with

an idea or a program in mind that will help their community. Participants learn how to write effective grant proposals and navigate the grant process, develop ideas into winning proposals, identify potential funders and understand the full proposal development, submission and review process. Participants bring an idea and leave with a proposal outline and all resources needed to expand the outline into a full proposal. Participants return several weeks later with their full proposal ready for a peer review. During the workshop, they learn strategies to find funding and polish their proposals, and they receive advice from grant writing professionals.

Data from follow-up surveys collected from participants who attended the first year's workshops provides promising support of the new BGGW. Nearly 95 percent rated BGGW very to extremely beneficial. Respondents reported that, as a result of BGGW, they had submitted proposals to funders, and some of their proposals had already received funding. The most significant outcome includes nearly 4-million-dollars in grants awarded to 51 proposals submitted. Many indicated they had taken on new leadership roles, engaged in strategic planning, leveraged new partnerships, and logged numerous volunteer hours planning community initiatives. Many said they were able to identify short, medium, and long-term goals for their proposed initiatives and appreciated the networking opportunities made through the workshop.

BGGW has received a $13,500 in grants from State Farm to offer the program statewide. Many community foundations contribute sponsorships and provide in-kind support for individual workshops. BGGW has proven successful in helping participants increase skills to write, submit and, ultimately, receive funding to support Indiana organizations and communities.

Sustainable communities: Environmental watershed planning with the Tipping Point Planner

For communities to achieve ecosystem sustainability, they must know what land and habitat components are necessary to sustain their ecosystems. Communities need to understand science-based environmental limits or "tipping-points," so that they can institute land use policies and restoration plans to ensure they stay in a "safe operating space" that maintains critical ecosystem services.

Tipping points are thresholds of ecological or social systems that separate good and undesirable states. Systems often "tip" into undesirable states due to human activities that move them out of the good state. To better understand where communities are with regard to local tipping points and how decision-making about land management at a watershed scale can keep them in a safe operating space, researchers and Extension professionals at several Great Lakes universities in Illinois, Indiana, Michigan, Wisconsin and Ohio, calculated environmental tipping points that communities should avoid.

A web-based decision support tool, Tipping Point Planner (TPP), developed by a Purdue-led team, organizes community objectives, data, models, and planning tools into an online interactive framework. TPP helps watershed leaders identify land-based activities that contribute toward nutrient loading, increased runoff, and non-point source pollution, which ultimately threaten the sustainability of their watersheds. These tools allow the team to explore what-if scenarios for the future of their community, applying state-of-the art green infrastructure (GI) programs that provide estimates of costs and benefits of various GI options.

Purdue Extension's Conservation through Community Leadership, along with TPP, and in collaboration with Illinois-Indiana Sea Grant, supported communities to facilitate, implement and maintain locally driven natural resource management plans. Team members conducted workshops with Northwest Indiana, West Lafayette, Portage, Union Township, Pendleton,

Gibson and Kosciusko counties in Indiana; Green Bay, Wisconsin; Ottawa, Illinois; the Shiawassee National Wildlife Refuge, Michigan; and Perrysburg, Ohio. Community programs in Michigan and Ohio have included education and visioning sessions with community stakeholders, and action planning meeting series with steering committees of local experts. Additional work included assisting Huron Pines, a Michigan-based environmental non-profit, in creating a watershed management plan for Au Gres River and East Au Gres River Watersheds in Saginaw Bay. Extension also collaborated with Indiana State Department of Agriculture to create a new guidebook, "Community Planning for Agriculture and Natural Resources: A Guide for Local Government" that provides education resources for community land use planning.

Extension and Illinois-Indiana Sea Grant guided community participants in using TPP to evaluate ecosystem services and develop action plans to direct conservation and management of resources. Responses were positive, ranging from very good to excellent. Many reported learning about environmental land use planning and management, and building connections to planning and management resources. Knowledge levels increased in assessing ecosystem health for management options and applying decision support tools to make decisions that ultimately can improve ecosystem health. All participants reported a better understanding of environmental land use planning and management issues facing their community. These important efforts contribute to the improved health of watersheds and help communities achieve ecosystem sustainability in Indiana and across the Great Lake States.

Collaborators

Agriculture

CROPS

Advancing soybean production through soil fertility and plant nutrition research

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Building organic farming in Indiana

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Source:

- https://www.purdue.edu/dffs/organicag/

DriftWatch™: Purdue Extension responds to save lives, horses, crops and bees

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Source:

- https://driftwatch.org/

Indiana Small Farm Conference: Building capacity, networking for small-scale farmers

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Source:

- https://www.purdue.edu/dffs/smallfarms/small-farm-conference-2020/

Industrial hemp production, processing and marketing

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Source:

- https://purduehemp.org/

Produce safety training helps growers comply with regulations

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Source:

- https://ag.purdue.edu/extension/safeproduce/Pages/default.aspx

Professionals and hobbyists prepared for safe and legal use of UAV's

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Source:

- https://extension.purdue.edu/uav/

Regulation of photosynthetic processes research

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Source:

- https://ag.purdue.edu/btny/mcadam/

Research, identification and classification of foodborne pathogens

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Source:

- http://www.cyto.purdue.edu/robinsonlab?_ga=2.263103244.1448270229.1586177915-302381371.1559094136

Research on global change and the challenges of sustainably feeding a growing planet

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Research on harnessing chemical ecology to address agricultural pest and pollinator priorities

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Source:

- https://www.entm.purdue.edu/ecolab/

Research on the regulation of phenylpropanoid metabolism in plants

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LIVESTOCK

Addressing animal welfare

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Analyzing welfare attributes for cattle: Supply and demand for livestock production process

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Antimicrobial resistance research

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Horticulture and Natural Resources

A multidisciplinary approach to increase the sustainability of turf areas

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Source:

- https://turf.purdue.edu/

Invasive plant control for woodland owners

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- Orange County Invasives Partnership
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Natural resources conservation through collaborative community leadership

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Source:

- http://tippingpointplanner.org/resources/regional-planning, www.purdue.edu/fnr/extension/scep/programs/conservation-through-community-leadership

Rainscaping to prevent polluted runoff

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Source:

- https://extension.purdue.edu/rainscaping/

Research of beneficial reuse of residuals and reclaimed water: Impact on soil ecosystem and human health

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- Lazcano-Kim, R., Choi, Y., Mashtare, M. Lee, L.S. 2019 Characterizing and Comparing Per- and Polyfluoroalkyl Substances in Commercially Available Biosolid and Nonbiosolid-based Organic Products. Environ. Sci. Technol. https://doi.org/10.1021/acs.est.9b07281

Research on best practices for water quality protection at the watershed scale

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Research on spatial linkages of soil and water resources for sustainable agronomic production in Indiana

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Food, Nutrition, Families and Health

Increased knowledge of safe home food preservation practices in the North Central Region

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Source:

- https://www.ag.ndsu.edu/ncrfoodsafety, puext.in/food-preservation

Interactions of diet, flavor, and saliva for eating healthy foods research

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Mental health first aid

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Source:

- https://extension.purdue.edu/mhfa/

Co-parenting for successful kids

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Source:

- https://www.purdue.edu/hhs/extension/programs/detail.aspx?programId=67&category=family&programContactTitle=educator&_ga=2.223195675.1232889594.1592832564-1363517616.1591617854

Research on school readiness disparities and the role of region, family, community and preschool experiences

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Source:

- https://www.purdue.edu/hhs/hdfs/directory/faculty/schmitt_sara.html

Youth Development

4-H adult volunteer positive impacts on Indiana youth and communities

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- North Central Region 4-H Volunteer Specialists

Sources:

- https://extension.purdue.edu/4h/Pages/volunteer.aspx
- https://extension.purdue.edu/4h/Documents/North_Central_Volunteer_Impact_Summary.pdf
- https://extension.purdue.edu/4h/Documents/IN4HVolunteer_Impact_Summary.pdf

INWork: INnovate, INvest, INspire: Skills for tomorrow's workforce

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Source:

- https://extension.purdue.edu/article/25371

Youth experiences at the Heifer Ranch increase understanding of global hunger and poverty

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Source:

- https://sp2013.extension.ag.purdue.edu/4h/Pages/GlobalGateway.aspx

Community and Business Development

Enhancing the value of public spaces: Creating healthy communities

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Source:

- https://cdext.purdue.edu/signature-programs/quality-places/evps-health/

Beginner's Guide to Grant Writing benefits Indiana communities

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Source:

- https://www.cdext.purdue.edu/signature-programs/community-organizational-planning/beginners-guide-to-grant-writing/

Sustainable communities: Environmental watershed planning with the Tipping Point Planner

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- http://tippingpointplanner.org
- https://cdext.purdue.edu/guidebook

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