2019 Annual Report of Accomplishments and Results

Indiana
Purdue University

I. Report Overview

The NIFA reviewer will refer to the executive summary submitted in your Plan of Work. Use this space to provide updates to your state or institutions as needed.

1. Executive Summary (Optional)

No updates

II. Merit and Scientific Peer Review Processes

The NIFA reviewer will refer to your Plan of Work. Use this space to provide updates as needed or activities that you would like to bring to NIFA's attention.

Process	Updates
1. The Merit Review Process	No updates
2. The Scientific Peer Review Process	No updates

III. Stakeholder Input

The NIFA reviewer will refer to your Plan of Work. Use this space to provide updates as needed or activities that you would like to bring to NIFA's attention.

Stakeholder Input Aspects	Updates
1. Actions taken to seek stakeholder input that encouraged their participation with a brief explanation	No updates
2. Methods to identify individuals and groups and brief explanation.	No updates
3. Methods for collecting stakeholder input and brief explanation.	No updates
4. A Statement of how the input will be considered and brief explanation of what you learned from your stakeholders.	No updates

IV. Planned Program Table of Contents

V. Planned Program Activities and Accomplishments

Please provide information for activities that represent the best work of your institution(s). See Section V of the Guidance for information on what to include in the qualitative outcomes or impact statements. Add additional rows to convey additional accomplishments. You may expand each row as needed.

No.	Title or Activity Description	Outcome/Impact Statement	Planned Program Name/No.
1.	Advancing Soybean Production through Soil Fertility and Plant Nutrition	**Issue**: Growers are deeply concerned that annual gain in soybean yield over the past few decades has been minimal, especially compared to corn. Soybean yield over the past 90 years has increased annually 0.34 bu/ac in the U.S. and 0.40 bu/ac across the Midwest. Yield gains have been attributed to advances in genetics, pest control and production practices. Recent studies have documented faster yield gains since the 1970s than the previous 50 years. Much of the fertility recommendations for soybean and nutrient allocation were based on research from the 1970s. A greater rate of yield gain is desired by growers to increase profits. Maximizing yield potential of soybean demands an updated investigation in nutrient uptake and allocation. Fertilizer inputs are among the costliest inputs in soybean production. Improving efficiency of soybean use of phosphorus (P) and potassium (K) will improve profitability while reducing environmental impact (e.g., P in surface waters). **Target Audience:** Farmers, soil scientists **What has been done:** The overall research goal is to advance soybean yields by establishing solid foundations in soil fertility and fine-tuning plant nutrition. Specific objectives include: (1) Solid Foundations in Soil Fertility - Identify changes in critical soil fertility levels for modern soybean cultivars and determine optimal fertilization approaches in crop rotations, and (2) Fine-Tuning Plant Nutrition - Determine appropriate methods to improve plant nutrition from cropping systems (previous crop, management intensity, cover crops), application methods (soil, seed, foliar, irrigation), timings (previous season, pre-planting, in-season), and nutrient sources/additives (commercial fertilizer, manures, cover crops, product formulations). **Results**: Objective #1. Small plot yields were collected for corn and soybean in low potassium (K) testing fields at Pinney, Throckmorton, and Southeast Purdue Ag Centers with historical K application range. Soybean yields plateaued at the moderate soil K, which was the result of the original application of 120 lb K_2O/ac at Pinney. The yield increase was ~11 bu/ac in 2017 and 2018 at Pinney. Soybean yields increased linearly in 2019 with the historical increase of K	1.1 Global food security and hunger

		applied; however, the yield levels were very low (22 to 30 bu/ac) due to extremely wet early season and dry late season. Soybean yields in 2017, 2018, and 2019 did not differ at Throckmorton regardless of the historical K application. The yield levels were mid-40s in 2017 and 2018 and upper 40s in 2019. Higher yield levels may be needed to determine soil K effects on soybean. Corn yields were variable at Pinney and highly influenced by the soil K levels at Throckmorton. Soybean yields averaged 16 bu/ac in 2018 at Southeast with little variation from historical application of K. Fertilizer potassium rates of 0, 45, 90, 135, and 180 lb K2O/ac were applied for the 2019 season of soybean. Yields of two soybean varieties in 2019 were comparable across the K rates with 20 bu/ac with no application and increased to the plateau of 45 bu/ac with the application of 135 lb K2O/ac. Higher K supply improved soybean defense against downy mildew and hastened maturation by nearly 10 days. Leaf K concentration was nearly a linear increase with each application rate (0.7 to 2.0% K sampled at R3). Establishment of the fertilizer K response is planned for the 2020 season at the other locations. Sulfur: Since 2015, soybean yield has been documented in response to sulfur applications near LaCrosse (northwest Indiana). The greatest and most consistent yield response has been to ammonium sulfate (AMS) broadcast-applied at 20 lb S/ac prior to soybean emergence: 12 bu/ac in 2016, 13 bu/ac in 2017, and 10 bu/ac in 2018. The research team also documented a 6 bu response to the same treatment near Vincennes (southwest Indiana) in 2016. Multiple sources of S fertilizers were evaluated in 2018 and 2019 at this S-responsive site (LaCrosse IN) with promising results from pelletized gypsum and co-granulated AMS and elemental S. The same S-responsive site was used to determine the optimal rate of S from AMS and mixture of AMS and elemental S. Over 2016 and 2017, 10 lb of S as sulfate/ac maximized soybean yield (mid-60s). Thus, the total S rate needed to optimize soybean yield was 10 lb S/ac for AMS, but twice as much for the blend of AMS and elemental S (20 lb S/ac). Foliar applications (5 lb S/ac with spraygrade AMS) were promising in 2016, but mixed yield results in 2017 (4 to 7 bu/ac improvements). Crop injury has been noted in later season applications where temperatures are higher and leaf development is finishing. If leaf S indicate sulfur is needed (near critical levels of 0.25% S or N:S of 18:1), foliar application of 4 lb S/ac will optimize the yield with early reproductive stages. However, the positive yield response to the foliar S application was still 5 bu/ac less than the standard pre-emergence application. Over 100 field-scale demonstrations and replicated trials were conducted across Indiana in 2018 to determine the distribution of soybean responsiveness to sulfur. The standard sulfur treatment was 15 to 25 lb of S/ac via AMS as close to planting as possible. Plant tissue samples (R2 to R3) and aerial imagery were	

		taken on every field. Nearly a third of the plant tissue samples indicate a potential for sulfur response based on the nitrogen to sulfur ratio. The current approach to determine soybean responsiveness to sulfur is to apply 20 lb S/ac via AMS. This treatment was imbedded in twelve new trials in 2018 located across Indiana. The most interesting findings in 2018 was the influence of planting date on sulfur responsiveness or, in other words, soil temperature and moisture effects on mineralization of organic matter and nodulation/N fixation. Soybean planted early were more responsive (7 to 15 bu/ac) to various S applications on prairie soil (4% organic matter) compared to the same variety and treatments applied during the first week of June. The late planting of soybean was not impacted from any S application. Future research is directed to determine the distribution of S responsiveness fields and the management scenarios that explain the responses (positive or none). Objective #2. Preliminary studies evaluating the starter placement of UAN (28%), 10-34-0, thiosul, and K-Row 23 was initiated in 2016. The treatments ranged from rates, placement (single or dual), distance (2, 3, and 4 inches from the row), and row configuration (15-in vs. 30-in rows). Late planting conditions in wide rows seemed to have a marginal benefit from starter (UAN or 10-34-0 in 2016; KTS or ATS in 2018) and in-furrow (8 lb P_2O_5/ac via 10-34-0) in 2016 and 2018. Sulfur starter fertilizer trials were initiated in 2019 near Wanatah (Pinney PAC) and West Lafayette (ACRE). Treatments were designed in a 2 x 3 x 4 factorial: two placement methods (single, dual offset of 2-in dribble), three S fertilizers (ATS, KTS, KFuse), and four S rates of 5, 10, 15, and 20 lb S/ac. Minimal yield responses were noted at Wanatah with the placement method, source, and rate. Near West Lafayette, the dual placement of ATS and KTS at 20 lb S/ac individually impeded soybean height three to four inches compared to untreated soybeans. Only the high rate of ATS in a single placement appeared to impact soybean growth (~2 inches shorter than untreated control). All three of these treatments yielded less than untreated control: ATS-Dual at 20 lb S was 9 bu less, KTS-Dual at 20 lb S was 13.5 bu less, and ATS-Single at 20 lb S was 4.5 bu less at West Lafayette. The single and the dual placement of ATS at 10 lb S/ac improved yields 3 and 2.5 bu/ac, respectively, with no effects on plant heights (positive or negative). 2019 was one of the latest planted seasons on record for Indiana, and thus, findings are preliminary and subject to evaluation under normal or even early planting conditions. In-furrow evaluation of orthophosphate was embedded in several trials in 2018 and 2019 at Wanatah and West Lafayette. Orthophosphate applied at 8 lb P_2O_5 /ac increased soybean yield 4 bu/ac pooled across two locations in 2018, but did not affect yield in 2019. Undercover® research boom was designed and fabricated in 2016. Three trials	

		were initiated in 2017 to compare delivery method (Undercover vs. Over-The-Top) at R3 (first pod) and R5 (first seed) growth stages. Sulfur (West Lafayette only) and Manganese (West Lafayette and Wanatah) were the two nutrients of interests, which were applied alone and in single combinations with multi-nutrient foliar fertilizer, fungicide, and insecticide then all together. The source was the main driver with ~3 bu responses to sulfur and 8 to 14 bu response to 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. The interaction of Source x Method was minimal. These three trials were repeated in 2019 and will be evaluated once data has been fully collected.	
2.	Applied Animal Behavior and Welfare	**Issue.** Issues related to animal welfare are increasingly under scrutiny from the public. To understand what is best for the animal, behavior is often used as a tool and indicator. The team is conducting research to develop novel behavioral and physiological indicators of animal welfare. Heat stress and disease are being addressed in turkeys. Other projects are evaluating how broiler chicken behavior changes in response to heat stress, and how behavior of laying hens changes in response to parasite (poultry bug) infestations. This research will identify changes in hen behavior that may be used as early indications of changes in hen health and welfare. Research to characterize feather picking behavior of domestic ducks will be conducted to develop methods to mitigate feather picking and improve duck welfare. A significant amount of work is being done to develop welfare indicators in swine. Thermal stress can result in losses in productivity, increase incidence of illness and morbidity and negatively impact animal welfare. The team received funding from USDA in 2018 to re-define the range of thermal comfort for sows of various parities and stages of gestation, evaluate the 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 genetic angle. Breeding programs have improved genetic potential of swine, resulting in greater performance at 55-70% increase cost in heat production for lactating sows. This will reduce their ability to cope with high temperatures leading to economic losses, especially as number and severity of heat waves increase globally. Overall goal of this project is to identify novel traits and validate genomic selection methods to improve heat tolerance while improving lactating sow performance. Occurrence of pleasurable behaviors in swine will be evaluated to determine if certain enrichments may increase those behaviors. Multiple data sources will be integrated to maximize efficiency of genomic selection for docility in Angus cattle. Temperament traits have a profound effect on the long-term sustainability of the beef cattle industry, as it impacts	1.2 Global food security and hunger

		animal productivity and welfare, longevity, and management practices. Furthermore, aggressive animals are a safety risk to those involved in the farming operations. **Target Audience:** Public, farmers, and commodity groups. **What has been done:** (1) To develop novel behavioral and physiological indicators of animal welfare. (2) To strengthen the scientific basis of animal welfare assessment and auditing programs. **Results:** Heat stress in pigs – 1. Temperature preference of sows was found to fall within the Ag Guide's recommended range but was at the low end of the range. However, stage of gestation did affect preference, with late gestation sows choosing cooler temperatures. Physiological data as well as the decision support tool projects are still ongoing. 2. Genomics of heat tolerance: heat tolerance based on reproductive traits is a heritable trait and can be used in selection breeding schemes. Various genomic regions and candidate genes associated with important biological functions have been identified in various pig chromosomes. Poultry – Research has been conducted to examine welfare issues and behavioral indicators of welfare in ducks, broiler chickens, and laying hens. In a recently completed trial with commercial ducks, it was demonstrated that ducks primarily performed feather pecking among conspecifics, rather than directing pecking at themselves, and that this pecking behavior peaked at 27 to 29 days of age. Most of the pecking behavior was directed at the tail, wings and back. Research is ongoing to examine strategies to mitigate injurious pecking of ducks. Results from a trial investigating broiler chicken behavioral changes in response to heat stress indicated that heat stress significantly affected broiler chicken behavior, with birds spending less time preening during heat stress. Core body temperature differed depending on the behavior birds were performing and was higher when birds were panting compared to when they were not panting. Research with laying hens is ongoing to examine how parasites, poultry bugs, influence laying hen behavior. Preliminary results indicate that mortality and productivity did not differ among hens in barns with poultry bugs and hens in barns with no poultry bugs. However, feather damage and footpad condition were worse for hens in barns with no poultry bugs, whereas keel bone deformities and fractures were worse for hens in infested barns. Cattle – (1) Docility in American Angus is a heritable trait (0.44) and can be improved through genetic selection. (2) A systematic review of 62 studies was performed to better understand the underlying genomic mechanisms for various behavioral indicator traits in cattle, pigs, and	

		sheep. A total of 2,521 genomic regions and 1,014 candidate genes were retrieved for the three species. Significant biological pathways related to suckling behavior, hippo signaling pathway, insulin secretion, and lipid processes were found. Additionally, suggestive biological pathways related to GnRH and estrogen signaling, steroid, and olfactory pathways, and *in utero* embryonic development were identified.	
3.	Harnessing Chemical Ecology to Address Agricultural Pest and Pollinator Priorities	**Issue:** Agricultural crops are valuable to the culture, economy and future of the Northeast. For example, the total value of principal crops in the Northeast was > $5.32 billion and Northeast vegetable growers harvested over 133,000 acres with a value more than $700 million. New York alone ranked 5th in the nation for vegetable production and garnered $323 million from fruit, berry and grape production. This region has numerous large cities that import food; thus, a robust regional agricultural productivity is essential for food security for these population centers. While the value of agriculture to the Northeast is indisputable, these agricultural systems mostly remain reliant on pesticides to ensure profit. On behalf of stakeholders, the Northeast IPM Center states that they "are enthusiastic about alternative, non-pesticidal strategies that unite several disciplines and lead to sustainable solutions." Northeast regional priorities for fruit, vegetable and specialty crops are replete with calls for research and sustainable practices to reduce the impacts of insect pests and to protect valuable pollinators. Organic agriculture continues to grow in both demand and production and is particularly reliant on developing holistic, ecology-based systems. **Target Audience:** Farmers (traditional, organic, specialty crops), scientists, public **What has been done:** (1) Develop chemical ecology tools and information to support sustainable agriculture by reducing damage by pests in crops such as potatoes, brassicas, cucurbits, apples, blueberries, and sweet corn, while maintaining pollinator health in agricultural systems. (2) Define variability of chemically mediated interactions between pests, crops, and beneficial organisms in terms of plant chemistry, species interactions and landscape factors in the Northeast. (3) Characterize the non-target effects of pesticides on pollinators and natural enemies of pests. (4) Assess the impact of domestication on plant and animal chemical ecology in agricultural fields and identify unifying patterns of human and natural selection on chemical interactions of crop plants. (5) Extension to facilitate adoption and awareness of science-based chemical ecology tools to support sustainable production. **Results:** During the past year, work has taken place to address goals 1 (chem ecology tools), 3 (non-target effects of pesticides), and 5 (extension). One of these projects involves studying the effects of volatile chemicals, emitted from cucurbit flowers or aggregation pheromones,	1.3 Global food security and hunger

		on the attraction of striped cucumber beetles. This project is designed to provide organic control options for this species, which is one of the biggest insect pests in organic systems. During the summer of 2018, the effects of floral volatiles and live striped cucumber beetles (SCB) for mass trap-and-kill of SCB 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 that were drilled to create holes for beetles to enter and contained soapy water to drown the captured beetles. Each jug contained either: 1) floral volatiles, 2) ten live SCB, 3) floral volatiles + ten live SCB and 4) control (nothing). Lures were purchased from TRÉCÉ, Inc. and contained three floral volatiles known to be attractive to SCB: 1,2,4-trimethoxybenzene, indole, and trans-cinnamaldehyde. For treatments containing live beetles as bait, ten live SCB were placed in ventilated containers. These beetles were collected from the wild and were maintained in the laboratory until needed. After use, the wild-caught SCB were returned to the laboratory. Traps were placed in late May, near SCB emergence, and were removed in early September when SCB activity began to decline. Each week, SCB were scouted on 15 random plants within each plot to estimate the SCB population. Trap contents were collected weekly and counted. Lures were replaced every other week and live beetles were replaced weekly. The old bait containers were returned to the laboratory to count the number of surviving beetles. In late May and early June, the control and beetle traps were most attractive to beetles and those containing floral lures, regardless of the presence or absence of beetles, was repellent. Few beetles were caught throughout the summer and there were no differences in preference between treatments. However, that changed in late July when traps containing floral lures or beetles and floral lures became more attractive than traps containing beetles or nothing. These results reflect similar results from last year, where there is a shift in preference based on the beetle generation. During both years, the early season beetles that had overwintered from the previous year found the control traps that did not contain floral volatiles were most attractive to the adult beetles. Toward the end of the season, the second generation of beetles preferred floral and or floral/beetles to those without floral volatiles. 3,600+ beetles were trapped this year and 2,700+ the last, demonstrating that these traps could be an effective management option for organic growers. Because the majority of beetles were captured in the early and late season and beetle preference was different for each, it is recommended that the traps are used at the beginning and end of the growing season and that growers should tailor the lures based on the time of the season for maximum effect. Since other projects in the lab are	

		focused on pollinator health, the impacts of pesticides on pollinators, including monarch butterflies and bees (managed honeybees and wild species), was assessed. The primary work for this project, now in year 3, compared an integrated pest management (IPM) vs. conventional corn/melon system. Within this experiment, data was collected on pest population dynamics, crop yield, bee health and abundance, and pesticide residues in various matrices (leaves, soil, pollen, hive products). The data from summer 2019 are thus far consistent with 2018; IPM plots had higher pest densities (but largely remained below economic thresholds), but equivalent or higher yields and better performance of pollinators. Pesticide residues are currently being quantified in the lab.	
4.	Regulation of Photosynthetic Processes	**Issue:** Photosynthesis is the process by which sunlight and carbon dioxide is converted into energy used by almost all life on Earth. Plant biomass, including foods, fuels and wood products, is primarily generated by photosynthesis. This project will address a key objective of a large multistate project aiming to understand and improve the regulation of photosynthetic productivity. A critical component of this project is focused on understanding the developmental and environmental limitations of photosynthetic productivity. 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. This specific project will focus on understanding the stomatal regulation of photosynthesis. Experiments will be conducted using methods that measure stomatal movements and photosynthesis to better understand how stomata regulate photosynthesis. The main goal of these experiments is to gain new knowledge on how stomata regulate photosynthesis. This improved understanding will provide key genetic and physiological targets for plant breeders to improve photosynthesis through altering stomatal behavior, in addition it will allow for the ability to predict the plant productivity responses to environmental conditions. **Target Audience:** Plant breeders, scientists **What has been done:** Develop strategies to overcome limitations to photosynthetic productivity caused by developmental and environmental factors. **Results:** Stomatal aperture places one of the greatest limitations on carbon exchange and photosynthesis. To better understand the ancestral mechanisms of stomatal regulation in angiosperms, the nature of stomatal responses in ferns and the role of leaf anatomy and hydraulics in regulating gas exchange in these early vascular plants was investigated. It was determined that ancestral stomatal regulation in vascular plants is a very simple process	1.4 Global food security and hunger

		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.	
5.	Supply and Demand for Livestock Production Process Attributes: Analyzing Welfare Attributes for Cattle	**Issue**: Today's meat and dairy product shoppers are increasingly sensitive to processes employed in production of livestock products. Evidenced by labels seen displayed on products on supermarkets shelves, and in restaurants and advertisements, marketers are increasingly appealing to consumers by selling 'how' a product was produced. Livestock products evoke consumer sentiment regarding treatment and welfare of animals in production processes for meat and milk products. Beyond animal welfare, other attributes of increasing interest are treatment of employees, impacts on environment, and other externalities that production processes may produce. Consumers are linking concern for companion animals with preferences for rearing practices employed for food animals. This is exemplified by popularization of animal protection organizations, such as People for the Ethical Treatment of Animals (PETA) and the Humane Society of the U.S. (HSUS) and changing political landscape of food and agricultural markets. As increasing numbers of savvy consumers demand beef and dairy products produced from cattle reared under alternative management systems, cattle producers are faced with decisions surrounding how to rear cattle and produce meat and milk products. In today's volatile markets, agricultural producers are required to adjust practices to satisfy changing consumer preferences. Agricultural producers are facing changes due to pressures from large retailer supermarkets and restaurants. Changes in production practices on farms can be attributed to market pressures rather than changes in legislation as increasing abilities of consumer groups to influence issues relating to animal handling. Pressure for change via traditional regulatory channels also exists. Cattle producers could potentially face changes in production, which are deemed acceptable in their operations by regulatory and market forces. Improved understanding of consumers' preferences and how those preferences correspond to observable demographics, household characteristics, or views on key social issues can aid livestock industries, and the entire meat and milk product supply chain, in effective communication with consumers and stakeholder groups. Research connecting consumer demand and producer willingness to supply various products can aid on-farm decision-making of production systems to employ and whether investments in long-term assets (buildings and livestock equipment) are likely to be profitable, or reconsidered in light of fast-changing market conditions.	1.5 Global food security and hunger

		Target Audience: Livestock producers, scientists, public, regulators, meat and milk shoppers/consumers, veterinarians, livestock industry stakeholders. **What has been done:** Previously completed and published research explored consumer preferences for pig and dairy cattle handling and treatment practices. Building upon past findings, the primary goal of this project is to improve the understanding of the impacts of potential animal welfare enhancing changes in dairy and beef cattle rearing systems on the supply and demand of beef and dairy products. Practices such as tail docking and dehorning are currently receiving a great deal of attention for dairy cattle, while non-conventional housing systems are a focus in today's modern beef production facilities. It is hypothesized that consumers' perceptions of the welfare of beef cattle associated with various practices are significantly different than those associated with dairy cattle. Objectives of continued work in this area include comparisons of additional beef and dairy products to previously completed work to continue to explore reasons for potential variation in consumer and producer preferences for animal handling and treatment. The specific objectives of this research are to: (1) Estimate consumer demand for beef and dairy products produced under various production systems (and thus, with differing impacts on the perceived welfare of beef and dairy cattle); (2) Understand the potential supply-side impacts of adoption of cattle welfare attributes in existing production systems; and (3) Evaluate potential costs and returns of investments in various potential cattle welfare production attributes in a range of production systems currently used in livestock production, as well as systems currently being proposed. **Results:** Using a series of representative samples of respondents from the U.S. it was found that demand for production process attributes varied across animal species and the specific food product produced. Positive and statistically significant mean differences in willingness to pay estimates were identified for dehorning with pain relief and polled dairy cattle in consumers making purchasing selections among cheddar cheeses. Consumer demand for pasture access of dairy cattle was also found, and as with most other attributes identified, that demand varied across consumers with differing demographics (i.e., gender, household income, and region of residence).	
6.	Industrial Help Production, Processing and Marketing in the U.S.	**Issue:** Research and production of industrial hemp (IH) was allowed under the 2014 U.S. Farm Bill sec. 7606 Legitimacy of industrial hemp research and under Indiana Public Law Indiana Code at 15-15-13 (Senate Bill 357). The state bill authorizes industrial hemp production while federal law authorizes work but limits the efforts to "purposes of research conducted under an agricultural pilot program or other agricultural or academic research." Purdue University has	1.6 Global food security and hunger

		been actively involved in the agricultural pilot program since 2014. Some examples of IH efforts taking place at Purdue include: (1) Have developed a team of faculty and extension educators from across the state and college. (2) Applied for and received a federal importation permit to allow us to bring hemp seed across the border from Canada and Europe. (3) At the end of August 2015, we held the first field day on hemp in Indiana. Field days were planned for experienced farmers, new farmers-organic farmers, law enforcement, extension educators, and the general public. We have held two subsequent field days related to hemp production. We have graduated an MS and Ph. D. student who worked on hemp and we are in the process of preparing publications from the work. With the changes under Hemp Farming Act of 2018, we have: (1) Hired an Extension specialist to help growers in the state set up their hemp production programs. (2) Worked with some 30 companies as they start the process of establishing hemp as a commodity in the state. (3) Worked with some 100 farmers as they develop their licensing packages and get ready for large scale productions. Despite the economic importance of IH in Indiana, best practices to maximize yield and profits remain unclear. As such, this project aims to provide recommendations on best agronomic processes for IH in Indiana and across the Midwest. **Target Audience:** Farmers, public, scientists **What has been done:** In the first year of research on agronomic practices to determine effects on grain, fiber, or dual-purpose productivity as functions of establishment practices, soils, and planting dates in field studies. **Results:** Field trails have addressed nutrient levels, harvest issues, disease and insect pressure and fiber production. Work within the group (led by Dr. Kevin Gibson) showed few peer-reviewed studies on hemp exist on any subject and weed control and weed management. Specifically, only three studies designed to address weed management issues exist in the literature dating back to 1900. Thus, there is an extensive gap in the hemp literature related to the impact of weeds on hemp production. Research was conducted to characterize the growth and phenology of hemp cultivars and determine the effect of delayed planting on the phenology and growth of seed and fiber hemp varieties in the Midwest. 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. **Other Information:** https://purduehemp.org/	

7.	Driftwatch: Purdue Extension Responds to Save Lives, Horses, Crops and Bees	**Issue:** Starting mid-August 2019, horses and a group of mosquitoes from Elkhart County, Indiana tested positive for Eastern Equine Encephalitis (EEE) virus. In late September 2019, horses began dying of EEE in northern Indiana and southwestern Michigan. LaGrange County has nearly 15,000, and Elkhart County has just over 10,000 horses. When horse cases of EEE appear, human cases follow. EEE has a mortality of nearly 90% in horses and nearly 33% in humans who get sick from a bite from an infected mosquito. Deaths of four people in Michigan, and three people hospitalized in Elkhart County occurred when the Indiana State Board of Health approached county commissioners about spraying to control mosquitoes. Mosquitoes become infected when they feed on infected wild birds. Infected mosquitoes can spread EEE to horses and people. Infection can occur anytime during mosquito season (May to October), but is most common in late summer months. Aerial spraying of insecticide to control for mosquitoes can negatively affect organic farming acreage and beehives, risking loss of organic certification requiring a three-year transition to recertify, and loss of hives and bees. **Target Audience:** Organic growers, beekeepers, public **What Has Been Done:** An alert was issued by the Indiana State Department of Health (ISDH), "Indiana Health Alert Network Notification- Sept. 12, 2019, Eastern Equine Encephalitis Virus Activity Detected in Northern Indiana." The Indiana State Department of Health, in conjunction with local health departments and the Centers for Disease Control made plans for aerial spraying efforts to reduce mosquito populations in LaGrange, Elkhart and Noble counties. CDC provided emergency funding to ISDH. On September 26, 2019, ISDH offered state support for mosquito spraying. Participants in a planning call for spray events, included Elkhart County Government, Purdue Extension, ISDH, Indiana State Board of Animal Health, and Indiana State Department of Natural Resources. The plan goal was to interrupt EEE virus transmission by killing vector mosquitoes at breeding sites. Aerial applications were planned for Elkhart, LaGrange and Noble counties, sites designated wetlands and within a 5-mile radius of EEE-positive horses and mosquitoes. Purdue Extension responded. Elkhart County Commissioners approached Purdue Extension-Elkhart County about reaching out to beekeepers and organic farmers about scheduled spraying. Purdue Extension specialists quickly provided information on insecticide to be used and how to protect bees, and educators were sharing and distributing these messages, along with how to opt-out of spraying for organic farmers. Purdue Extension–LaGrange County was notified by Indiana and local health departments about the spray zones and dates. Over 315	1.7 Global food security and hunger

		Amish organic farms in and near the spray zones for LaGrange and Noble counties were notified. Purdue Extension assisted in registering organic acreage and beehives on Driftwatch. DriftWatch and BeeCheck are free, voluntary online specialty crop and beehive registries and mapping programs created by Purdue's College of Agriculture, operated by non-profit, FieldWatch. This tool improves communication and collaboration between producers of specialty crops, beekeepers, and pesticide applicators via technology where producers and beekeepers map their sites. Commercial pesticide aerial applicators access Driftwatch to identify at-risk acres and beehives, then upload maps to their flight plans which automatically stop spraying as the airplane goes over registered fields and beehives. Using the USDA Integrity database for local organic growers, Extension Educators reached out to all organic growers with information to register their farms in Driftwatch. Community objections and concerns to spraying were anticipated, so communication reached all residents in affected counties. Educators distributed instructions on how to register, assisted individuals in registering organic fields and beehives, completed several television and local newspaper interviews, and responded to hundreds of phone calls from residents. Educators located every beehive in the spray zones and called owners, and notified organic farmers and beekeepers, agricultural groups, and the Michiana Beekeepers Association via emails and social media. In LaGrange County, where most organic farmers are Amish and do not use computers, communication was done in person. In Elkhart County, on October 2, 2019, aerial insecticide spraying for mosquitoes was conducted in two areas of the county, covering 32,000 acres. Spraying started at 7 p.m. Weather delayed spraying in the northwest spray zone for 2.5 hours. Blast emails were sent over the course of the spray days to lists of farmers, Master Gardeners, horticultural professionals, beekeepers, local leaders and people with horticulture interests. During the evening of the spraying, Purdue Extension sent messages to update them on the status of the spraying. In LaGrange and Noble Counties, on October 2 and 3, 2019, at dusk, the spraying occurred in an area covering over 11,000 acres. **Results:** These aerial spraying events effectively stopped the spread of EEE in Indiana. No discernible bee deaths were reported after the event (some bees reportedly died in unrelated incidents after the spraying event). One human and 14 horse fatalities occurred prior to the spraying event. No new cases occurred after the spraying. As a result of Purdue Extension efforts, Elkhart County registered 35 new beekeepers, enrolled 470 hives, and 6 new organic farms (about 1,400 acres), and LaGrange County added more organic farms to registration.	

		This will help with future communication for safety with insecticide applications for organic and beekeeper operations. Purdue Extension efforts to communicate, educate and register organic farms and beehives continues since the spraying occurred. These efforts associate safety for humans and horses from EEE, and organic farms and beehives from insecticide spraying in Indiana. **Other Information:** https://driftwatch.org/.	
8.	Indiana Small Farm Conference: Building Capacity and Networking for Small-Scale Farmers in Indiana	**Issue:** Small farms (by area or acres) are significant in Indiana. Over the last 30 years, according to the U.S. Census of Agriculture, the number of Indiana farms has decreased significantly from 70,506 in 1987 to 56,649 in 2017. During that time, the only farms to increase in number, other than farms of 2,000 acres or more, are farms with 49 acres or less, which increased from 20,544 in 1987 to 26,287 in 2017. Farms with fewer than 180 acres represent 71% of Indiana farms. During this time, many Indiana farms had to expand to remain profitable. This is not an option for many small-scale or beginning farmers, or people who would like to start farming. Unlike many Indiana commodities, farms that have increased in number in recent years have been vegetable, fruit, some livestock farms, and organic farms. According to the 2017 census, Indiana has 23,262 producers who identify as new or beginning. These numbers indicate a market for small-scale agriculture production in Indiana and farmers are filling this demand. The Indiana Small Farm Conference provides education and an opportunity for peer networking for these small-scale and beginning farms in a state that has traditionally lacked these resources. **Target Audience:** Small-scale farmers **What Has Been Done:** 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. Goals are to: 1) educate and increase awareness on a variety of topics in agriculture; 2) increase adoption of best practices; and 3) bring a variety of people together, create a space for networking, and increase collaboration. Purdue Extension hosted the sixth conference in March 2018, with 506 attendees, 50 exhibitors, and the seventh conference in 2019, with 431 attendees and 40 exhibitors. Conference agendas contain content for crop production, livestock operations, sustainable practices, and technologies, business operations and marketing. For 2018, presenters shared approaches for improving soil health, practicing food safety, marketing products, accessing farmland, livestock production, setting prices at the market, and more. Topics presented in 2019 focused on crop and livestock	1.8 Global food security and hunger

		production, business planning, sustainable agriculture, marketing, food safety, urban agriculture, and exploring options for diversifying farm operations. For the 2018 conference, a nine-month follow-up online survey was implemented. For the 2019 conference, an online post-survey was emailed to participants. For the 2018 follow-up, there were 43 respondents. For the 2019 post, there were 153 respondents. Demographic data were male 50.34%, Hispanic 2.78%, those who had not attended the Conference in the past 50.34%, those who currently farm 68.06%, and those affiliated with an organization, farm, operation or group that is minority- or women-led 38.57%. There were 34% in the 30-39 age group, 73.61% were White, and 42.67% with Bachelors' degrees. **Results:** Since attending in 2018, 86% reported they had shared information they learned about agricultural practices, business or operation details, the positive experience and helpful resources of the conference, and specific individuals or farms that shared their experiences with others, including farmers, co-workers/colleagues, and groups. Some 67% continue or develop relationships, connections or interaction with others they met at the conference, expressed as building partners/customers, identifying with whom they continue connections, connection to the structured networks, describing how they continue to connect and use of social media, that they met someone new, and that they have ongoing relations and still keep in touch. Many (77%) adopted recommended agricultural practices, including farming (33%), sustainable practices and technologies (31%), producing crops (24%), and raising livestock (9%). Most frequently reported adopted practice was cover cropping. For business or operations, adopted practices were marketing, farmers market sales, and ways to track income and expenses. Many (65%) adopted practices that were very/extremely helpful, resulting in increased efficiency (25%), conservation of resources (25%), increased yields (15%), increased economic return (13%), and reduced inputs (10%). Some 48% adopted recommended practices for business planning, finances, or marketing, including posting on social media more often. About a third had started a new business plan, revised an existing plan, or completed a new business plan. Two respondents had started a new business since the conference. 2019 Conference respondents learned about sustainable practices and technologies (63%), diversified farming (58%), business planning, finances or marketing (48%), crop production (44%), and livestock production (25%). Many (76%) learned about available assistance and/or technical support: Purdue Extension (75%), USDA/NRCS (51%), Farm Service Agency (26%), and ISDA (25%). Other assistance included various networks, coalitions and co-ops like Black	

		Farmers Co-op Indianapolis, Indiana Farmers Union, farmer networks and organizations, National Young Farmers Coalition, Hemp Co-ops. Others mentioned included SARE, Veteran Assistance, SWCD, Hoosier Mushroom Society, BOAH, Indiana Brown, Conservation Cropping Systems Initiative, Farm Bureau, food safety training programs, IU Sustainable Food Systems, and Purdue market reports and specialists. Most learned something about the role of diversified agriculture in a local food system, with almost 90% learning "some," "quite a bit," and "very much." Most respondents: agreed/strongly agreed the Conference provided a good networking opportunity (89%), connected with a more experienced farmer/producer (83%), and developed relationships, interactions or connections with other farmers, producers and people interested in diversified farming and local food systems (92%). A "Trade Show Passport" was used to encourage more interactions between attendees and exhibitors. There were 25 attendee and ten exhibitor Trade Show Passport participants, which accounted for 250 interactions that might not have occurred otherwise. Most (94%) 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, greenhouse, fungal/ecosystem integration, cover crops, seed saving, lean farming, and cucumber grafting. Many (61%) planned to adopt recommended business planning, finances, and marketing practices including: business planning, ideas for market, social media, market analysis, and marketing strategies. Some 47% started developing or have completed a business plan for their operation/organization, 42% intend to start a new or revise an existing business plan, and 17% plan to start a new business within the next year. Most (93%) reported the conference was inspiring. The Net Promoter Score® was 47 indicating a positive customer experience. The annual Indiana Small Farm Conference contributes to the knowledge, networking, and adoption of practices for small-scale farming operators and enthusiasts across the state. **Other Information:** https://www.purdue.edu/dffs/smallfarms/small-farm-conference-2020/.	
9.	Professionals and Hobbyists Prepared for Safe and Legal Use of Drones	**Issue:** Unmanned Aerial Vehicles (UAV) technology is becoming increasingly popular including hobbyists and commercial uses in agriculture, marketing, surveying, and real estate. Many UAV operators or potential operators do not have proper understanding of required certifications for use. Others have the equipment but are unsure of potential applications to their operation. Safe and legal use of UAV for any purpose is important. **Target Audience:** Public, Regulators	1.9 Global food security and hunger

		What Has Been Done: Purdue Extension developed a new program to help participants engage in safe and lawful operation of UAVs (AKA drones) for personal and professional applications. The UAV Training series was 16 hours and addressed device maintenance, meteorology, data management, and developing flight plans. The first half was on material for the FAA Part 107 Remote Pilot Knowledge Test. The second half included hands-on flight and applications. A total of 54 participants attended one of three series offered in 2019. Participants most often indicated their role as farmer or state regulator. Of the 32 responsible for management decisions for an agricultural operation, most (76%) managed more than 1,000 acres. **Results:** As a result of the training, respondents (100%) reported being more aware of the legalities and safety protocols of UAVs and were better able to understand applications associated with UAV technology. All but one (98%) reported being more aware of the troubleshooting techniques. Respondents (94%) felt prepared to take the FAA Remote Pilot Knowledge Test, required for legal operation, and 74% plan to pursue test completion and application filing to become a Drone Pilot. Some 21% reported they are considering taking the test at some future point. Most participants (93%) reported they intend to use UAV technology in their professional capacities, which included farming and regulatory inspections related to farming. Many of the 43 respondents (84%) who felt they may or will save money by investing in UAV technology, stated that using the technology will 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. Since the training, over 30 participants have contacted Purdue Extension with news that they passed the FAA Remote Pilot Knowledge Test. Some 46 participants reported the UAV training series to be a valuable investment for the fees they paid. The Net Promoter Score was +56.6 which indicates excellent client satisfaction. Participants stated the training was useful, including "Great program. Was one of the better extension education programs I have been to. Right up there with the Diagnostic Training Center Days." "Valuable program at an appropriate time!" Another participant expressed "Awesome program! Informative and enjoyed it!" By offering this training, Purdue Extension can reach new audiences, enhancing opportunities for those in agriculture, and expanding beyond to include emergency responders, architects, engineers, construction companies, forestry and wildlife experts, videographers, urban planners/county commissioners, insurance adjusters, and others, to contribute to safe and legal uses of UAVs. **Other Information:** https://extension.purdue.edu/uav/.	

10.	Youth Experiences at the Heifer Ranch Increase Understanding of Global Hunger and Poverty	**Issue:** The United Nations Food and Agriculture Organization estimates about 815 million people (10%) of the 7.6 billion in the world, were suffering from chronic undernourishment in 2016. In Indiana, 1 in 7 people struggles with hunger, including 1 in 6 children. The world produces enough food to feed everyone, however, many people in the world still do not have enough income to purchase (or land to grow) enough food or access nutritious food. **Target Audience:** Youth **What Has Been Done:** Eleven Indiana county teams, comprised of four youth and one adult each, traveled to Heifer International in Perryville, Arkansas to participate in the Global Gateway Experience. These 44 youth and 11 adults were immersed in team-building activities and experiences meant to provide a greater understanding of global hunger. Participants experienced the Global Village where they were able to see recreations of urban slums, bamboo huts, shanties, refugee camps, and more. Groups of youth and adults were assigned to each type of village and expected to prepare a meal with limited resources and to stay overnight. This allows for experiences with inadequate shelter, food, water or cooking fuel. Upon return to Indiana, each team presented an activity to provide others with a better understanding of global hunger issues. **Results:** After participating in the Global Gateway Experience, youth shared their new perspectives: 100% described the importance of livestock as a resource for ending hunger and poverty, 98% feel like they are able to help end world hunger and poverty, 93% are more curious about international affairs on TV, the web, and other media after participating in this experience, 91% strongly agreed that because of this experience, they are more accepting of different cultures of people, and 81% strongly agreed that they can describe the difference between malnutrition and starvation. Regarding service to the community, 95% will encourage others to volunteer in their community, 93% will participate in a community service project, 82% will help plan a community service project, and 75% will lead a community service project. Youth stated their favorite part: "I really enjoyed spending the night in the village because it helped me to see what extreme poverty is like." "Being able to camp in the villages really gave me a perspective and an unforgettable experience." "I liked to learn how people in different places and in poverty live, and I liked when we work together." Through Global Gateway Experience, Purdue Extension is contributing to positive youth development for community awareness, service, and leadership relating to poverty and hunger.	1.10 Global food security and hunger

11.	Building Organic Farming in Indiana	**Issue:** Indiana organic field crops have increased in operations 45% and acres 36% since 2016. There were 536 farms on 36,629 acres in 2019 (Mercaris, 2019 Organic & Non-GMO Acreage Report), yet Indiana is still lagging in organic field crop production compared to the North Central Region. Meanwhile, demand for organic grains continues to grow, and a shortfall of U.S. production has forced users of organic grains to satisfy demand with imports. Based on USDA data and estimates from Mercaris, about 26% of organic corn supplies and 75% of organic soybean supplies were imported during 2018-2019 crop marketing year. This mismatch in demand and domestic supply provides opportunity for Indiana grain farmers to diversify. Educational programs and resources are lacking for Indiana farmers looking to enter organic marketplace, along with absence of networking opportunities to connect with input suppliers, grain buyers, consultants, certifiers, experienced organic farmers, and other transitioning-to-organic farmers. Despite potential financial returns from organic grain price premiums, organic production presents unique risks, particularly with navigating the 36-month transition. Farmers indicate barriers and challenges faced in transitioning to organic production: weed management, certification process and expenses, sourcing organic inputs, managing soil fertility, and maintaining yields. Farmers cite one-on-one technical assistance and support from consultants as the most-needed resources. The U.S. Organic Grain Collaboration identified a shortage of technical service providers who understand organic production. To substantially grow organic acreage, optimize organic production systems, and maximize potential for success, an increase in number and geographic spread of service providers is necessary. **Target Audience:** Organic growers, growers in transition to organic, growers starting organic production, and crop/organic consultants. **What Has Been Done:** Making organic production information available to Indiana farmers, Purdue Extension partnered with Jasper County Soil and Water Conservation District (SWCD) and the IDEA Farm Network to host the Indiana Organic Grain Farmer Meeting. This 2-day annual education, networking and trade show has grown to meet demand for more organic grain production and marketing information. The first day was Transition to Organic Grain Production delivered for farmers exploring or just starting a transition of acreage to certified organic grain production, including topics of addressing the National Organic Program (NOP), organic certification, inspection, and recordkeeping, organic crop budgets and markets, and organic transition strategies and key tools. The second day, attendees selected from advanced production and marketing presentations: diversified crop rotations, value-added small grain	1.11 Global food security and hunger

		production and marketing, organic hay production and marketing, nitrogen management in organic cropping systems, weed management, grain market update and buyer panel discussion, organic crop insurance options. The trade show allowed networking among attendees and industry representatives from seed dealers, input suppliers, equipment reps, agronomists, and certification agencies. Over 90 participants attended day 1, and over 180 day 2, with over 200 attending. Most (78%) were from Indiana, but some traveled from Illinois, Kentucky, Michigan, Ohio, and Wisconsin. About 57% were farmers, and the rest agricultural professionals, extension, conservation and certification agency staff. Most (81%) were male, 98% non-Hispanic, and 96% white. About 58% were under age 50, and 43% under 40. To showcase existing organics practices, Purdue Extension hosted the Organic Agriculture Summer Series with three Indiana organic farming operations. The Series provided farmers and agricultural professionals tours of different systems of management on working Indiana organic grain operations. Each site opened had an update on organic grain price trends, considerations in transitioning to organic grain production, and an overview of the Purdue Extension organic program. Then host farms delivered presentations about their organic cropping operation, including transition strategies/considerations, crop rotation, fertility and weed management, marketing, and certification. Next, an Office of Indiana State Chemist representative presented Fertilizer Application Rules, emphasizing requirements with staging and application of manures, which are crucial in organic cropping systems. Ending each day, were field rotations, based on aspects of the host farm: weed management equipment and control strategies, inter-seeding cover crops, seed corn production, hemp grain production, markets, and regulations, manure management, and soil health and realities of organic no-till systems. The Summer Series had 75 attendees (68% male) with Noble Organic Grains, 51 attendees (80% male) with Klemp Family Farms, and 71 attendees (90% male) with Ramerview Holstein Farm, for a total of 197 attendees (79% male) for the series. To address the lack of service providers for organic production, Purdue Extension partnered with industries, non-profits, agencies, and agronomists, and started the Organic Agronomy Training Service (OATS), a collaboratively managed, science-based train-the-trainer program for agriculture professionals working with organic or transitioning producers in the U.S. Training included basic agronomic services, shifts in thinking for success in organic crop production, organic certification and inspection, advising producers on compliance with all regulations of the NOP, profitable and diverse crop rotations that meet rotational requirements, organic weed control strategies, integration of cover crops and reduced tillage,	

		organically-approved pest control strategies, basic organic fertility, and current research for organic production. Three OATS programs were delivered across the North Central Region: North Dakota, Indiana, and Wisconsin. Instructors included USDA researchers, Land Grant University faculty, professional agronomists, Extension educators, and farmers. Continuing Education Units (CEUs) were available for certified crop advisors. A total of 54 people attended OATS, and 43 provided demographic information: 76% male, 93% non-Hispanic, 95% white; 22% age 18-29, 32% age 30-39, 10% age 40-49; and 34% age 50 and older. Participants were: 23% agronomist/CCA, 28% ag business/ag retail, 19% farmer, 9% extension/NGO, 2% government, 19% other. Most (79%) had experience working with organic or transitioning clients. **Results:** For Meeting Day One - Transition to Organic Grain Production, 59% of attendees (n=53) completed the post-program evaluation. As a result of attending, respondents improved their understanding of: organic transition strategies and considerations (98%), certification to the NOP (89%), basics of organic grain production (88%), organic crop budgets and financials of transition (77%), and organic grain markets (77%). Most (96%) plan to apply ideas learned during the workshop to their farm operation or agricultural business/organization, including cover crops, crop rotations, financial planning, and transition cropping strategies. For those operating a farm, 97% plan to use what they learned to develop or make changes to their farm's organic transition plan or current organic production, including recordkeeping techniques, market opportunities, and cropping system strategies. Also, 92% plan to share information learned with other individuals, such as farmers, colleagues, and peers. For Meeting Day Two, 38% of attendees (n-68) completed evaluations. As a result of the meeting, respondents improved understanding of organic crop rotations (97%), weed management (91%), value-added and food-grade production (87%), and organic grain markets (81%). Nearly all respondents (99%) plan to apply ideas learned to their farm operation or agricultural business/organization, including crop rotations, weed management, and adding small grains to their cropping systems. Of those operating a farm, 94% plan to use information learned to develop or make changes to their farm's organic transition plan or current organic production. In addition, 96% plan to share information learned during the program with other individuals, such as farmers, colleagues, and peers. For the Summer Series, 22 (29%) responded from Noble Organic Grains farm indicating improved understanding of organic transition and cropping systems and organic seed corn production (91%), and inter-seeding cover crops and hemp agronomics and regulations (86%).	

		At the Klemp Family Farms, 18 (35%) respondents indicated improved understanding of mechanical weed control in organic row crops (88%), manure application regulations and manure management in organic row crops, and organic transition and cropping systems (83%). At Ramerview Holstein Farm, 26 (37%) respondents indicated improved understanding of soil health in organic row crops and roller crimping (96%), mechanical weed control and flaming in organic row crops (92%), organic transition and cropping systems (88%), and manure application regulations (84%). For the full series, 60 (83%) indicated they plan to apply ideas learned to their farm operation or agricultural business/organization, including: "Consider a …seed production contract." "Study more on [crop] rotation and weed suppression." "Every field is different. Get off the tractor and evaluate and adjust as needed. Must think way out ahead of your actions. Better understanding of rotary hoe and weed zapper." "Flame weeding; shorter season hybrids." "Not farming yet, but on my way and field days help. Crop rotations, weed control and soil health." Of those operating a farm, 37 (92%) plan to use information learned to develop or make changes to their farm's organic transition plan or current organic production including: "cover crops, crop rotation, testing manure to be applied," "weed control, N management," "info about crop rotation," and "flame weeding, shorter season hybrids." Also, 63 (94%) attendees plan to share information learned with other individuals, such as farmers, colleagues, and peers (N=63), including: "I'm a lender. We get phone calls. Want to be more knowledgeable." "Organic seed production option to area landowners with certified organic, irrigated land." 'Info on the licenses you need if getting… manure from a CAFO that is not yours." Matched pre- and post-assessments for OATS respondents (n=17) showed increased confidence of organic crop rotations (71% with positive change), organic weed control strategies (88%), nutrient management in organic systems, (71%), organically approved pest control strategies, (65%), and organic certification and inspection process (63%). Many (67%) improved in knowledge about where to find information for questions about organic production. Some 28% indicated a positive change in attitude toward organic production. All respondents indicated plans to use information in their farm operation or agricultural business/organization and provided these comments: "As a consultant I feel much improved on organic production concepts and methods so as to discuss with clients." "I'm at the low end of the learning curve – this has been incredibly beneficial." Indiana Organic Grain Farmer Meeting provided farmers and agricultural professionals with production, marketing, and certification information to improve management and increase	

		acreage of organic field crops in Indiana. Summer Series provided farmers and agricultural professionals with production and marketing information and networking opportunities to improve management and increase acreage of organic grains in Indiana. OATS increased confidence of agronomists and crop advisers in providing advice to client questions on organic grain production and transition. The meeting, summer series and OATS are providing information and opportunities for building the structures of and support for organic farming production in Indiana. **Other Information:** https://www.purdue.edu/dffs/organicag/	
12.	Antimicrobial Resistance	**Issue:** 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 needed on the farm to mitigate disease outbreaks. The project goal is the establishment of a multi-disciplinary network of scientists to perform comprehensive and integrated risk-based research and outreach to improve safety of food from farm to fork. The project aims to understand prevalence and frequencies of pathogens and antimicrobial resistance within the environment, food products and food production processing, distributions and consumer systems. The project is unique for its comparative and comprehensive focus encompassing multiple pathogens linked to antimicrobial resistance (AMR), multiple animal species susceptible to AMR microorganisms and its integrative approach. Purdue University is investigating alternatives to feed antibiotics, including potential for bacteriophage additives or treatments that include a cocktail of phage types to control pathogenic bacteria including *Salmonella* and *E. coli* O157:H7 in both live animals and food matrices. Ongoing research is directly tied to strong Extension programming to facilitate rapid transfer of the findings into educational programming and application. Purdue University has launched an online course, *Diversity in Veterinary Medicine*, for students and faculty at veterinary colleges across the U.S. and to veterinarians in private practice. While the topic is different, this online course could be used to create courses to educate and certify people who work in food production on the important topic of AMR, combining data from studies such as selective dry cow therapy currently in progress at the University of Illinois and antimicrobial alternatives research at Purdue. **Target Audience:** Veterinarians, livestock farmers, scientists, public	2.1 Food safety

		What has been done: (1) Determine the ecology and mechanisms involved in resistance and transmission of AMR. (2) Create and deliver programs on antibiotic stewardship in food production systems through education and outreach. **Results:** (1) Enhance surveillance and monitoring of antibiotic resistance and develop improved diagnostic tests. In collaboration with Purdue engineers, veterinarians and animal diagnostic lab, efforts are underway to develop a rapid diagnostic test to diagnose and recommend treatment for bovine respiratory disease (BRD). Developed assays for the four most common bovine respiratory disease (BRD) pathogens. Improve the agreement between BRD pathogen resistance genotypes and phenotypes by identifying additional resistance marker genes. *Impact*: Will provide veterinarians a rapid test to aid in the antibiotic prescription decision-making process and will increase antibiotic stewardship and hopefully decrease resistance 2) Determine the ecology and mechanisms involved in resistance and transmission of resistance. Project 1: Environmental fate of antibiotic resistance genes in the bovine and swine agroecosystems (*collaboration with Bo Norby). Sampled dairy and swine manure, stored manure, as well as corn field prior to, and immediately, 3 weeks and 6 weeks after manure application at the Purdue University farm. Established partnerships to sample farms in Finland, Michigan, and New York. Used epicPCR, a molecular technique to link a taxonomic marker (16S) and a resistance gene, to allow culture-independent identification of bacteria that encode resistance genes. *Impact:* Improve understanding of the impact of soil manuring and the environmental fate of antibiotic resistance genes Project 2: Effect of carbadox and Zn Cu additives on antibiotic resistance gene profiles. Used a highly parallel qPCR array (WaferGen) to determine the abundance of hundreds of antibiotic resistance genes (ARGs) in feces from pigs fed Zn and Cu, Carbadox or no additive. Each treatment resulted in unique ARG profiles and some enriched ARGs. *Impact:* Zn and Cu are already available and used as antibiotic alternatives but may co-select for all the resistance genes that prompted the Veterinary Feed Directive rules. We are investigating their impact on the animal microbiome and resistome. Project 3: Plasmid-mediated transfer of antibiotic resistance genes to *Enterococcus faecalis* JH2-2 in poultry litter (*collaboration with Torey Looft). *Enterococcus faecalis* JH2-2 usually acquires two resistance gene at a time. The same genetic element with the same resistance genes were found with different flanking elements in different plasmids.	

		Impact: Quantifying and understanding the horizontal transfer of resistance plasmids will allow us to judge the impact of animal management practices. This is also a novel method to study the ecology of antibiotic resistance genes. 3) Develop and evaluate interventions (including alternatives to antibiotics) that reduce antimicrobial resistance in food production systems. Determination of resistance gene profiles when alternatives to antibiotics are included in animal diets. Swine experiments were completed with treatment groups that received the normal diet amended with Zn and Cu, beta glucan, wheat bran, glutamine, dextrin, and other complex oligosaccharides. High-throughput qPCR arrays (WaferGen) were used to determine the resistance gene profile and 16S rRNA gene sequencing was also completed. Analysis is still underway. *Impact:* We are testing marketed alternatives to antibiotics for their selective pressure for antibiotic resistance genes. This will aid companies and producers to increase their antimicrobial stewardship.	
13.	Identification and classification of foodborne pathogens	**Issue:** 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 many tools and technologies available for testing foods, reagents, liquids, etc. for pathogens, many tests are time consuming and/or expensive. Some can only be performed within high-technology environments, and some cannot be adapted to all types of samples. One of the important goals of this application is to design and implement test systems that are low cost and easy to perform, and therefore provide a huge return on the investment to society at large. While the U.S. is a highly technological society with tremendous infrastructure, many countries cannot afford current technologies. The proposed technology will not be expensive to manufacture, and because it is reagent-free, the cost of pathogen detection is significantly reduced. Therefore, as the technology matures, low-cost versions may become available in resource-poor environments. **Target Audience:** Farmers, food harvesters/processors, scientists, clinicians **What has been done:** Microbial identification is essential in biosecurity, food safety, and the clinical environment that would be relevant to this technology might be the monitoring and preventing nosocomial infections. In general, three steps are needed to deliver correct identification of a species: sample acquisition/preparation, microbe detection, and microbe identification. Throughout the years, most effort in instrument development using optical technology has been focused on the development of a colony counter, which is essentially a	2.2 Food safety

		simple detection device; further testing is required for identification of organisms however. To identify and classify bacterial colonies, morphological methods, which observe the morphological characteristics of the bacterial colony via visual inspection, are widely studied. The objectives of this project are: 1. Provide low-cost, reagent-free pathogen-identification technologies that enhance all aspects of food safety; 2. Provide a low-cost method for monitoring microbial species in a variety of situations; and 3. Develop a series of software suites that allow direct and rapid analysis of the results. This project 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. **Results:** A key accomplishment in the present cycle was the submission of a new patent based on developing an alternative approach to lateral flow assay development. This new technology will be highly advantageous in the future for multiplexed assays. This patent is very important for detection of toxins and pathogens via laser spectroscopy. The potential for this technology is to be able to move detection out into the field, with hand-held instruments using low cost tests. **Other Information:** http://www.cyto.purdue.edu/robinsonlab?_ga=2.263103244.1448270229.1586177915-302381371.1559094136	
14.	Increased Knowledge of Safe Home Food Preservation Practices in the North Central Region	**Issue:** Home Food Preservation is a process that when done correctly can produce a bounty of food. However, when home food preservation practices are not correct, undesired food safety issues can result leading to illness and possibly death. Many residents of Indiana preserve foods throughout the year. It is critical to food safety that those participating in home food preservation use the most recent research-based home food preservation information. **Target Audience:** Public interested in preserving food at home **What Has Been Done:** North Central Region (NCR) Extension educators worked together on a food safety program to consumers across the region, including 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 (by Wisconsin) based on home food preservation starting in 2017, then expanded to include produce safety for food pantries in 2018. Food preservation topics included boiling water bath, dehydration, fermentation, freezing, pickling, pressure canning, steam canning, and sweet spreads. Programs were made available as lecture/demonstration, lecture/hands-on, and via a series or an all-in-one session.	2.3 Food safety

		Results: For results of the NCR, in 2017, a total of 1,620 participants enrolled in home food preservation classes. Almost all (96%) of workshop participants reported that they learned information in the program that was new to them. A subset of participants (n=201) responded to a 3-to 6-month post-workshop follow-up online evaluation. Most (67%) had changed their food preservation practices, 93.5% indicated they always practice safe home food preservation practices, 94.5% had shared Extension resources with others, and 96% indicated greater confidence in their ability to preserve food safely as a result of Extension home food preservation training. From 2017-2018, a total of 3,381 NCR participants completed a revised, common end-of-session evaluation. Almost all (99%) workshop participants would recommend the educational program to others. As a result of participation, nearly 80% planned to use the resources provided, 74% planned to preserve food more often at home, 66% planned to share what they learned with other people, and 59% planned to check if the food preservation resources they used at home were up-to-date. For Indiana, in 2019, 67 participants completed Home Food Preservation evaluations, 28% of those who completed training. Some 36% had been preserving food at home less than one year, and 31% had been for over 10 years. As a result of the workshops, ratings for confident/very confident increased, including: knowing where to go for safe, research tested recipes for preserving food at home (before, 29 (43%), after 65 (99%), ability to follow safe home food preservation practices (before, 32 (48%), after 61 (93%), and knowledge of safe home food preservation practices (before 15 (22%), after 58 (88%). All participants would recommend this program to others. Participants reported they were going to: use the food preservation resources provided (88%), follow the directions provided by Extension and USDA (85%), and preserve food more often at home (84%). Afterward, participants reported the workshops were "very informative", and they were "going to try new recipes/canning methods." As a result of Home Food Preservation workshops, participants who gained knowledge and skills to preserve food will help contribute to food safety for residents of Indiana, and the states of the North Central Region. **Other Information:** https://www.ag.ndsu.edu/ncrfoodsafety	
15.	Produce Safety Training Helps Growers Comply with Regulations	**Issue:** 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 things, 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) curriculum is currently	2.4 Food safety

		the only curriculum that is currently FDA-approved. Classes may only be delivered by trainers and lead trainers certified by the PSA. **Target Audience:** Produce growers and workers **What Has Been Done:** Purdue Extension began preparing for these new regulations in 2014, when funding was secured to train educators in the FDA-recognized curriculum. Approval of the Produce Safety Alliance curriculum by FDA took an extended length of time, causing a delay in the delivery of training. Purdue Extension pursued certified lead trainer status and the team currently consists of eight trainers, three of whom have lead trainer status allowing them to conduct trainings throughout the U.S. Purdue Extension has also 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. **Results:** The Produce Safety Alliance (PSA) curriculum was made available nationally in the Fall 2016. Since then, Purdue Extension has offered statewide trainings. During 2016 –2017, nine 8-hour workshops we 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, and 195 individuals receiving certificates. The three-year totals are 37 events, reaching 451 participants. Based on the list of attendees, it is estimated that within the first year, at least 50% 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% of total acreage in Indiana. One-year follow up surveys from participants of the 2017-2018 programs indicated that 100% had made some sort of change to their farm to improve food safety practices since attending the training. Some 50% 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 many states in the North Central Region and has conducted more trainings than several larger vegetable-producing states such as Texas, Georgia, North Carolina, South Carolina, and Arizona. These trainings contribute to regulation compliance and safer production for Indiana produce growers. **Other Information:** https://ag.purdue.edu/extension/safeproduce/Pages/default.aspx	

16.	Interactions of diet, flavor, and saliva for eating healthy foods	**Issue:** "Good medicine tastes bitter" is a saying that dates perhaps all the way 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. In foods, many bitter compounds in vegetables are the exact same chemical compounds that could fight cancer, reduce risk of diabetes, or protect against obesity. The result is a fundamental problem for human nutrition: foods we should eat are the same foods our mouths tell us are unacceptable. **Target Audience:** Researchers in food, nutrition, weight management **What Has Been Done:** The research goal is to find ways to improve healthy food flavor through modification of saliva. Preliminary data indicate saliva influences flavor perception for specific, potentially healthy food compounds (unsaturated fat, spicy compounds, polyphenols), and may be useful for making unpleasant sensations less intense. Research objectives were: 1) Determine salivary protein changes before and after adding target flavor compounds (unsaturated fat, spicy compounds, polyphenols) to the diet, and whether flavor perception is altered by changes in salivary proteins, and 2) Determine changes in salivary proteins during dietary interventions (e.g., low sodium diets, non-nutritive sweetener diets). Polyphenols are reducing agents that, together with antioxidants (Vitamins C and E, and carotenoids), protect the body from cancers, coronary heart disease and inflammation. Experiments were conducted with human subjects (healthy adults, age 18-45, with no food allergies) who tasted beverages containing bioactive flavors (unsaturated fat, spicy compounds, bitter polyphenols), food-based flavors, and no flavors. Participants provided baseline saliva (spit into collection tube) and stimulated saliva (chew on wax and spit into collection tube). Then, they tasted three beverages and spit again. Researchers analyzed the expectorate and identified: 1) high and low sensitivity to the flavor of interest, and 2) high and low expression of the salivary protein of interest. Next, a 6-week dietary intervention was completed with participants from identified groups (high/low flavor sensitivity, high/low expression of salivary proteins). Participants drank a different set of three 12-ounce beverages each week, then saliva and sensory ratings were collected. Saliva samples were frozen until subjected to protein analysis using liquid chromatography-tandem mass spectrometry. **Results:**	3.1 Childhood Obesity

		Successful completion of one study demonstrated exposure to polyphenols (the bitter stuff in cocoa products) in a chocolate milk mixture caused saliva to change, which could potentially 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, confirms that saliva adapts to diet to reduce the bitterness of certain foods. Knowing that diet changes saliva in ways that influence the flavor of that diet is critical. Not just to better understand why people find certain foods bitter and palatable and others do not, but to help with the messages. 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. Compiling a database will help uncover relationships between dietary behaviors and salivary proteins. 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.	
17.	Enhancing the Value of Public Spaces: Creating Healthy Communities	**Issue:** In Indiana, community leaders make decisions about public spaces such as parks, trails, farmers markets, schools, and Main Streets every day 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. **Target Audience:** Decision-makers and local leaders with oversight and management of community public spaces, including parks boards, plan commission, public officials and staff, members of organizations whose missions relate to services, programs, or management of public spaces. **What Has Been Done:** 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, and a series of instructional videos for use in a flipped classroom training. 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 through: community design coupled with information resources, case studies, and strategies	3.2 Childhood Obesity

		to enhance food access and active living via community-based programs and improvements to public spaces. The goal is to strategically guide policy, systems, and environmental changes relevant to how high-value public spaces promote health. Communities prepared with a public spaces action plan, can boost economic development, improve quality of life, and create a healthier place for individuals and families. A community-based Purdue Extension team coached community groups through developing action plans for public spaces, which guided decisions and positioned communities to take advantage of opportunities to promote healthy eating and active living. **Results:** Gaston, in Delaware County, developed a public spaces action plan for a new community center, trails, and community wellness activities. Terre Haute, in Vigo County, completed an updated Parks and Recreation master plan. Connersville, in Fayette County, focused on integrating health and wellness into community initiatives, including downtown public space revitalization, to update the city's comprehensive plan. On a post-survey, completed by 21 Terre Haute participants, they felt CHC met/exceed expectations for: presentation of information, facilitation of activities and encouragement of discussion (100%), opportunities for learning about public spaces (95%), and building connections to resources (86%). All participants reported CHC was useful in providing new knowledge to help make decisions, and to take actions to develop new or enhance existing public spaces. Significant takeaways: "Becoming more involved in issues relating to our community." "Let others know the issues and how public spaces affect our overall health." "The importance of public spaces to public health outcomes." "How to narrow consensus and invite opinion." "Health of the community and its connection to public space." "Working with youth to use parks as a tool for healthy living." "Stats on Terre Haute as healthy community; Better knowledge of community assets." "It was a great way to identify resources, gather ideas and garner support for programs. I will try this facilitation style in my current job." Some 45 Gaston and Connersville participants indicated: they felt engaged in activities (95%), they felt the discussion was meaningful (93%), they found the workshop to be informational (91%), and their knowledge about how to create healthy communities had increased (80%). Respondents were likely to use information from CHC for future public spaces planning (89%). Participants shared what they will apply in their community: "Work with others to achieve goals." "It takes a whole community to move forward." "Collaboration is necessary for community building." "We have the ability to leverage what we already have to make a difference." "We must learn to do more to promote and encourage healthy living."	

		For Fayette County and Connersville, their two-year process engaged over 64 community members and representatives from key agencies and stakeholder organizations generating 482 volunteer hours for community work, totaling $11,631. A kick-off meeting with community leaders from Community Voices, the Fayette County Area Plan Commission, Discover Connersville, Connersville city government, and the Fayette County Community Foundation started a series of community workshops focused on Quality of Life, Parks and Recreation, Institutional Assets, and Transportation. After action-planning meetings, nine Fayette County participants responded: all agreed that CHC fostered a collaborative environment for community decision-making, meetings were well organized, and the group had chosen to work on important problems. Some 89% agreed action plan objectives had/will have a positive effect on the community, and planning meetings had been useful. Many (89%) reported they enjoyed attending these meetings, and 55% agreed they were confident this group would be able to accomplish goals set. For next steps, participants stated: "The committee is looking for ways to fund some of the projects they have in mind. They are seeking more volunteers to assist." "Fayette County Community Voices as well as Discover Connersville have benefited from this program as well. Collaboration in looking for recipients and vendors has worked well for all concerned." "Funding ideas have developed from this program as well." A class of Purdue University Landscape Architecture students, led by Dr. Aaron Thompson, were meeting with the community in a parallel process to develop a plan to use vacant land in downtown Connersville as green space. Purdue Extension guided the community to deliver a report with updated data, objectives, strategies, and community input for its comprehensive plan, and presented to the Fayette County Community Foundation in December 2019. Meetings with the Purdue students culminated in Fayette County participants traveling to Purdue's West Lafayette campus to attend student presentations of renderings/concepts for downtown Connersville. Due to these student efforts, the Connersville Mayor, who participated in this project, authorized $100,000 for purchase of land in downtown Connersville, implementing several suggestions about green space and community gardens developed during CHC. Currently the land serves as a community garden known as "the Oasis." One participant commented, "We got some great ideas from Purdue students…We can take some pieces from different designs and incorporate them into the lot and make it more visually appealing and more suitable for outdoor activities, not just for growing produce. We want it to be a green space people can use."	

		Through Purdue Extension's CHC three communities are working to develop high-quality public spaces action plans to boost economic development, improve quality of the environment, and create a healthier place (including making space for and supporting physical activity and healthy eating to reduce obesity) for individuals and families. **Other Information:** https://cdext.purdue.edu/signature-programs/quality-places/evps-health/.	
18.	Global Change and the Challenges of Sustainably Feeding a Growing Planet	**Issue.** Since the 2007/2008 commodity crisis, there has been a resurgence of interest in sustainability of the world's food system and its contributions to feeding the world's population and to ensure environmental sustainability of the planet. Elements of this grand challenge are by now quite familiar. The number of people the world must feed is expected to increase by another 2 billion by 2050. When coupled with significant nutritional improvements for 2.1 billion people currently living on less than $2/day, this translates into a very substantial rise in demand for agricultural production. FAO estimates increased demand at 70% of current production, with nearly 100% in developing countries. Over the past century, global agriculture managed to offer a growing population an improved diet, primarily by increasing productivity on existing cropland. Signs of slowing yield growth for key staple crops and public opposition to genetically modified crops has slowed growth in application of promising biotechnology developments to food production in some parts of the world. Growing use of biomass for energy generation has introduced an important new source of industrial demand in agricultural markets. Water, a key input into agricultural production, is rapidly diminishing in availability in many parts of the world, and many soils are degrading. Agriculture and forestry are increasingly envisioned as key sectors for climate change mitigation policy. Farming and land use change, induced by agriculture, account for about one-third of global greenhouse gas emissions, but if incorporated into a global climate policy, these sectors could contribute up to half of all mitigation in the near term, at modest carbon prices. Any serious attempt to curtail these emissions will involve changes in the way farming is conducted and placing limits on expansion of farming; this is particularly true in the tropics, where most agricultural land conversion has come at the expense of forests, either directly or indirectly via a cascading of land use requirements with crops moving into pasture and pasture into forest. Limiting conversion of forests to agricultural lands is also critical to preserving the planet's biodiversity. These factors restrict potential for agricultural expansion in the wake of growing global demands. Finally, agriculture and forestry are likely to be economic sectors whose productivity is most sharply affected by climate change. This will shift the pattern of global comparative	4.1 Climate change

		advantage in agriculture and may well reduce productivity of farming in precisely those regions of the world where poverty and malnutrition are most prevalent, while increasing yield variability and the vulnerability of the world's poor. **Target Audience:** Public, scientists **What has been done:** 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-third of total GHG emissions and could offer up to 50% of efficient abatement potential at modest carbon prices. Yet current predictions of land use change and GHG emissions over the coming century are highly uncertain and often ignore the dynamic interplay between these forces as high priority. To improve on current state of knowledge and policies, project objectives are: (1) Understand and quantify the drivers of global changes in land use and GHG emissions, project such changes forward to 2050 or 2100 and formulate optimal policy responses to such changes, (2) Evaluate the impact of uncertainty in climate impacts, climate change mitigation policies and energy prices on both optimal and observed land use change at global scale over the long run, (3) Assess the impact of future water shortages on global food production, trade and land use, and (4) Assess the impacts of these global changes on world food prices, food security, livelihoods and poverty in developing countries. **Results:** Upon removing the spatial variation in climate impacts on global agriculture, the terms of trade impacts (changing export prices, relative to import prices) are cut in half. Given inherent heterogeneity of climate impacts in agriculture, this points to the important role of trade in distributing associated welfare impacts. When biophysical impacts of climate change on crop production are allowed to vary across empirically estimated uncertainty range taken from the meta-analysis the welfare consequences are highly asymmetric, with much larger losses at the low end of the yield distribution. This interaction between magnitude and heterogeneity of biophysical climate shocks and their welfare effects highlight the need for detailed representation in projecting climate change impacts. Impact of policies aimed at curbing greenhouse gas emissions from conversion of tropical forests to palm oil production in Malaysia and Indonesia was evaluated. Rapid expansion of oil palm in Malaysia and Indonesia (M&I) has contributed to record levels of deforestation, carbon emissions, and biodiversity	

		loss. Sustainability certification schemes seeking to address this have fallen short of stated goals, leading to calls for more aggressive measures. Three alternative conservation policies within a global economic framework were evaluated; market mediated responses were found to confound efficacy and distributional impacts of these policies. Simply limiting palm oil production or consumption is unlikely to halt deforestation in M&I in the absence of active forest conservation incentives. M&I would benefit economically by taking domestic action rather than waiting for others to act.	
19.	Spatial linkages of soil and water resources for sustainable agronomic production in Indiana	**Issue.** Water, its availability and our access to it, is essential to health of many ecosystems. Access to water is complicated by pressures and needs of communities and environmental factors including rainfall, severe weather, and increasing climate variability that reduces our ability to accurately plan for future water needs. Many communities react to current situations rather than plan proactively for future water needs. Drastic impact of insufficient planning and lack of scientifically based policies has led to problems including rapidly declining groundwater supplies, land-degrading overuse of irrigation for high-value specialty crops, and water shortages in areas of unplanned and rapid urban growth. Such problems have been avoided in much of the Midwestern Corn Belt as irrigation use has been limited to high-value specialty crops and seed production. As corn and other grain prices increase, farmers are increasingly turning to irrigation to hedge risk of climate-related losses in productivity. Soil water is critical in the decision to irrigate. Thus, understanding relationships between soils and water-holding capacity will be imperative in context of a changing climate and irrigation demand. Soils and their ability to store and deliver water vary across landscapes. Many areas of the Midwest depend on access to underground water reserves for agricultural production, but few proactive, reasonable and scientifically ground water management policies have been effectively enacted. This is a classic example of interdisciplinary problem: future water needs for agriculture are determined by crop modelers, while soil scientists evaluate differences in water holding capacity. Aquifer studies that characterize extent and conductivity of groundwater formations are conducted by hydrogeologists who develop "typical" cross-sections of regional geology, while surface water managers are trained to think at watershed scales defined by topographic boundaries, which may not match boundaries of underlying aquifers, especially confined aquifers that serve as water supplies in much of the country. This illustrates how integrated water management is also a scaling problem. Datasets needed to support integrated water management activities are not available in a form that can be easily integrated into simulation models. Traditional soil surveys are based on taxonomic and	5.1 Natural resources and the environment

		morphologic variability and often multiple map units have similar water storage properties. Through the efforts of the U.S. Geological Survey (USGS) and others, there are huge quantities of data detailing the subsurface characterization of hundreds of aquifers, or water yielding geologic formations across the U.S., but large portions of this data do not exist in geodatabases that can readily be adapted to regional scale analysis, or they are available as data layers for individual states and are truncated at political boundaries that do not represent aquifer boundaries. The seamless datasets proposed will enhance the usability of the wealth of data already compiled, which reside in archived reports or difficult-to-find in-state archives. By making a spatially explicit and continuous raster-based product, land managers and producers can gain a gain a greater understanding of water management. **Target Audience:** Farmers, land managers, public, scientists **What has been done:** The long-term goal of this project is to quantify the water storage capacity in the soils and aquifers of Indiana and how future changes in the quantity and timing of water supply and water demand will affect agronomic production. Specific research projects will focus on the 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. The broad objectives to be addressed by this project include: 1. Quantify the subsurface water storage capacity in Indiana both in soils and in groundwater aquifers; 2. Evaluate agricultural water use in Indiana in relationship to climatic extremes and projections of future climate change and water demand; and 3. Integrate findings into on-line spatial databases for use in research, Extension and teaching. **Results:** Objective 1: Parameterization of surface storage parameters for the Buffalo River and Red Rivers has been completed using a novel method integrating observations of inundation area from MODIS and daily streamflow immediately following periods of observed inundation to estimate volume. Code to create lake and wetland parameter files using this method are in the final stage of development and simulation testing will continue into 2020. Compilation of a database of soil, vegetation, wetlands and open water, and forcing data to start running model simulations at a spatial resolution of 1 /16th for the U.S. is nearing completion with preliminary testing completed in Indiana. Work is currently underway to develop a version of the VIC model incorporating all Purdue-based code updates, including groundwater, agricultural drainage, and surface inundation. Testing of the merged code is expected to begin in the immediate future.	

		Objective 2: 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), a project involving researchers and stakeholders from across the state to develop a statewide impacts assessment on major sectors including water resources (PI Cherkauer, lead author), and agriculture (Co-PI Bowling, lead author). The VIC-CropSyst simulations have so far been focused on the simulation of major crops, including corn, soybean and winter wheat using the methods developed for the calibration of hydrology and crop yields for SWAT simulations. The VIC-CropSyst model has been updated to include process representations developed at Purdue for subsurface drainage and urban areas. VIC-CropSyst code is significantly different from the stand-alone VIC model code so integration is independent of Objective 1, though changes and bug fixes are being completed in the merged VIC-CropSyst version of the code. Once integration and testing has been completed, VIC-CropSyst will be applied over a large portion of the Midwest to evaluate climate impacts on crop yields and water use. Over the summer of 2019, field experiments were also conducted to quantify variations in biomass and yield development by water availability. Measurements included high-resolution remote sensing from UAS as well as physical sampling of experimental plots during the growing season. This was a particularly difficult year with exceptionally wet spring conditions resulting in late planting, near-drought summer conditions, and harvesting that has continued into December for some plots. This data will be used to parameterize the VIC-CropSyst model in 2020 to improve the representation of crop growth under conditions of water stress. *Objective 3:* Final Dominant Soil Parent Materials (DSPM) maps were published to Soil Explorer for Iowa and Michigan, and a draft DSPM map was published for Arkansas. Existing draft DSPM maps for North Dakota, South Dakota, Nebraska, Kansas, Minnesota, and Missouri are in various stages of review and revision. A new Soil Explorer app for the Android operating system was published to Google Play in May 2019. Soil Orders, Soil Moisture Regimes, and Pedogenic Features maps for the Arequipa Region of Peru were published to Soil Explorer in May 2019 and feature descriptive text in both English and Spanish.	
20.	Beneficial Reuse of Residuals and Reclaimed Water: Impact on Soil	**Issue:** 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. While several rules have been put in place to reduce concerning metal and associated constituents in biosolids, growing awareness of the presence of trace organic chemicals (TOrCs) in municipal biosolids has garnered much attention from the public and	5.2 Natural resources and the environment

	Ecosystem and Human Health	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. Ability to assess such risks is often hindered by: (1) lack of data typically used for evaluating risk or (2) inappropriate use of typically used data because the behavior of many TOrCs do not follow previously used paradigms for predicting risk. Behavior of ionizable compounds is pH dependent, and for those that exist as cations in the environment (e.g., azithromycin and ciprofloxacin), octanol-water partition coefficient (Kow) and associated organic-carbon normalized sorption coefficient (Koc) are not appropriate for predicting behavior in soil and water. Primary goal of research is to optimize use of municipal biosolid for land reclamation and provide needed environmental fate data (leaching, persistence, and plant uptake) on trace organics present in municipal biosolids towards enhancing risk assessment protective of human and environmental health. **Target Audience:** Public, scientists, public and environmental health specialists, regulators **What has been done:** (1) Evaluate short- and long-term chemistry and bioavailability of nutrients, potentially toxic inorganic trace elements, and pharmaceuticals and personal care products (TOrCs) in residuals, reclaimed water, and amended soils in order to assess environmental and health risk-based effects of application at a watershed scale. Specific tasks: 1.1 To develop and evaluate *in vitro* (including chemical speciation) and novel *in vivo* methods to correlate human and ecological health responses with risk-based bioavailability of trace elements and TOrCs in residuals and residual-treated soils. 1.2 Predict long-term bioavailability and toxicity of trace elements and TOrCs in residual-amended urban, agricultural and contaminated soils. 1.3 Evaluate long-term effects of residuals application and reclaimed wastewater irrigation on fate and transport of nutrients, trace elements, TOrCs, and emergence/spread of antibiotic resistance in high application rate systems. 1.4 Evaluate plant uptake and ecological effects of potentially toxic trace elements and TOrCs from soils amended with residuals and reclaimed wastewater. (2) Evaluate uses and agronomic and environmental benefits for residuals in agricultural and urban systems. Specific tasks: 2.1 Evaluate the ability of *in situ* treatment of contaminated soil with residuals to reduce chemical contaminant bioavailability and toxicity. 2.2 Determine the climate change impacts of organic residuals end use options (i.e., C sequestration, N_2O emissions). 2.3 Quantify sustainability impacts such as water quality (reduced N impairment) and quantity benefits (increased plant available water, increased drought tolerance) and soil quality improvements associated with a range of organic residuals end uses. 2.4 Explore the potential for waste by-products to be used	

		in urban areas including urban agriculture, stormwater infrastructure, green roofs, and in urban green space. 2.5 Evaluate ecosystem services of degraded urban soils amended with residuals. 2.6 Use tools such as life cycle assessment to understand and compare the impacts of a range of residuals end use/disposal options. **Results:** Impact 1: The quantitative data of trace organic chemicals (TOrCs) biosolids and composted city wastes, which include yard trimmings and food packaging and other paper wastes among other compostable materials and used in both agricultural and urban settings, are helpful in ecological risk assessments. Currently, the TOrC concentrations of greatest concern are a 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 (ppt). PFAAs were detected in all composts and biosolid-based fertilizers. PFAAs quantified included perfluorinated carbon chain lengths of C4 to C18 carboxylates and C4 to C8 sulfonates. Total PFAAs in the < 2 mm fraction ranged from a few ng/g in yard wastes (considered background levels) to over detection limits to ~70 ng/g dry weight (ppb) for composted city wastes from 2016 and ~190 ng/g dry weight for biosolid-based fertilizers from 2014. The shorter chain PFAAs (≤ C6) dominated although perfluorooctane sulfonate (PFOS) was also consistently present. Analysis of more recent biosolid-based fertilizers reflected a substantial decrease in total PFAAs as well as additional decreases in the longer chain compounds (> C6) that have been phased out in most applications. Increasingly lower allowable concentrations of PFAAs in groundwater and surface water by some states is increasing 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. Impact 2: Release and degradation of trace organics from biosolids appears to be slower than when an organic chemical is artificially spiked into a soil. These results suggest that although trace organics resident in biosolids may be more persistent (longer half-life), release concentrations of trace organics from biosolids and subsequent leaching to groundwater or plant uptake will be less than predicted from soils where contaminants are artificially added. Support of Impacts 1 & 2: For the waste-based soil amendments and fertilizers for which we had characterized PFAA levels and subsequent PFAA concentrations in porewater in earlier years, we identified PFAA precursors through a targeted screening of 30 known PFAA precursors. Several PFAA precursors were identified. The 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. The trace organics other than PFAAs that was targeted included azithromycin (antibiotic), carbamazepine (anticonvulsant), miconazole (antifungal), triclocarban and triclosan (antimicrobials) had mixed uptake patterns but overall uptake was low. Carbamazepine, miconazole, triclocarban, and triclosan present in biosolids amended to soils all exemplified slower degradation and release rates than observed in soils for which a chemical was added to the soil directly.	
21.	Quantification of best management practice effectiveness for water quality protection at the watershed scale	**Issue:** The overall aim of this multistate project is to develop tools and techniques that can be used to accurately predict Best Management Practice (BMP) performance effectiveness across a range of spatial scales. Achieving this aim will permit more informed and cost-effective watershed management decision making. A multistate effort is required because of the plethora of BMPs to be investigated and because of site-specific nature of selected land uses and associated BMPs. Successfully completion of this project will reduce uncertainty and costs associated with BMP implementation efforts and improve local, regional, and national water quality. Monitoring of BMP effectiveness at the subwatershed scale is needed to gain insights into nutrient and pollutant transformation rates and impacts of export to downstream receiving waters. To scale these findings and simulate functions, sub and watershed scale water quality monitoring will be combined with distributed hydrological water quality modeling. Models developed through this work should be spatially distributed to capture impacts of individual BMPs and physically based to simulate pollutant fate and transport processes. Ideally, these models should be tested against both distributed and watershed scale (stream) observations. These will be used to predict effectiveness of BMPs and BMP implementation at the farm, subwatershed and watershed scales, improve and assess ability of watershed management models to address emerging environmental issues. **Target Audience:** Land managers, public, scientists **What has been done:** (1) Monitor water quality from a variety of watersheds with a range of conditions (e.g., differing land use and associated implemented BMPs, varying geographic/geologic conditions), (2) Develop and evaluate models for predicting BMP	5.3 Natural resources and the environment

		performance and water quality at the field and watershed-scales when considering climate change. **Results:** Effectiveness and societal acceptance of best management practices (BMPs) across the rural-urban gradient. Project goals are to: (1) characterize current pollutant loads from two representative watersheds draining to Lake Michigan based on resident group (i.e., urban residential, suburban residential, rural residential, small agricultural, and medium/large agricultural), (2) determine willingness of resident groups to adopt conservation and management practices, and (3) aggregate potential pollutant reductions based on willingness scenarios and share results with stakeholders. Model results demonstrated that agricultural land is the primary developed land use in both watersheds with corresponding annual loads of nutrients. Sediment loads were attributed to streambank erosion and allocation to land use was dependent upon number of stream miles within each land use. The team conducted a mailed survey to explore residents' awareness of and attitudes towards water quality improvement practices, their likelihood of adopting these practices, and factors that influence their likelihood of adoption. Respondents valued improved environmental quality and reduced flash flood risk as benefits of adopting water quality improvement practices and identified not knowing enough about specific conservation practices and concerns about how to install and maintain practices as main barriers to adoption. Survey results were integrated into modeling efforts to illustrate trajectory of knowledge of practice to implementation. For rain barrels, there is high adoption and knowledge, but this is with limited impact on water quality outcomes because it collects only a small fraction of potential runoff. With cover crops there is higher knowledge but likelihood of adoption is much smaller, suggesting that other hurdles exist to implementation. Assessment of ecosystem services of urban rain gardens: Urbanization impairs water quality and ecological health of streams and rivers by intensifying hydrology and mobilizing pollutants within watershed. Stormwater control measures (SCMs) disconnect impervious surfaces from receiving waters reducing flood impacts and increasing pollutant removal, both are critical regulating ecosystem services. SCMs can also provide supporting and cultural services such as habitat, aesthetics, and sense of community. 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. For this project, the focus was on rain gardens as they are commonly used, ecologically based and scalable; they have potential to provide multiple ecosystem services	

		throughout urban landscape. To assess regulating and supporting services, water quality was measured for runoff and soil water via lysimeters in three rain gardens in each city from January 2017 through May 2018. The team measured soil properties, denitrification via enzyme assays seasonally, and plant biodiversity (species richness, abundance) during peak flowering in the summer. Cultural services were characterized by spatial distribution of socioeconomic factors (e.g. income, education, home prices) around each rain garden. All sites were on public lands (schools, parks) in neighborhoods with varying socioeconomic factors, which influenced levels of maintenance, weed removal and mulch application. Elevated concentrations of NO_3, PO_4 and dissolved organic carbon were observed in shallow soil water, attributed to active mineralization of organic matter and development of anoxic conditions during flooding. Highest denitrification rates in rain gardens were observed with greatest plant density and NO_3 concentrations. Ecological functions are currently being combined with social factors to classify and quantify multiple ecosystem services and understand the role of community stewardship in delivering ecosystem services in urban landscapes. Environmental trade-offs in water quality and climate regulation resulting from floodplain restoration using the two-stage ditch: Our overall objective for this project was to assess the environmental tradeoffs between water quality and climate regulation that may exist when best management practices (BMPs) are implemented in agricultural watersheds. We focused on two-stage channels that are implemented in agricultural drainage networks. These practices are constructed by creating inset floodplains within the existing channel thereby tripling the overall width. Specifically, the team sought to answer the following questions: (1) what is the contribution of denitrification to N retention at the reach scale? (2) what biophysical processes control phosphorus retention/export in streams with two-stage floodplains? Three two-stage channels in Indiana were monitored for sediment and water characteristics, including surface water chemistry, soil carbon and extractable phosphorus. Rates of denitrification, nutrient flux, and pools of phosphorus in floodplain sediments were measured seasonally. In summer 2017, a larger survey of 10 two-stage channels was conducted and focused on phosphorus dynamics in the floodplains and streambed at sites of varied ages and soil types. The results demonstrated that denitrification was higher on older floodplains (e.g., 2007 construction), which we attribute to higher organic matter from the combination of stream sediment deposition during flooding and seasonal growth and decomposition cycles of floodplain grasses. Further, floodplain soils stored significantly more P than streambed sediments and that P retention was most closely linked to organic matter	

		content and amorphous iron oxides in the soil. The research team measured less loosely sorbed P and more amorphous iron oxides in constructed floodplains compared to naturalized counterparts, which indicates that the highly vegetated, wider constructed floodplains contribute less reactive P to surface waters when activated and have greater sorption capacity. Soil testing during the early stages of a project could help identify those sites best-suited for P management via two-stage channels and other management practices that rely on soil-based approaches (e.g., grassed waterways).	
22.	A Multidisciplinary Approach to Increase the Sustainability of Turf Areas	**Issue:** Turfgrasses are estimated to cover over 16 million hectares in the U.S. with estimated value of $75 billion annually. In Indiana, production and maintenance of amenity turf is estimated as a $2 billion industry including golf courses, athletic fields, sod farms, commercial lawns and residential turf. Turf is maintained under a broad range of environmental regimes with equally diverse budgets and expectations, by individuals ranging from seasoned professionals to inexperienced homeowners. Turf quality, durability, and vigor are determined by decisions made before (establishment decisions) and after (management decisions) the turf stand is planted. Establishment decisions determine long-term performance of the turf stand. Results of poor establishment are inherited by future managers and may limit ability to maintain turf without significant expenditures in labor, irrigation, fertilizer and chemicals. Selection of proper specie(s) and cultivar(s) when establishing turf is critical for long-term performance with fewest possible inputs. Improved genetics and changing functional, aesthetic and climatic demands are driving the need to re-evaluate turfgrass establishment and maintenance recommendations for Indiana and the Midwest. Improved winter tolerance of warm-season grasses, new zoysiagrass and bermudagrass germplasm, increased turf quality in turf-type tall fescue, and improved drought tolerance and endophyte-mediated pest resistance in a variety of species are more recent advancements. Emerging issues facing the turf industry today and in the future are addressed by this project including: biological control, carbon sequestration, climate change, nutrient use, organic agriculture, pest resistance, sustainability, water quality, and water use. Management decisions regarding irrigation, fertilizer use, pesticide applications, and mechanical maintenance practices influence turf quality and vigor on a day-to-day basis. These management decisions carry significant economic costs, raise environmental concerns, and influence the long-term vigor of the turf sward. **Target Audience:** Public, scientists, turf managers	5.4 Natural resources and the environment

		What has been done: The overarching goal of this multi-disciplinary project is to enhance sustainability of managed turfgrass systems by reducing environmental footprint from inputs and developing novel strategies to maintain persistent turf that provides functional, social, and aesthetic benefits. In working toward this goal, this five-year research and extension project broadly focused on: 1. Identify turf species and cultivars that require fewer inputs than currently used systems and then refine establishment practices for those species. 2. Refine maintenance and pest management practices that minimize inputs and optimize management outcomes. **Results:** These research and extension efforts aim to provide fact-based information for managers to preserve and protect the environment by using fewer chemical and cultural inputs while maximizing turfgrass appearance to primarily protect water quality and enhancing our quality of life (e.g. provide healthy, safe recreational turf areas). In entomology, combined research and extension efforts aim to provide turfgrass managers and the general public with science-based recommendations for sound insect pest management, and the development of environmentally sustainable, next-generation pest management tools useful for managing turfgrass insect pests. Chemical ecology work with billbugs is opening the door for exploiting chemical communication to manage this important pest complex, while 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 a garden experiment of populations of buckhorn plantain (*Plantago lanceolata*) and presented research on non-chemical control options. Dissemination of data related to importance of identifying weeds and selecting appropriate herbicides has continued to help turf managers maximize efficacy and minimize herbicide applications in the field. Research on the whole-plant response to drought, heat, salinity and flooding stresses is providing insight on how to improve turfgrasses. Germplasm characterization and gene identification will benefit turfgrass breeders for genetic improvement of stress tolerance in turfgrass. The research group continues to work on ways to help turf managers be efficient with use of water in landscape. A combined approach was based on both molecular and applied research, such as identifying specific peroxidases, 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. Infrastructure and replicated field plots were established again in 2019 to increase capacity to better assess chronic drought stress at different mowing heights and the supplemental irrigation needs of common lawn species. Additional research was initiated to provide important information on whole plant response to drought, salinity and flooding stresses. Germplasm characterization and gene identification will benefit turfgrass breeders for genetic improvement of stress tolerance in turfgrass. We also performed research on the ecology of weeds prevalent in non-irrigated turfgrass to learn more about weed management in non-irrigated turf based on various mowing and fertilization practices.	
23.	Rainscaping to Prevent Polluted Runoff	**Issue:** There is a need for education on sustainable landscape practices to prevent polluted runoff. Landscape practices such as rain gardens, which direct stormwater to be absorbed by plants and soils, are of increasing interest among Extension clientele and conservation partners. **Target Audience:** Master Gardeners, conservation agencies and organizations, stormwater professionals, and landscape companies and consultants. **What Has Been Done:** Rainscaping is a combination of sustainable landscape design and management practices that prevents polluted runoff from reaching water bodies, directing stormwater to be absorbed by plants and soils. Purdue Extension built on the highly successful Purdue Master Gardener program, to form the Purdue Rainscaping Education Team. Curriculum materials were created for delivering workshops statewide, instructional videos, participant and marketing materials, and local host guide. Instruction covers introduction to rainscaping and rain gardens, rain garden site selection, plant selection and garden design, installation, maintenance, and community engagement. A flipped classroom where participants watch videos before 15-hour in-person training of hands-on activities, interactive discussions, and field trips to community rainscaping projects. A smartphone app "Rain Garden" was launched in collaboration with the University of Connecticut containing a specialized list of plants suited for Indiana. Rainscaping participants gain experience by creating a demonstration rain garden with community partners in a public space. Custom designed interpretive signs are installed to promote education. Participants are encouraged to attend Rainscaping as community teams to support implementation of public education programs and provide technical assistance for homeowners or small-scale public projects afterward. Programs have been delivered in eight Indiana counties and in partnership with Illinois Extension.	5.5 Natural resources and the environment

		Results: Johnson, Marion and Posey Counties (35 participants) installed demonstration rain gardens. Johnson and Marion counties partnered with Master Gardeners to install a rain garden on the Extension office property. Posey County worked with Soil and Water Conservation District and Master Gardeners to update a demonstration rain garden in Mt. Vernon Riverfront Park. Steuben, Lake, Boone and Warrick Counties (51 participants) installed demonstration rain gardens and interpretative signage. Steuben County Master Gardeners partnered with Pokagon State Park to install a rain garden on park property. Lake County worked with Soil and Water Conservation District to create a demonstration rain garden on county government grounds. Boone County Master Gardeners collaborated with a church to install a rain garden next to the public community gardens. Warrick County worked with County Soil and Water Conservation District, county parks department and Master Gardeners to install a new rain garden in Friedman Park. St. Joseph County with the Soil and Water Conservation District (27 participants) planted a demonstration rain garden in South Bend. Purdue Extension team planted a demonstration rain garden at the Purdue University Wright Center. Purdue Extension formed a partnership with Illinois Extension, the Illinois Indiana Sea Grant, and the Peoria Innovation Team, to install a demonstration garden in Peoria, Illinois (25 participants). On post-surveys, participants indicated an increase in knowledge, and would recommend Rainscaping to others. For 61 respondents, 98% indicated Rainscaping increased their ability to plan and install a rain garden, and 98% intend to directly apply information within the year. Plan to use what they learned included: 1) I plan to educate others who want to build rain gardens. 2) I plan to create several rainscaping methods to install on our property to leverage as education opportunities in our area! 3) My job involves outreach to a wide range of stakeholders for pollution mitigation so I will certainly share my deeper knowledge. My volunteer life involves green infrastructure so I will use this information and share in this aspect of my life too. 4) Through presentations with customers, informal conversation and hopefully presentations to groups. Follow-up interviews found participants using program materials and resources to launch broader community education rain garden activities in their communities. Report activities were rain garden installations, tours, community education programs, and exhibitor booths. An online database is available for tracking rain garden installation projects and calculate ecological benefits (e.g., reduction in stormwater runoff). Demonstration rain gardens installed as part of Rainscaping from 2017-2019 have the capacity to reduce runoff leaving the	

		properties by 760,720 gallons per year. This reduction in flow and associated nutrients can improve water quality in Indiana communities. **Other Information:** https://nemo.uconn.edu/tools/app/raingarden.htm, https://extension.purdue.edu/rainscaping/	
24.	Woodland Owners Increased Knowledge and Skills for Invasive Plant Control Strategies and Resources	**Issue:** Approximately 150,000 residents of Indiana own property that includes 10 or more acres of woodlands. Most of these individuals are unaware that their properties are infested with invasive plants that threaten the health and survival of their woodlands. A need for education and training regarding the management of these private woodlands is necessary to maintain the health and beauty of the ecosystems for current landowners and future generations. **Target Audience:** Woodland owners **What Has Been Done:** The Purdue College of Agriculture's Southern Indiana Purdue Agricultural Center (SIPAC) is an active research and training center nestled on 1518 acres with 635 of that as wooded forest, just 160 miles from the university's West Lafayette campus. SIPAC's forestry and natural resources professionals have been helping residents manage their woodlands for more than 38 years. Invasive Plant Control Training for Landowners, a day-and-a- half workshop, was made available through a collaborative partnership with the Southwest Conservation Department, the Invasive Species Awareness Coalition of Dubois County, the Four Rivers Forestry Committee, Orange County Invasives Partnership, and the Indiana Department of Natural Resources. Instruction and hands-on training in the SIPAC forest addressed the three pillars of invasive management – prevention, early detection, and strategic management of existing infestations. Topics included assessing an invasive plant problem (species, size, and amount), invasive plant control options, selection of methods best suited for woodland situations, proper herbicide application, how to seek funding and technical assistance, putting a plan into place for long term restoration, enhancement, and when to hire a contractor. Thirty-one participants attended the training. **Results:** On post-surveys from 31 property owners, who cumulatively represented 4189 acres of land in and around Indiana, rated their level of knowledge (a scale of 1 for not at all, to 5 very much) before and after training. Respondents reported very little knowledge of the "three pillars" of invasive species plant management, and by the end of training, they had gained the most knowledge on this (average rating pre 1.83, post 4.23). For herbicide use on species, how much to use, and resources to contact for assistance, knowledge levels showed great improvement (average rating pre 2.16, post 4.20). At end of training, respondents	5.6 Natural resources and the environment

		reported highest levels of knowledge for: why invasive plants are considered a threat (average 4.73), how to get help with managing invasive vegetation on their property (average 4.45), and how to assess the invasive species, then prioritize and plan to address infestation on their property (average 4.37). The Net Promoter Score® (NPS®) (Fred Reichheld and Satmetrix Systems, Inc.) is a measure of customer experience. When asked how likely they would be to recommend this field day to a friend or colleague, respondents could mark on a scale from zero (not at all likely) to ten (extremely likely). Respondents selecting zero to six are considered "detractors" (critics or unhappy customers), those selecting seven and eight are considered "passives" (satisfied but unenthusiastic), and those selecting nine and ten are considered "promoters" (loyal enthusiasts). Most (90%) identified as promoters (loyal enthusiasts), 10% Passives (satisfied but unenthusiastic), and no detractors (critics or unhappy customers). The NPS®, determined by subtracting the percentage of detractors from the percentage of promoters and can range from -100 to 100, was 90, considered "world class", showed participants were greatly satisfied with training. Respondents indicated training was useful for providing new knowledge to help them make future decisions (100%) and take actions (97%) to manage invasive plants on their property. Respondents indicated plans to adopt practices from the training within the next 12 months, including identifying invasive plant problems on their property (97%), taking steps to prevent new infestations (84%), assessing infestation, prioritizing and managing invasive plants (81%), incorporating invasive plant management in their forest/wildland management plan (81%), and seeking professional expertise in managing invasive vegetation (71%). As a result of the training, private woodland property owners gained knowledge and skills for adopting the three pillars of invasive plant management (prevention, early detection, and strategic management of existing infestations), on their forests and wildlands which can help contribute to the saving of Indiana's woodlands.	
25.	Sustainable Communities: Environmental Watershed Planning with the Tipping Point Planner	**Issue:** For communities to achieve ecosystem sustainability, it must be known what land and habitat components are necessary to sustain their ecosystems. Communities need to understand science-based environmental limits or "tipping-points," to institute land use policies and restoration plans that ensure critical green infrastructure and maintain habitat-sustaining ecosystems. Developing new policies that solve natural resource challenges at local to global scales will require close collaboration between the scientific community that has studied these problems and the policy community that understands how planning can be crafted to improve human and environmental well-being.	5.7 Natural resources and the environment

		Target Audience: Extension specialists, coastal managers, consultants who work with plan commissions, watershed planning committees, municipal officials and planners, local government entities (town councils, plan commissions and parks departments), non-profit staff, and interested stakeholders in the community. **What Has Been Done:** Tipping points are measures of ecosystems or social systems that determine whether systems are moving from a "good state" to an "undesirable state" along ecological dynamics altered by human activities. To better understand tipping points and apply them to decision-making about land at a watershed scale, 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 the Purdue-led team, organizes community objectives, data, models, and planning tools into a simple interactive framework. TPP helps watershed leaders identify land-based activities resulting in nutrient loading, increased runoff, and non-point source pollution, threatening sustainability of ecosystems in watersheds. 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. Team members conducted workshops with Northwest Indiana, West Lafayette, Portage, Union Township, Pendleton, and 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 included education and visioning sessions with community stakeholders, and action planning meeting series with steering committees of local experts. Work with Huron Pines, a Michigan-based environmental non-profit, and Michigan Sea Grant gathered regional stakeholders for three meetings on creation of a watershed management plan for Au Gres River and East Au Gres River Watersheds (Saginaw Bay, Michigan). The team guided community visioning sessions to determine priorities for watershed management to better inform next steps for local and regional planners. The team worked with Ohio Sea Grant and Reveille, Ltd. in Perrysburg, Ohio (Maumee River Watershed) to support development of a city-wide land use plan. The team worked with a steering committee and guided community visioning sessions to determine priorities for watershed development and water quality. Purdue 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, available free online, which provides	

		education resources and examples how to integrate agriculture and natural resources in community land use planning and in comprehensive plan updates. **Results:** Many (75%) of participants (12) from Au Gres, Michigan and Perrysburg, Ohio workshops, rated workshops very good/excellent for learning about environmental land use planning and management and for building connections to resources. Respondents increased knowledge levels: 1) assessing ecosystem health for natural resource management options (before 30%, after 75%). 2) applying decision support tools to make decisions and take actions on ecosystem health (before 38%, after 66%). 3) Forming diverse community partnerships to create and implement environmental land use action plans (before 46%, after 66%). Participants identified a most significant item they will apply in their community: 1) How listing assets and opportunities can show strengths and opportunities for growth, 2) How certain types of land use can change and affect stream quality in different ways, 3) That stakeholders across sectors are all thinking about and recognizing the economic and community development approaches from high-quality natural resources, and 4) Focus on application of tools and information. All reported better understanding of environmental land use planning and management issues facing their community. Most (92%) reported they were likely/very likely to use information for future environmental land use planning and management. All stated they would use information within 12 months. Respondents shared how they plan to use what they learned: 1) Future programmatic planning to target the topics developed in discussions, 2) Future land acquisition and development planning, 3) I believe that we will use different tools (ex. conservation easements, reduction of impervious surfaces) to benefit the region, and 4) I was made aware of the issue that growth will cause in the future. Purdue 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 ecological resources. These efforts will contribute to improved health of watersheds in the Great Lakes region. **Other Information:** http://tippingpointplanner.org, https://cdext.purdue.edu/guidebook.	
26.	Regulation of phenylpropanoid metabolism in plants	**Issue:** 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	6.1 Sustainable energy

		pathways in plants. One most significant 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. Enzymes of lignin biosynthesis have been identified, but we know little about how expression is regulated. Several transcription factors have been isolated, but it is unclear how expression and activity dictate or contribute to allocation of photosynthate to lignin as opposed to other plant components such as cellulose or starch. Two novel, plant-specific proteins (REF4 and RFR1) have been identified that 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. Mutants of Arabidopsis that lack REF4 and RFR1 are viable and show few developmental changes, making them a tractable system to examine the function of Mediator. These mutants accumulate more phenylpropanoid end products including lignin. Plants carrying a mutant dominant form of REF4 show the opposite phenotype. REF4 and RFR1 appear to be components of a system that determines amount of carbon allocated to the phenylpropanoid biosynthetic pathway. **Target Audience:** Scientists, public **What has been done:** 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. Chromatin immunoprecipitation will be used to identify targets of REF4 and RFR1 proteins in the *Arabidopsis* genome to understand which genes must be altered to divert more or less carbon into the lignin biosynthetic pathway. Finally, we determined the functional differences between REF4 and RFR1 by altering relative expression levels in different tissues. We are learning how REF4 and RFR1 function to coordinate transcription of genes required for lignin deposition and gain insights into how this pathway can be manipulated for human energy needs.	

		Results: The Mediator complex functions as a hub for transcriptional regulation. MED5, an Arabidopsis Mediator tail subunit, is required for maintaining phenylpropanoid homeostasis. A semi-dominant mutation (ref4-3) that causes a single amino acid substitution in MED5b functions as a strong suppressor of the pathway, leading to decreased soluble phenylpropanoid accumulation, reduced lignin content and dwarfism. In contrast, loss of MED5 results in increased levels of phenylpropanoids. Using a reverse genetic approach to identify suppressors of ref4-3, it was determined that ref4-3 requires CDK8, a kinase module subunit of Mediator, to repress plant growth. The genetic interaction between MED5 and CDK8 was further characterized using mRNA-sequencing (RNA-seq) and metabolite analysis. Growth inhibition and suppression of phenylpropanoid metabolism can be genetically separated in ref4-3 by elimination of CDK8 kinase activity; however, the stunted growth of ref4-3 is not dependent on the phosphorylation event introduced by the G383S mutation. In addition, rather than perturbation of lignin biosynthesis, mis-regulation of DJC66, a gene encoding a DNAJ protein, is involved in the dwarfism of the med5 mutants. This study reveals genetic interactions between Mediator tail and kinase module subunits and will enhance understanding of dwarfing in phenylpropanoid pathway mutants. Plants produce several hundreds of thousands of secondary metabolites that are important for adaptation to various environmental conditions. Although different groups of secondary metabolites are synthesized through unique biosynthetic pathways, plants must orchestrate their production simultaneously. Phenylpropanoids and glucosinolates are two classes of secondary metabolites that are synthesized through apparently independent biosynthetic pathways. Genetic evidence has revealed that the accumulation of glucosinolate intermediates limits phenylpropanoid production in a Mediator Subunit 5 (MED5) dependent manner. Analysis of the transcriptomes of a suite of glucosinolate-deficient mutants using RNAseq identified mis-regulated genes that are rescued by the disruption of MED5. The expression of a group of Kelch Domain F-Box genes (KFBs) that function in PAL degradation is affected in glucosinolate biosynthesis mutants and the disruption of these KFBs restores phenylpropanoid deficiency in the mutants. This study suggests that glucosinolate/phenylpropanoid metabolic crosstalk involves the transcriptional regulation of KFB genes that initiate the degradation of the enzyme phenylalanine ammonia-lyase, which catalyzes the first step of the phenylpropanoid biosynthesis pathway. Nevertheless, KFB mutant plants remain partially sensitive to glucosinolate pathway mutations, suggesting that other mechanisms that link the two pathways also exist.	

27.	Disparities in school readiness: The role of geographic region, family, community, and preschool experiences	**Issue:** Fewer than half (48%) 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 (e.g., letter recognition, early math), social-emotional health, and self-regulation (e.g., executive function processes). Early school readiness skills influence more than just kindergarten academic outcomes. Children with strong school readiness, measured between ages 4 and 5, 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 utilizing a nationally representative sample suggest that elementary school age children living in rural communities are less proficient in their early literacy skills and 60% more likely to be placed in special education services compared to their urban counterparts. However, scant, if any, research has been dedicated to understanding whether geographic region plays a role in children's development before kindergarten entry, and specifically whether it has an impact on school readiness. **Target Audience:** Public, childcare and developmental specialists, rural educators **What has been done:** 1. Identify differences between family, community, and preschool experiences of low-income children across the urban-rural continuum. 2. Explore differences in three aspects of children's school readiness (pre-academic skills, social-emotional health, and executive function) across the urban-rural continuum. 3. 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. **Results:** All data for these stated objectives have been collected. Analyses have been completed and results either have been or are currently being disseminated. Key findings: (1) Children from rural communities and small cities are more demographically at-risk relative to children living in urban communities (e.g., lower parental education and family income). (2) Children from rural communities experience slightly higher preschool classroom quality compared to their urban counterparts. (3) There are few differences in children's school readiness across the urban-rural continuum; however, children from rural communities were	7.1 Human, family, community health and well-being

		rated by their teachers as having higher social competence compared to children in urban communities. Children who live in rural communities, and to some extent, children from 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.	
28.	INWork: INovate, INvest, INspire: Skills for Tomorrow's Workforce	**Issue:** 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 skills needed to make for a productive and successful workplace. **Target Audience:** High School Youth **What Has Been Done:** 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, Purdue 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 a minimum of 6 hours of 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. **Results:** As a result of INWork, high school youth recognized the importance of being on time to work (100%), doing their job well (100%), being trusted by their employer (99%), and to respect others in the workplace (99%). Youth (90%) reported that they understand the importance of having a professional image on social media. For future careers, 87% successfully explored career options, and 81% were able to identify a career they would like to pursue. Looking ahead beyond high school, 79% plan to attend a 4-year university the year after high school, 72% identified jumping into the workforce as another viable option within the first year of high school completion, 70% plan to attend a community college, and 52% plan to attend vocational college. By completing INWork, these youth showed positive development preparing them to work after high school, with skills that will help them succeed.	7.2 Human, family, community health and well-being
29.	4-H Adult Volunteer Positive Impacts on Indiana Youth and Communities	**Issue:** Adult volunteers are highly used to conduct programs in the 4-H Youth Development Program. Significant staff and financial resources are expended for developing volunteers to work with various aspects of the 4-H Program. Are these volunteers effective? What types of impact does	7.3 Human, family, community health and well-being

		their service provide? The North Central Region 4-H Volunteer Impact study provided these answers. **Target Audience:** Adults, Youth **What Has Been Done:** The Indiana 4-H Youth Development Program relies heavily on adults who care about the development of youth to deliver positive youth experiences. There are a variety of opportunities for adult volunteers, they can: help with a one-time event/program, lead a 4-H Club, help with a 4-H project, help with an afterschool program, help with a summer program, sit on a county governing board, volunteer on a fair organizing committee, and serve as a judge for 4-H project exhibits. All adult volunteers must pass a background check and participate in training. The Youth Safety and Reporting Child Abuse training is completed every two years, New 4-H Volunteer Orientation is done via online modules, and the 4-H Mentor Manual along with many other resources are available in collaboration with Extension Educators in each county and on the 4-H website. A North Central Region 4-H Volunteer Impact Study was conducted with adult volunteers in the 4-H Youth Development program. The purpose of this 12-state study was to better understand the value of being a 4-H volunteer. A total of 1,000 randomly selected volunteers from each state were asked to reply to an electronic survey. Reports were developed summarizing North Central Region data. This statement shares the results for Indiana. **Results:** Some 255 Indiana 4-H Adult Volunteers responded to the survey (25.5% response rate). Top reasons they volunteered were to help others, make a difference, and support a child in 4-H. Some (47%) volunteers reported having a tenure of at least 11 years, another 25% had volunteered 2-5 years, while 23% volunteered between 6 and 10 years. Nearly two-thirds of the volunteers were part of 4-H as a child. Indiana adult volunteers personally benefitted from their 4-H involvement. Volunteers (90%) 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.” Volunteers (87%) gained skills that are useful in other settings. One volunteer stated, “I’ve used some of the activities I’ve taught in club meetings in an after-school mentoring program I volunteer with in one of our city’s most troubled neighborhoods. Tried and true activities that have worked for my 4-H kids have been well received with these less fortunate students.” Volunteers (79%) learned to think from	

		different perspectives. One stated, "Working with students with special needs. These students have unique personalities and want to be treated like other students or 4-Hers. They just need more help in accomplishing tasks." Indiana 4-H Youth benefitted from volunteers. On average volunteers give 8.3 hours per month, an annual contribution valued at $2,241/volunteer (based on Independent Sector hourly rate for Indiana - $24.13), 93% contributed supplies and 85% contributed financially. Most (95%) taught youth new skills. One said, "Getting kids involved in not only doing the projects but holding an office in our clubs helps them learn leadership skills which they carry into their school careers, into college, and then into life in our communities to help build a stronger, better world for all of us to live in." Many (88%) recruited new youth to 4-H. One volunteer stated: "4-H crosses all economic and social lines. It gives city kids the access to animals in the rural parts of the county. It gives kids skills that will last a lifetime. Who knows what skills will be valuable in the future? 4-H gives kids the flexibility to learn skills that they may use in the future." Many (85%) planned learning experiences for youth. One responded, "Young adults will become the future of our communities. Basics such as integrity, truth, honesty, hard work and responsibility are all attributes that are communicated through numerous 4-H activities." Communities are stronger because of 4-H Youth Development volunteers. Many said volunteering with 4-H: makes communities stronger (90%), contributes to better connected communities (88%), improves the health of communities (80%), and increases civic involvement (73%). The 4-H program helps youth build skills. One volunteer said, "The students I've met through 4-H are incredibly capable in a host of arenas. They can build a robot, fix a small engine, and decorate a cake. Skills make communities stronger. Communities need people who can do things. 4-H does that very well." Many volunteers reported taking on new community leadership roles and opportunities. One said, " For the very first time ever, my husband and I (both 4-H volunteers) became more vocal in the political process for our community and our state." The 4-H program would not be possible without volunteers. Through their 4-H training and service, adult volunteers grow personally, enrich the 4-H program, help youth build skills, and make Indiana communities stronger. **Other Information:** https://extension.purdue.edu/4h/Pages/volunteer.aspx	

30.	Co-Parenting for Successful Kids	**Issue:** Indiana is home to more than 1.5 million children under 18 years of age. Although some change in children's lives is normal, abrupt or involuntary disruptions can affect feelings of security. Instability is often associated with family stress and can negatively impact physical, emotional and cognitive development. In Indiana, when a family is going through a divorce or seeking child custody, co-parenting education is at a judge's discretion. With the national average of about half of all marriages ending in divorce, this situation affects a great number of our children. **Target Audience:** Parents, Court Systems **What Has Been Done:** Purdue Extension provided Co-Parenting for Successful Kids (CPSK) to meet the statewide need of co-parenting education. This four-hour program addresses several topics: how children are affected by divorce; stages of grief and adjustments; parenting styles; discipline; parenting plans; stress; and keeping children out of the middle of adult conflicts. Parents in Indiana completed the online course and received feedback about their journal submissions from trained Purdue Extension facilitators. Other parents attended one of the 52 onsite classes. There were 544 parents enrolled in CPSK, (190 online, 354 onsite), with 924 children relationships (online parents had 347 children, onsite parents had 577 children). A post-/pre-reflective evaluation was implemented at program end. A total of 525 parents completed the survey. **Results:** Parents learned to: keep children out of the middle of adult conflicts between the co-parents (96%); develop and follow a child-focused co-parenting plan with the other parent (95%); have more positive communication with the co-parent by using "I" messages (95%); and help their children adjust to the divorce or custody modification based upon the children's ages and stages (95%). All parents (100%) reported that they intended to use the strategies learned, to keep children out of the middle of conflict with the other parent, and to help their children adjust to the new co-parenting arrangements. Parents (99%) intended to: search for the positive in the other parent and actively point this out to their children; use "I" messages more frequently than prior to the class; stop criticizing the other parent in front of their children; develop and follow a detailed, child-focused co-parenting plan with the co-parent; and stop asking children to relay messages to the other co-parent. Parents indicated the most useful information was: communication and the use of "I" messages; followed by creating and following a cooperative co-parenting plan; discipline and parenting styles; and dealing with stress. Parents wrote: "The information based off of ways of disciplining as well as age groups needs was important to me. These are the foundations to	7.4 Human, family, community health and well-being

		making their lives more functional so that he and I can work together easier. I also found the information about how to speak to him so that he doesn't feel as if I'm attacking him just by how I say things when I don't mean it negatively is very important for our communicating." "I learned about how stress affects kids on the different stages of age. I learned about the different parenting styles and which one I need to work towards and this program also made me realize that I was not parenting the right way." "I'm not gonna talk negative about the other parent. I'm gonna mention to the kids the good qualities of their mother. I'm gonna create a great parenting plan, good for us parents and kids. And I'm gonna give my 100 percent so the divorce don't affect the kids too much." An online parent wrote "I was not sure how I was going to feel about this course, but I was really surprised, pleasantly, at how much the material made me think through this process. Thank you for putting together such a solid course. I also really appreciated the feedback comments." Purdue 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.	
31.	Mental Health First Aid	**Issue:** Mental health and substance use issues are widespread concerns in the U.S. and often perceived differently than physical health conditions. This 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 surrounding community. Community members can gain skills to support one another, similarly 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. **Target Audience:** Adults **What Has Been Done:** Purdue Extension provides Mental Health First Aid (MHFA) courses to adults about signs and symptoms of mental health and substance use issues, as well as 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/or substance use issues. MHFA was presented 15 times during 2018-2019, reaching 414 individuals. There were 381 (92% response) who completed	7.5 Human, family, community health and well-being

		the post-evaluation, and identified as female (74%), aged 24 years or older (94%), and Caucasian/White (93%). **Results:** Pos-evaluation results showed that MHFA was well-received by and beneficial to participants. Participants (97%) agreed/strongly agreed that they are confident in recognizing signs that someone may be having a mental health problem, substance use challenge or crisis. Participants (95%) agreed/strongly agreed that they are confident in being able to reach out to someone having a mental health problem, substance use challenge or crisis, and that they can recognize and correct misconceptions about mental health, substance use and mental illness. Some 93% agreed/strongly agreed they are confident 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." To the program's ability to provide a starting point in mental health education, one participant commented, "It was definitely helpful for 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. **Other Information:** https://extension.purdue.edu/mhfa/	
32.	Natural Resources Conservation through Collaborative Community Leadership	**Issue:** 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 Extension serves. **Target Audience:** public agency staff, nongovernmental organizations, those serving on boards/commissions with emphasis on natural resources management, conservation, agriculture and land use **What Has Been Done:** Purdue Extension's Conservation through Community Leadership (CCL) is a statewide natural resource program to enhance decision-making for community implementation. This Indiana-based 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. It includes resources: 1) for a community-based multi-meeting series on background resources for land use planning and invasive species management, promotional materials, meeting facilitation guidelines, and measurement and evaluation protocols, 2) available online with the Tipping Point Planner, to provide county land use planning dashboards for	7.6 Human, family, community health and well-being

		communities to better understand natural resources, and 3) for land use planning and invasive species management online. CCL is a roadmap for communities to identify issues, assess community conditions and resources, create a shared vision, and develop an action plan and implementation strategies. This can take up to two years and involves convening community leaders as a local working group meeting four times with Purdue Extension facilitators supporting community visioning, sharing innovative management strategies, and coaching them through action plan development. Results are 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 program was tailored for local issues. Kosciusko and Pendleton focused on integrating natural resource elements into comprehensive plans. Gibson convened to support a watershed management plan. Dearborn supported a community garden initiative. Owen and Pulaski developed invasive species activities. **Results:** Participant feedback shows CCL is meeting action planning needs for community groups. Participants rated knowledge about forming diverse community partnerships to create and implement land use and natural resource management action plans before and after the program. Participants rated their knowledge excellent, before, 37%, and after 80%. Comments: Great tool for assessing resource concerns and setting priorities.; I learned a lot in total regarding (the community's) assets, opportunities, and natural resources as a whole!; Great group process, Excellent facilitation, encouragement in working together in groups.; This was a great workshop. It helped educate many leaders and interested residents. Helped our community see our town through a different lens. Pulaski had 15 participants from Pulaski County Soil and Water Conservation District and Indiana Invasive Initiative whose CCL experience produced a 36-page action plan to guide formation of the Cooperative Invasive Species Management Area (CISMA). All reported a better understanding of natural resource issues facing their community and will apply knowledge and tools gained within three months. The group convened to “think outside the box about potential partnerships in the community.” All reported a favorable/very favorable response that CCL increased confidence in ability to plan for new invasive species collaboration efforts. Participants commented, “This has been helpful to know what challenges the local community is facing” and “I like how the program created a framework for brainstorming and	

		gathering group input. As far as I could tell everyone was comfortable sharing ideas, which seems to be rare in group settings." The 26 participants from Dearborn County Soil and Water Conservation District, and Purdue Master Gardener State Coordinator and Gardeners collaborated to produce an action plan to expand county-wide community gardening. Participants reported CCL was useful/very useful for taking actions for next steps (91%) and making decisions about community gardening (83%). Most (88%) said CCL was excellent for making connections to resources for implementing action plans. Participants planned to apply what they learned, including: 1) This was an excellent opportunity to brainstorm and work together as a community. The afternoon was well-organized and on task. Looking forward to next steps! 2) Expand the network to support growth of community garden development in southeastern Indiana, 3) This takes people and money and time and education, and 4) There are many people and organizations involved in making our community better. Owen County Soil and Water Conservation District launched a Cooperative Invasive Species Management Area (CISMA) effort via their CCL experience. All seven members reported a favorable/very favorable in desire to get involved / increase involvement, and 86% increased confidence in ability to plan for new invasive species collaboration. All reported better understanding of natural resource issues facing their community and will apply knowledge and tools gained within six months. Participants plan to use what they learned: invasive control on private land, planning displays – decision-making, in starting other groups (watershed council), working with board of supervisors, and taking better care of my land. CCL supports development of high-quality local/regional action plans and strategies for implementation in Indiana communities. Group planning can lead to a more collaborative process with 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. **Other Information:** http://tippingpointplanner.org/resources/regional-planning, www.purdue.edu/fnr/extension/scep/programs/conservation-through-community-leadership	

33.	Beginner's Guide to Grant Writing Helped Citizens Submit Proposals Awarded nearly $4 Million for Indiana Communities	**Issue:** Competitive grant proposals are an increasing revenue source for nonprofits, educational institutions, and local governmental units. According to the National Center for Charitable Statistics 13.3% of all nonprofit revenues came from private charitable giving and 33% came from government contracts (24%) and grants (8%). For Human Services nonprofits, 65% of revenue came from government contracts or grants. 81% of nonprofits receive government grants (2013 survey). Many people working in nonprofits and local governments find themselves in positions in which they need or want to write grants but have little or no training to do so. 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. **Target Audience:** Staff/Volunteers from local governments, nonprofits and educational organizations, community groups, clubs, and concerned citizens **What Has Been Done:** For the reporting year, Purdue Extension's Beginner's Guide to Grant Writing (BGGW) was delivered 15 times to 203 participants. Each workshop is hosted by an Extension 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 learned 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 and learn strategies for finding funding. During workshop, they polish their proposals, get feedback from grant writing professionals, and search for grant funds with a short-term subscription to a grant database. Purdue Extension received a $5000 grant from State Farm to offer BGGW statewide. Several community foundations contributed sponsorships and in-kind support to individual workshops. **Results:** Participants completed a survey at the end of the second day, then receive emails at 6, 12, 18, and 24 months after the workshop inviting them to complete follow-up surveys. Results reflect data from five surveys collected over two years for two cohorts. There were 199 participants and 104 survey respondents (52%). Participants rated BGGW moderately to extremely beneficial (94%) with most rating it very/extremely beneficial (70%). Respondents reported, that as a result of BGGW: 76 (73%) submitted proposals to funders, 51 proposals received funding, $3,907,459 in grant funding was awarded, 44 participants took on new	7.7 Human, family, community health and well-being

		leadership roles, 10 organizations engaged in strategic planning, 106 partnerships formed, 25.5 jobs were created, and 695 volunteer hours were completed ($16,770.35 value, Independent Sector). Respondents commented: "The BGGW was one of the better workshops I've ever attended. I've always felt that I was a strong grant writer, but this training helped me see grant writing from the perspective of many other organizations and fields rather than just my own. One of the key components I took from this training was the ability to identify short, medium, and long-term goals that an organization should have when pursuing and securing grant funding." "I appreciated the workshop. I know how to write grants but planning on how to spend money and have actual evidence of what we want and how we are going to follow up with it was extremely helpful." "Great workshop. Really appreciate the follow up, and I'd play up the networking opportunities in the workshop." "Reviewing other grant proposals written by workshop attendees and having my grant proposal reviewed was very helpful and instructive." BGGW helps participants increase skills to write and submit, and ultimately, receive funding to support Indiana organizations and communities.	