

**Purdue Extension
2018 Annual Accomplishment Report to USDA NIFA
Impact Statements by Planned Program**

The Purdue Extension and Research outcomes and impact statements are organized into these seven Planned Programs:

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Outcomes provide the metrics that our Educators and Specialists report across research and Extension program efforts. The impact statements shared highlight a program or project addressing the outcomes and provide narrative on the issue, what has been done, and the results. There are impact statements for research projects, for Extension programs, and for integrated research and Extension activities.

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Childhood Obesity

Title

Health-related impacts of nutrition and exercise across the life span

Research

Wayne Campbell, Nutrition Science

Outcome

50 - GSFH 4.5, 4.7, 4.8; FCS 1.3 - # of discoveries, innovations, technologies that relate to human health (including cancer), nutrition and well-being (including bioactives and botanicals), chronic Diseases, and impacts of environmental factors on health

Issue

2015 Dietary Guidelines Advisory Committee report emphasized several important points. First, most U.S. adults are overweight or obese; they consume excess energy and foods and beverages that are nutritionally poor. They also have health profiles characterized by high risks of developing cardio-metabolic diseases and cancer. Second, research supports the effectiveness of consuming healthy dietary patterns, including a Mediterranean-style diet or a Dietary Approaches to Stop Hypertension (DASH)-style diet, and improving body weight body composition through diet and exercise to counter obesity and disease. Third, there is ambiguity and inconsistency in scientific literature regarding the impact of red meats in diets designed to promote health. While the overall recommendation is to reduce consumption of red and processed meats, it is not well known whether this recommendation includes lean, minimally processed red meats. Fourth, national survey data show that the majority of dietary protein is obtained by consuming animal-based foods, including meats, poultry, dairy, eggs, and fish. Recommendations to change how much of these protein-rich foods and beverages are consumed may impact not only consumer health, but agricultural infrastructure and practices.

What has been done

Collectively, four research studies are focused on these important aspects of the Dietary Guidelines Advisory Report, to assess the impact of dietary protein intake and protein-rich animal-based agricultural food commodities on the

effectiveness of healthy diet patterns. Specific objectives include: 1) To assess the effects of within-day patterning of dietary protein intake (even vs. skewed) on energy-restriction and strength training-induced changes in body composition, skeletal muscle size, appetite, glucose response, and metabolic syndrome parameters. 2) To assess the health effects associated with the inclusion of greater amounts of red meat (pork and beef) versus poultry and fish into a healthy Mediterranean-style dietary pattern, which recommends restricting red meat consumption. 3) To assess associations between the quantity and sources of protein intake and body composition in a nationally representative sample of U.S. adults aged 50 years and older.

Results

For the within-day dietary protein patterning study, findings showed: 1) The effectiveness of dietary energy restriction combined with resistance training to improve body composition is not influenced by the within-day distribution of protein when adequate total protein is consumed; 2) Consuming a rapidly digested whey protein snack two hours after a slowly digested, lower protein breakfast resulted in a greater peak plasma essential amino acids (EAA) concentration but comparable plasma EAA availability than consuming a single higher protein breakfast. Further analyses showed: 1) Concurrently with resistance training, consuming protein supplements with meals, rather than between meals, may more effectively promote weight control and reduce fat mass without influencing improvements in lean mass; 2) Whey protein (WP) supplementation improves body composition of women by modestly increasing lean mass without influencing changes in fat mass. Body composition improvements from WP are more robust when combined with energy restriction. The Mediterranean-style dietary pattern study results supported that adults who are overweight or moderately obese may improve multiple cardiometabolic disease risk factors by adopting a Mediterranean-style eating pattern with or without reductions in red meat intake when red meats are lean and unprocessed. A review of dietary recommendations regarding consumption of muscle foods, such as red meat, processed meat, poultry or fish, found studies largely rely on current dietary intake assessment methods, including: 1) food frequency questionnaires; 2) food disappearance data from the USDA Economic Research Service; and 3) dietary recall information from the National Health and Nutrition Examination Survey data. These reported methods inconsistently classify muscle foods into groups, which creates discrepancies in estimated intakes. Researchers who classify muscle foods into these groups do not consistently consider nutrient content, leading to implications of scientific conclusions and dietary recommendations. These factors demonstrate the need for a more universal muscle food classification system. Further specification would improve accuracy and precision to classify muscle foods in nutrition research. Dietary protein intake and body composition results in elderly men who consumed diets containing at or below recommended dietary allowance (RDA) for protein and had skeletal muscle dysfunction were: controlled protein intake for six months exceeding the RDA did not increase lean body mass (LBM), muscle performance, physical function, or well-being measures. The RDA for protein is sufficient to maintain lean body mass, and protein intake exceeding the RDA does not promote lean body mass increase or augment anabolic response to testosterone. Also, findings from a study of older men and women who consumed a high-protein diet with whole eggs or a normal protein diet without eggs for 12 weeks showed a high-protein diet promotes lean mass retention with modest weight loss, but does not positively influence muscle composition, cardiometabolic health or systemic inflammation, compared to a normal protein diet void of eggs. The important, novel findings may be used by scientists, health practitioners, and nutrition and health policy and program officials to develop and implement dietary guidelines to help people improve their health by consuming within-day and infradian patterns of healthy foods and beverages.

Title

Contracting in Agriculture: Theory and Implications for Agribusiness Management and Public Policy

Research

Steven Wu, Agricultural Economics

Outcome

4 - CO 1.9 - # Of discoveries, innovations, technologies that relate to economic and/or community policies that impact childhood obesity (e.g. serving sizes/products available in schools, legislation regulating drink sizes/refills such as in NY, etc.)

Issue

A rigorous study of modern food marketing requires agricultural economists to adopt and make methodological improvements to economic tools, such as contract theory (the study of incentive and pricing design). The methodological toolkit currently used is based on older models appropriate for studying small producers and consumers. Modern agribusinesses are large, sophisticated and characterized by substantial strategic interaction with suppliers and customers. Contracting is pervasive and essentially incentive mechanisms to coordinate marketing strategies. Contracting models are useful for studying strategic pricing schemes that provide incentives to consumers to purchase more or to self-select into different market segments. According to MacDonald and Korb (2011), use of contracts in agriculture has been increasing over the last several decades. In 1969, contracts governed only 12% of the total value of U.S. agricultural production, but this has increased to 39% in 2008. For specific commodities such as hogs, poultry, and many fruits and vegetables, contracts dominate most production. Contracts are pervasive between food manufacturers and wholesalers and/or retailers, yet agricultural economists have not studied these downstream contracts in a rigorous manner (Myers, Sexton, and Tomek 2010). Food retailers are using increasingly sophisticated marketing and strategic pricing schemes to market food to consumers. Lack of methodological development in contract theory within the agricultural economics community has limited ability of agricultural economists to study important contemporary policy issues.

What has been done

This research focused on food marketing and contract theory (the study of how incentives and strategic pricing mechanisms should be designed to induce people to enhance productivity, minimize costs, purchase products, and/or achieve social objectives in policy making). However, contract theory has limited real-world application. Activities were to: 1) Make methodology improvements to theoretical contracting models to be more robust for applied work - that is, imposing minimal critical assumptions. 2) Test the models and their robustness using experimental economics. 3) Use the models that have been successfully stress tested to investigate relevant contemporary agribusiness or food policy issues.

Results

The main accomplishment was completion of a theoretical model that makes predictions about how people will structure contracts across different contract enforcement institutions. A key distinguisher of different enforcement institutions is the availability of performance measurement technologies that can enable third-party verifiability (e.g. by courts or arbitrators) of contractual performance. Next, researchers examined how people structure contracts in different trading environments, including several thousand longitudinal trade observations. A key finding was that the contracting party with stronger bargaining position will design contracts that shift more risk onto the weaker party. Also, people tend to contract for lower performance objectives when they worry about counter-party risk. These results lend insight into how contracts should be structured to minimize counter-party risk especially when there is market power. Finally, research examined contracting models related to the New York City ban on sodas in large containers, taxes on soda, and who gains and who loses from the restriction. The key finding is that the size-restriction predicted to reduce the size of sodas across all size categories, actually caused a decrease in size of the large soft-drink only. Sellers will keep the size of smaller drinks unchanged. This should lead to a reduction in consumption only by heavy soda consumers, which appears politically desirable. Low-consumption consumers will largely be unaffected. Soft-drink consumers will suffer more welfare losses under the tax than the size restrictions because the price per ounce will increase under the tax. Not surprisingly, soft-drink sellers are likely to have their profits reduced. These studies provide insight into the marketing and contracting related to agribusinesses.

Title

Jackson and Lawrence Counties Address Obesity with Evidence Based Interventions

Extension

Donna Vandergraff, Martha McDavid, Timothy Gavin, Molly Marshall, Tanya Hall

Outcome

48 - # of counties that have active health coalitions

Issue

In 2012, Jackson and Lawrence Counties had an adult obesity rate over 40%, the highest in Indiana. Obesity is linked to negative health outcomes like diabetes, heart disease and some cancers. Regular physical activity and healthy eating can help reduce these risks but, citizens of rural areas and from low-income backgrounds are less likely to have access to recreation opportunities, and fresh and healthy food retail. Amenities and services that promote healthy behaviors tend to be primarily available residents in particular geographic areas. Rural communities often have limited resources (e.g., capital, leadership) which may fuel negative perceptions that there is little support to improve health outcomes or improve health promotion efforts.

What has been done

With six counties added in 2018, now Indiana has a total of 48 counties with one or more active health coalitions. In Jackson County, the Healthy Jackson County Coalition, and in Lawrence County, the Live Well Lawrence Coalition, represented small groups of individuals who saw a need to develop new opportunities for health in their communities. The Healthy Jackson County Coalition aims to: 1) lead efforts focusing on communication, education, access, sustainability, and collaboration among community members, 2) provide and promote access to healthy foods, 3) provide education and promotion on how to use and consume healthier foods, and 4) provide opportunities for all community members to participate in physical activity. The Live Well Lawrence Coalition aims to: 1) establish a community voice for health across the entire county, 2) enable and support local organizations to integrate healthier food options, and 3) promote the many free physical activity opportunities across the county to community members. Both coalitions were motivated to pursue projects and programs but, general support had waned over the past few years. Both coalitions were poised for a revitalization and redirection to pursue policy, system, and environmental (PSE) changes to foster long-lasting health benefits in their communities. To avoid common pitfalls of coalitions (members focus on leading single, short-term activities and programs, and ignoring operating structures and processes) and to support a long-lasting coalition that initiates sustainable change, considerable time and resources were devoted to supporting coalition function, partnerships, and leadership. The work of these coalitions provided the context to seek Centers for Disease Control and Prevention (CDC) funding for the health of Jackson and Lawrence County citizens. A vital aspect of the partnership between the CDC and Purdue was to ready citizens in both counties to support healthy lifestyles in their hometowns long after the grant period ended. Purdue Extension team members focused on building coalitions that used evidence-based practices to pursue their aims. Purdue Extension led initial meetings on establishing trust, building partnership, and learning about organizations and people that share common interests and goals, focusing members on sustainability by educating them on the importance of PSE changes, facilitating transition to more community-led leaders by establishing committee chairs and mentoring potential leaders, and building momentum for coalition activities by pursuing quick victories to keep members energized and committed. Many activities required onboarding of new partners and community leaders. The coalitions steered clear of hosting single events (e.g., half marathons) and, instead, worked to educate the public, change environments, and make policy changes to instigate longer lasting change.

Results

Community accomplishments for Healthy Jackson County Coalition included: 1) Safety activities: new downtown crosswalks and bike lanes in Seymour, updated and additional crosswalks near schools and public pool in Brownstown, and, purchase of the comprehensive CATCH health promotion curriculum for after-school and preschool nutrition and physical activity programs in Seymour, Brownstown, Medora and Crothersville. 2) Increasing healthy food consumption activities: School wellness policy for over 6,900 students in Seymour, Medora, Brownstown, and Crothersville schools, Farmers Market SNAP benefit promotion, distribution of healthy food donation guidelines, gardening projects led at youth clubs, healthy concession stands at schools and youth sport leagues for over 32,000 residents and at city recreation facilities for over 76,000. 3) Physical activity efforts: exercise ideas signage on Refuge Trails with 170,000 annual visitors, "walk your city" signage in Seymour with 48,000 visitors per year, and improved crosswalks, bike lanes, and new fitness equipment in Seymour for over 48,000 potential users. Community accomplishments for Live Well Lawrence Coalition included: 1) Safety activities: National Walk to School Day, active routes to school, and reflective paint on crosswalks in Mitchell, complete streets policy in Bedford, and continued work to establish Mitchell as a Trail town. 2) Increasing healthy food consumption activities: school wellness policy for 6,200 students, healthy concession stands for over 6,000 participants, and healthy food pantry donation guidelines for facility with 19,000 people served. 3) Physical activity efforts: established the Blue Jacket Trail for 45,000 residents with 1.1 miles of marked walking trail with signage, online map of trail system, adult outdoor exercise equipment for Mitchell, Judah, Fayetteville, and Springville,

and installation of bike racks, benches, and active transportation signage on Main Street in Mitchell. As demonstrated by the reach and leveraged funds, the coalition influence extends beyond the activity and serves as a mobilizer of new people and places to support the health of citizens.

Title

Food systems, health, and well-being: Understanding complex relationships and dynamics of change

Research & Extension

Bhagyashree Katare, Agricultural Economics

Outcome

5 - HHS 1.3 - # of discoveries, innovations, technologies relation to Health Disparities

Issue

Major health issues arise from the American food system, as prevalence reports show food-related issues: chronic disease (such as diabetes, cancer, and heart disease), obesity and food insecurity. Understanding why and how obesity rates are stabilizing among some groups while increasing in others is key to developing strategies for decreasing obesity across populations. One link is the connection between obesity and food insecurity. Nearly 15% of households (over 50 million people) were food insecure in 2008 (up from 11% in 2007), meaning that at times they did not have enough money for food. Many food-related health problems disproportionately affect children, women, ethnic minorities, and low-income people. Addressing food insecurity, nutrition, and food-related diseases, requires understanding of the processes of institutional change, structural conditions, perceptions, and decision-making. As the obesity epidemic dominates healthcare, prevention and treatment, and as food insecurity increases, nutritionists are beginning to understand that efforts must move beyond individual behavior change. New and community-engaged approaches to conceptualization, study, outreach and integration are needed to address constraints to health and well-being including obesity, food insecurity, diabetes and other chronic diseases.

What has been done

This project examines family, community, and institutional dynamics to better understand how the food system influences individual and population health. This includes investigating the interaction between food consumption by families and how family food selections are influenced by interactions family members have with one another and with their food environments. Activities included: 1) Analyze best practices proven effective at increasing individual, household, and community food and nutrition security, and identify individual and systemic strategies for developing and disseminating initiatives to improve food and nutrition security. 2) Utilize food systems approaches to assess and address nutrition, health, and wellness challenges of vulnerable population groups (e.g., children, elderly, low income, immigrant, minority) with focus on food availability, appropriate policy systems and environmental changes. 3) Assess key strengths and weaknesses of current public and private emergency food assistance systems relevant to improving food security and addressing the health and nutritional needs of program participants.

Results

Researchers developed an innovative, reliable, and validated tool to measure perceptions of participants of direct education programs that affect their access to food and physical activity. Results showed a classroom nutrition education program was able to increase student knowledge about fruits and vegetables, recognition and nutrition content, but there was no effect on increasing consumption of fruits and vegetables. For individual perception of the environment on health outcomes, Extension educators collected data from 1,743 SNAP-Education participants from seven Northern and Central states about food, physical environment, and self-reported health characteristics. Participants were: 78% females, average age 44.43 years. 42% married, 41% employed, 55% reside in urban areas, and 59% non-Hispanic white. There were 43% classified as obese and 74% overweight. More than 68% agreed there is a large selection of fresh fruits and vegetables available, while 82% agreed there are plenty of opportunities for purchasing fast food. 75% shop for most of groceries at supermarkets or super stores, and these stores were, on average, 4.5 miles from their homes. Preliminary analysis shows individual perception about food environment is associated with health outcomes (obesity and BMI). For SNAP effect on nutrition, several groups of participants and non-participants were studied. Findings do not suggest a large impact of SNAP on food choice, and do not support a claim that SNAP has a

negative effect on nutrition. For a study on effectiveness of an unobtrusive method (nudge) to encourage choice of healthier food items in a client-choice food pantry, food items were given a zero to three stars for nutritional value. Before entering, clients were randomly assigned to treatment or control groups. Treatment group clients completed a survey with nutritional rating sheet for pantry items, and clients indicated likelihood of selecting them. Control group clients completed the survey only. After clients selected pantry items, researchers recorded selected food items. All of these research activities will help to increase understanding of problems and solutions in systems of the food, nutrition and health in our communities.

Climate Change

Title

Trace gas emissions from landscapes and agricultural operations

Research

Richard Grant, Agronomy

Outcome

2 - CC 1.6 - # New assessment and management tools developed, including models and measurements of greenhouse gas emissions

Issue

It is estimated that agriculture is responsible for 6% of total U.S. greenhouse gas emissions: primarily from methane (CH₄) and nitrous oxide (N₂O) (USEPA, 2014). The largest single source of CH₄ is enteric fermentation (USEPA, 2014). Fertilizer application and other cropping practices account for 68% of estimated emissions of N₂O. CO₂ emissions from land surface and agricultural operations must be evaluated to understand carbon cycling (Riveros-Iregui and McGlynn, 2009). Among three greenhouse gases (GHG), the Intergovernmental Panel on Climate Change (IPCC, 2001) specified methods for nations to estimate the GHG emissions of each sector of the economy (IPCC, 1997), which is to multiply an activity (for example, tons of manure applied to cropland) by an associated emission factor (Kebreab et al 2006). While NH₃ is not a GHG, it is considered to be a secondary GHG because N₂O is often produced through oxidation of NH₃. Livestock management and fertilizer application contributed about 85% of total ammonia emissions in 1998 (USEPA, 2002). The USEPA inventory indicated typical N losses as NH₃ of 38% for dairies and 63% for swine operations (USEPA, 2004). Recently emissions estimation methods for livestock operations and land surfaces at farm-scale have been promulgated by the USDA (Eve et al, 2014), but there remain significant gaps in our ability to estimate GHG and NH₃ emissions.

What has been done

This study evaluates emissions from many agricultural operations where little is known, such as N₂O and NH₃ emissions from fields with applied manure or inorganic fertilizer and CO₂ and CH₄ emissions from pastureland. Project objectives are: 1) Develop methodologies to measure NH₃, CO₂, CH₄, and N₂O emissions from landscapes and fugitive sources including agricultural and natural gas production operations. 2) Measure NH₃, CO₂, CH₄, and N₂O emissions from cropping and livestock agricultural operations spanning a range of management practices and geographic/ climatological zones. 3) Determine the effect of animal type and management regime on livestock greenhouse gas (GHG) emissions and the effect of crop and soil type, and weather on cropped-land GHG emissions.

Results

Measurements of NH₃ were made in June 2018 using open-path tunable diode laser (TDL) NH₃ concentrations across a single fertilized field for a total of 272 half-hour periods. Measurements of N₂O emissions were made between May and July 2018 using cavity ring-down laser N₂O concentration measurements of line-sampled air collected around the edge of two adjacent fertilized fields for a total of 1692 half-hour periods. Measurements are being completed as part of a proof-of-concept of high-throughput processing of the diverse set of measurements (Internet of things) using edge-of-cloud preprocessing and a parallel stream transformational loader in combination with high performance computing of

the final emissions. Swine waste storage is a major source of agricultural NH₃ emissions. Hog manure is stored in slurry pits, tanks, or lagoons. Ammonia emissions from a ground-level midwestern hog finisher manure tank collecting manure from a mean of 3508 animals was measured for 8 to 20 days each quarter of the year for two years. Emissions from the tank were greater on an area basis but comparable on an animal basis relative to emissions from much larger anaerobic lagoons. Emissions were correlated with air temperature and manure composition, but not wind speed or friction velocity, probably due to the turbulence created by the tank structure under all winds. Crusting of the manure surface in the tank corresponded with a non-significant 10% increase in NH₃ emissions. Manure on dairies is the second largest agricultural source of NH₃ emissions. Ongoing analyses of ammonia emissions at a western open-lot dairy were conducted. Ammonia concentrations measured by TDL concentration measurements and turbulence by sonic anemometers were analyzed. Both 30-minute and daily average emissions were influenced by air temperature. Emissions were also linearly related to wind speed. A distinct daily pattern in NH₃ emissions was consistent with daily patterns in both wind speed and air temperature. The mean daytime emissions were twice the mean nighttime emissions. Daily emissions varied over the year with summer emissions twice that of winter. Annual emission for the farm was estimated with summer emissions twice that of the fall and winter. Additional studies are needed to evaluate the frequency of high emission days during the summer.

Title

A regional-scale study of invasive plant impacts on forest ecosystem

Research

Songlin Fei, Forestry and Natural Resources

Outcome

24 - CC 1.8 - # New climate relevant databases, monitoring systems, and inventories managed or under development

Issue

The Central Hardwood Forest is one of the most important forest ecosystems in the eastern U.S., harboring high diversity of native species and providing valuable economic and recreational opportunities to the citizens of the region. With ongoing fragmentation, new fire regimes, modern land-use and forest management practices, and other factors, invasive exotic plants are moving into these economically and ecologically important forest ecosystems, in some places reaching epidemic proportions. The health and longevity of these forest ecosystems are at risk. Long-term invasion of exotic plants can alter composition and reduce diversity of these ecosystems, especially those mast-bearing, fire mediated oak and hickory species. Such a compositional change could result in dramatic declines in wildlife population and diminished economic opportunities for the human inhabitants of these largely rural regions. Moreover, forests play an important role in U.S. economy. In the Central Hardwood Forest region alone, over 255,000 individuals are employed in forestry-related jobs (AFPA 2012). On the other hand, invasive species cost the American public about \$1,300 per household each year based on an earlier estimation (Pimentel et al. 2005). Therefore, research on the impact of invasive species on forest health and strategies in order to remediate the impact will have huge economic implications.

What has been done

The overarching goal is to understand impacts of invasive plants on forest ecosystem dynamics at the regional level by including spatial heterogeneity and system stochasticity. Understanding biodiversity-productivity relationships (BPRs) is of theoretical importance, and has important management implications. Most work on BPRs has focused on simple and/or experimentally assembled communities, and it is unclear how these observed BPRs can be extended to complex natural forest ecosystems. Research objectives are: 1) Evaluate the extent and severity of invasive plants impact on tree growth, mortality, and recruitment. 2) Understand the impact of plant invasions on soil organic carbon pools and temperature sensitivity. Researchers analyzed U.S. Forest Inventory and plant data from 2012-16 including species composition, diameter, height, age, and other attributes from more than 115,000 forest plots from the 48 contiguous states.

Results

Findings, reported in the journal Nature Communications (<https://www.nature.com/articles/s41467-018-07880-w>), reveal that relationships between biodiversity and forest productivity depend strongly on climate. Researchers

demonstrated there is a positive biodiversity-productivity relationship in dry, especially warm climates. Forests in dry, warm climates show a positive linear relationship between biodiversity and productivity, meaning the forest becomes increasingly productive as more species are introduced. As humidity rises, the relationship changes and productivity rises and then declines as species richness increases. But in areas that are humid, the relationship between biodiversity and productivity curves. Biodiversity and productivity increase together until a point at which more species begin to cause productivity declines. The findings are important for management, restoration and conservation of forests, many of which provide important ecosystem services but are threatened by deforestation, climate change and invasive species. Climate change needs to be considered when making these management decisions. A cool, wet forest today could look much different in the coming decades. Climate change is going to push these forests into a different climate zone, potentially changing the biodiversity-productivity relationship. Climatic variation is an underlying determinant of contrasting BPRs observed across a large spatial extent, while both biotic factors (e.g., stand age and density) and abiotic factors (e.g., soil properties) can impact BPRs within a given climate unit. These findings suggest that tradeoffs need to be made when considering whether to maximize productivity versus conserve biodiversity.

Title

Cover crop and drainage management systems impacts on crop production, soil health, N cycling and water quality

Research

Shalamar Armstrong, Agronomy

Outcome

1 - GFSH 2.13 - # of projects related to managing impacts from large-scale operations: non-point source pollution, water use & allocation, watershed impacts, model development

Issue

Within the Upper Mississippi River Basin, the autonomy of farmers in making nutrient management decisions for their row crop agricultural fields continues to be threatened due to the loss of nitrate via tile drainage that contributes to impairments in the Gulf of Mexico and local drinking water sources. Nutrient loading the Gulf of Mexico from tile-drained agricultural land continues to be an environmental issue that threatens the sustainability of row crop agriculture. In the future, farmers may be required to comply with federal regulations concerning surface and subsurface runoff leaving their fields. Whether specific conservation practices remain voluntary or become mandated in the Midwest, data from this research program will be a source of information for farmers to use to make critical management decisions. Strategies are needed to better enable subsurface tile drainage to perform its critical function in removing excess water in spring, while reducing the unwanted loss of nitrate in the drainage waters.

What has been done

This program identifies and investigates adaptive agriculture management practices that improve sustainability and resilience of cropping and nitrogen management systems to climate variation through increased soil health, water quality, and crop production. Understanding cover crop impacts on N availability and rate and soil health are vital in increasing cover crop adoption, reducing nitrate loading, and maintaining sustained profitable yield in the Upper Mississippi River basin. Project investigations are: 1) ability of cover crops to conserve N within corn and soybean cropping systems and reduce nitrate loading via tile drainage; 2) decomposition of cover crop residue after termination and the synchronization of cover crop N release with cash crop N demand; 3) cash crop utilization of N release from cover crop residue; 4) impact of cover crops on the diversity of the soil microbiome over time; and 5) impacts of cover crops on soil health and crop production. Soil samples were taken to characterize long-term changes in properties from subsurface drainage installation 35 years ago. Long-term tile drainage/water quality studies at Southeast Purdue Agriculture Center had drainage tiles installed at 5, 10, 20, and 40 m spacing in 1983, and changes in flow characteristics have been observed over time. Samples were taken at multiple depths and distances from the drains, to characterize bulk density, water retention, aggregate stability, carbon, nitrogen, and penetration resistance. Samples are being analyzed. Cover crop studies were continued at three Purdue research centers and 14 farmer cooperator sites, in collaboration with the Conservation Cropping Systems Initiative (CCSI) and other conservation partners in Indiana. A final soil health sampling occurred in summer 2018, to evaluate changes in soil health over a 5-year period from the baseline sampling in 2013. Individual farmer reports were prepared for each site through the 2016 sampling, and a

report of the more limited 2017 data was prepared. These reports are available on CCSI website:

<http://ccsin.iaswcd.org/>.

Results

Findings quantified the impact of different N management timings and the inclusion of cover crops on nitrate-nitrogen loading and determined that cover crops had the ability to significantly reduce the loss of nitrate-nitrogen from a tile-drained field despite the nitrogen application timing. Cover crops reduced the leaching of dissolved reactive phosphorus. A major accomplishment was characterizing the dynamic and extent of soil bacteria microbiome response to inclusion of different cover crop species. The soil microbiome is the driver of nitrogen availability, thus understanding its response to cover crop adoption will help inform farmers to alter nitrogen fertilizer management following adoption of cover crops for optimum production. Another significant accomplishment was the development of methodology allowing cover crop adopting farmers the ability to perform in-season cover crop stand surveys of biomass and nitrogen uptake with only limited field sampling. This in-season survey is critical because it informs the cover crop management (termination) and cash crop management (nitrogen application timing and rate and residue management setting on the planter). Other findings quantified the synchrony of cover crop carbon and nitrogen release with corn and soybean critical nitrogen demanding growth stages. Quantified actual nitrogen uptake by corn and soybean planted subsequent to a cereal cover crop. This accomplishment is critical because it will help educate farmers and associated community on what percentage of N from the cover crop residue is used by the following cash crop, which could lead to adaptive management. Significant advances were made toward determining short-term economic benefit and risk of cover crop adoption. Data generated from these studies have the potential to help farmers better understand how cover crops interact with fertilizer and soil inorganic N, the relationship between cover crop species, termination timing and N release from cover crop residue in the cash crop growing season, the availability of N from cover crop residue, and the range of improvements in soil health that can be expected from cover crops.

Title

Assessing and improving sustainability of confined animal feeding operations

Research

Al Heber, Agricultural and Biological Engineering

Outcome

25 - FME 2.1 - # of discoveries, innovations, technologies and technology transfer related to performance management of farms

Issue

In livestock industries, the primary objective is efficient production of high quality, nutritious and wholesome meat, egg and dairy products for health-conscious consumers at reasonable cost. In addition, accumulation of N and P in soils and the threat to quality of surface water are major livestock production sustainability issues. The need is great to minimize the flow of detrimental levels of dietary nutrients through animal manure for an environmentally-sustainable animal production practice. Therefore, the efficiency of dietary nutrient utilization to minimize the flow of detrimental levels of dietary nutrients through animal manure to the environment is an important research goal. Understanding the role of manure storage, treatment and application with respect to nutrients and GHG dynamics across air-soil-water interfaces and its impacts on local microbial function is expected to lead to substantial improvements in managing manure application and predicting its environmental impacts. Effective manure treatment and methods of application can have significant impact on N and P cycling, and gas emissions in agriculture and ecosystems.

What has been done

Research goals are: 1) determine the influence of exogenous enzymes and modified feed ingredients on ileal and total tract digestibility of N and P, and nutrient excretion and gaseous emissions. 2) Evaluate effects of diet on health status and environmental footprint of swine and broiler production. 3) Reduce impact of odor, particulate matter, and noxious gases emitted from confined animal facilities. 4) Improve understanding of the impacts of manure storage, treatment, and land-application on N, P, and greenhouse gas transformations and losses across air-soil-water interfaces.

Results

Thirty-two barrows were used in a 35 day experiment to evaluate effects of supplemental soluble fiber (dextrin) pre- and post-weaning on growth performance and volatile fatty acids (VFA) production. Fiber was suspended in chocolate milk and administered orally through a syringe from 14 days prior to weaning until 4 days post-weaning, after which it was included in the diet at 1%. At weaning, pigs were group housed by treatment and allowed ad libitum access to a common starter diet. On day 4 post-weaning, pigs were moved to individual pens and fed diets with or without 1% fiber. Weights and feed intake were recorded 14 and 3 days prior to weaning, and on day 0, 4, 11, and 21 post-weaning. On day 21 post-weaning, pigs were euthanized, and large intestine contents were collected for VFA analysis. Growth performance was not affected by treatment. A trend for an interaction of pre- and post-weaning fiber supplementation was observed for acetate and butyrate concentrations in large intestine contents. Pigs fed fiber only in the nurse had the highest acetate concentration, while pigs never receiving fiber had the lowest concentration. Pre-weaning fiber supplementation followed by no fiber in the nursery resulted in the highest butyrate concentrations with all other treatments being similar. Fiber supplementation pre-weaning tended to reduce isobutyrate concentrations. Pigs not receiving fiber post-weaning had increased valerate concentrations. Fiber supplementation caused alterations in VFA concentrations when fed during pre- and post-weaning, indicating possible shifts in the microbiome, immune status and barrier function of the intestinal tract. Researchers completed: 1) diet manipulation and air quality in an experimental swine building, and 2) effects of dairy manure anaerobic treatment on nutrient flow in the environment. A model to predict thermal environment inside sow gestation barns was completed. Model inputs are weather, building orientation, dimensions and materials, geographical location, and sow herd characteristics, and outputs are daily means of inside temperatures and ventilation rates, and annual costs of electricity and supplement heat. The model showed that total energy costs are influenced significantly by temperature set point, thickness of ceiling insulation, and minimum ventilation rate. For an indoor recirculation aquaculture systems study, 3 Tilapia and 2 shrimp buildings were surveyed in winter and summer, and temperatures were recorded for at least 2 weeks. Recommendations were made to remedy observed inadequate ventilation rates and air distribution, excessive surface condensation, excessive heat loss, improper attic ventilation, inadequately sized heat exchangers, ill-advised use of expensive dehumidifiers, improper vapor barrier installation, and ill-advised use of ceiling inlets. A spreadsheet model was developed to calculate building heat loss factors and heat and moisture balances, predict surface condensation, determine proper ventilation rates, and estimate energy usage. Calculations showed ventilation is more efficient for removing humidity than dehumidification, and uninsulated floors are responsible for a significant amount of building heat loss. Results and conclusions from these studies can provide supporting information to assist research-based decision making and lead to more eco-friendly manure management practices, which will effectively reduce environmental pollution from agriculture and preserve a sustainable environment.

Food Safety

Title

Retail Food Safety in Indiana

Extension

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Outcome

5373 - FS 3.2 - # Food handlers receiving food safety training and education in safe food handling practices

Issue

Foodborne illnesses are common, costly, yet preventable, public health problems. CDC estimates that 1 in 6 Americans gets sick from contaminated foods or beverages and 3,000 die each year. The USDA estimates that food borne illnesses

cost \$15.6 billion each year. Reducing foodborne illness by 10% would keep 5 million American from getting sick each year. Preventing a single fatal case of E. coli infection would save an estimated \$7 million.

What has been done

Purdue Extension Health and Human Science (HHS) Educators have become certified instructors and proctors for the ServSafe curriculum. Purdue Extension partners with the National Restaurant Association, Indiana Restaurant and Lodging, ServSafe, State and Local Boards of Health, and Ivy Tech community college to provide one- and two-day trainings, recertification training, proctoring of exams, and the Food Handler training for those in the food service industry needing certification to meet Indiana Food Code requirements. Other partnerships are with local area restaurants, hospitals, country clubs, schools, senior living facilities, food trucks and Illinois business owners.

Results

27 Health and Human Sciences educators and one specialist have become certified as dual instructors and proctors for the ServSafe curriculum for Manager Certification. In 2017-2018, 44 one-day, 12 two-day, 10 Recertification trainings and 278 Exam-Only sessions were taught and proctored across Indiana. There were 688 participants in the one- or two-day trainings with 602 (88%) achieving certification on the exam (average score 84%). 88 individuals participated in the recertification training with 77 (89%) receiving certification (average score 85%). 278 took the exam either online or on paper with 218 (78%) receiving certification (average score 81%). A total of 1,052 attempted the exam either with direct training and 897 (85%) received certification. The Food Handler program was offered 4 times with 36 participants and 29 (80%) received a certificate of completion (average score 78%). A total of 123 participants completed the end of session surveys: 1) 74% found the program valuable, 2) 95% felt the objectives were realistic, 3) 93% thought they learned more than reading on their own, 4) 93% felt the resource people were well prepared, and 5) 93% found the materials were presented at the proper level of difficulty. As a result of the training: 1) 74% were washing hands more frequently during food preparation of and service, 2) 80% were checking temperature of food to make sure it had cooked to a safe temperature, 3) 84% were taking temperatures of food to make sure it cooled quickly to a safe temperature, 4) 81% were keeping raw foods separate from ready-to-eat foods, and 5) 79% were making sure all work surfaces, equipment and utensils were cleaned and sanitized before preparing and serving foods. Having workers trained, certified, and adopting safe practices in food preparation will help contribute to reducing risk of food borne illnesses in Indiana.

Title

Colloidal Phenomena in Food and Bioprocessing

Research

Ganesan Narsimhan, Agricultural and Biological Engineering

Outcome

6 - FS 1.2 # Viable prevention, control and intervention strategies for all food production scales for foodborne threats along the food production continuum

Issue

Cell death resulting from pore formation in cell membranes by peptides has important consequences in biology. An important function of pore forming peptides is in the defense of plants and animals against invading microbes. These antimicrobial peptides could also be very useful for combating drug resistant microbes. The exact mechanism of pore formation and cell death is not well understood. Elucidation of this mechanism can be applied to arrive at guidelines for design of antimicrobial peptides to replace antibiotics. Much lower intensity ultrasound can deactivate a microorganism by thinning the cell membranes as a result of regular oscillations of bubbles produced by cavitation. Ultrasound has found recent applications in sterilization of food when used in combination with heating or high pressure (or both) by increasing the efficiency of the process. It is of interest to lower processing cost of food products to improve quality and safety at lower cost. For conventional sterilization processes, energy input required to produce products with impeccable safety is very high. It is believed that pore formation by antimicrobial peptides (AMP) will be assisted by thinning of the cell membranes that are caused by low intensity ultrasound. Combined use of antimicrobial peptides with low intensity ultrasound is expected to be more energy efficient than conventional processes with minimum loss of quality. Pathogenic bacteria are known to develop resistance to antibiotic which is its biggest limitation. As compared to

the traditional antibiotics, AMPs kill bacteria rapidly and can involve multiple targets. Naturally occurring AMPs are expensive and are of limited availability. Currently, there are no rational methodology for design of synthetic peptides (SP) with antimicrobial activity. Selection of SP for specific activity would require screening of large number of potential candidates. Such a screening by experimental investigation of kill rates of microorganism is currently empirical and is therefore not feasible. For example, synthesis of one gram of an AMP can cost up to \$400, whereas for a conventional antibiotic, this price can be under \$1. Thus, commercial-scale production platforms to synthesize AMPs are urgently needed.

What has been done

Curcumin (CUR) is a natural food ingredient with known ability of targeting microbial cell membrane. In this study, the interaction of CUR with different types of model lipid bilayer (POPE, POPG, POPC, DOPC, and DPPE), mixture of model lipid bilayer (POPE/POPG), and biological membrane mimics (E. coli and yeast) were investigated by all atom explicit solvent molecular dynamics (MD) simulation. CUR readily inserts into different types of model lipid bilayer systems in liquid crystalline state, staying in the lipid tails region near the interface of lipid head and lipid tail. Parallel orientation to the membrane surface is found to be more probable than perpendicular for CUR as indicated by the tilt angle distribution. This orientation preference is less significant as the fraction of POPE is increased in the system, likely due to the better water solvation of perpendicular orientation in POPE bilayer. In E. coli and yeast bilayers, tilt angle distributions were similar to that for POPE/POPG mixed bilayer with water hydration number around CUR for the former being higher. Insertion of CUR resulted in membrane thinning.

Results

The results from these simulations can provide insights into the possible differences in membrane disrupting activity of CUR against different types of microorganisms. Recent studies have shown that both low frequency (20-100 kHz) ultrasonication and antimicrobial peptides (AMPs) treatment processes have a significant advantage in inactivating bacterial cells than the conventional heat treatment due to higher food texture quality of the final product. However, the effect of the combined process has not been fully investigated in complex matrices such as food. In this study, deactivation of Escherichia coli in different concentrations of milk and orange juice were performed using three different treatments: low frequency ultrasonication (20 kHz) at different power levels, antimicrobial peptide Cecropin P1 at different concentrations, and combination of both. The results of all samples showed that the combined treatment is more efficient, reducing the cell density of E. coli up to four orders of magnitude, compared to individual treatments. However, the milk concentration results in lower synergistic effect. This is believed to be due to complexation of milk proteins with Cecropin P1 thus resulting in less availability of the latter for antimicrobial action. This dependence was not observed in orange juice samples.

Title

Characterization of the lettuce microbial community by metagenomic sequencing and optical light scattering

Research

Bob Pruitt, Botany and Plant Pathology

Outcome

3 - FS 4.1 # Projects focused on increased understanding of the ecology of fecal indicators and pathogens

Issue

There are major gaps in our understanding of how well human pathogenic bacteria persist as members of plant-associated microbial communities and what factors influence their survival. Fungal metagenomic data for fresh produce are lacking, as are datasets that combine both fungal and bacterial communities from leafy greens. Analysis of the community will allow us to identify changes that are associated with the presence of human pathogens. In addition, the fresh produce industry currently does not have a method to rapidly screen samples for spoilage and/or pathogenic microorganisms that may be associated with the product. Creating a database of BEAM scatter patterns and DNA barcodes from microbes that are associated with lettuce will provide the industry with a means to identify and prevent the distribution of contaminated product to consumers. Research is needed to generate baseline data for the bacterial and fungal communities that are present on lettuce and how this influences the entry and persistence of human

pathogenic bacteria into the plant phylloplane (leaf surface habitat for microorganisms). This research may also identify species that increase or decrease when pathogens are present. These indicator organisms may then be used to predict the presence of human pathogenic bacteria, even if the number of the pathogens is low. The work described here will extend the technology to characterize an entire bacterial community through the production of an extensive library backed by DNA sequence based taxonomic identification.

What has been done

The overarching goal of this project is to try and better understand the role that the natural bacterial community associated with romaine lettuce plays in the establishment and persistence of human pathogenic bacteria on commercially grown lettuce. To accomplish this goal we are adapting an existing technology (BEAM optical light scattering) to address a new type of problem: providing taxonomic identification of a wide range of bacterial species in a mixed community isolated from nature. Changes in the microbial communities will be characterized following the addition of bacterial pathogens. This will help establish possible indicator organisms that can be used to detect contamination if present, as well as establish a library for BEAM that can be used by the leafy green industry to rapidly sample products to determine the spoilage and/or pathogenic organisms present.

This has not been without its challenges, but additional work on both the protocols and the software can most likely meet these challenges. The team is beginning to directly look at how the composition of the native bacterial community affects the growth of the human pathogens on the lettuce leaf. These effects turn out to be highly sensitive to the environment in which the lettuce plants are growing and so additional work will be required to identify the critical factors involved. A photographic library of the colony morphology of the identified bacterial genera associated with romaine lettuce is also being created as a web-based tool to be used as an identification guide for the fresh produce industry.

Results

Objective 1: Develop and test BEAM library of bacterial and fungal genera associated with romaine lettuce and validate BEAM as a tool for making taxonomic assignments at the genus level. Four BEAM libraries of the lettuce microbial community by collecting scatter patterns of 31 bacterial strains representing the 10 most abundant genera of bacteria found on romaine lettuce have been. These strains were divided into 4 libraries based on the optimal incubation time for a well resolved scatter pattern. Training sets were created with these data, and the Positive Predicted Values (PPV) of the cross-validation (CV) matrix were above 90% for all but one of the genera. Validation with pure cultures achieved PPVs of greater than 80%, but some genera showed misclassification rates up to 44% when grown in mixed cultures. Five bacterial genera were identified that produce similar scatter patterns. This issue will be addressed by increasing the number of features differentiating these bacterial genera in order to decrease their misclassification rates as well as by using a two-step classification system that allows clearer distinctions to be made between a smaller number of closely related scatter patterns.

Objective 2: Determine the effect of lettuce bacterial community composition and spatial distribution on the ability of human pathogens to establish themselves in the community and survive treatment with chemical sanitizers. This objective will also identify organisms that are possible indicators for the presence of human pathogens. Inoculation experiments have been carried out using small numbers of human pathogenic bacteria (100-200 cells) on lettuce leaves either removed from the plant and kept in a controlled environment or on intact lettuce plants growing in the greenhouse. Inoculated leaves grown in highly humid environments demonstrated that the pathogens are able to persist and replicate at variable rates under these conditions, with the growth rate observed depending on the age of the lettuce leaf. Pathogenic bacteria inoculated on plants in the greenhouse proved to be eliminated rapidly, probably due to the very low humidity found in this environment. A controlled set of experiments at varying temperatures and humidity's is currently underway in growth chambers.

Title

Food Safety and Good Agricultural Practices for Growers

Extension

Amanda Deering, Scott Monroe, Rhonda Taylor

Outcome

268 - FS 3.1 # Growers, producers, and food workers completing GAPs, GMPs, HACCP, food safety certification and on-farm BMP programs to increase food safety

Issue

The Food Safety Modernization Act (FSMA) was signed into law in 2011. The law shifted the role of the FDA from reaction to prevention. This shift required all states to evaluate their programs and regulations regarding the production and sale of food along the entire food supply chain. The Produce Safety Rule was the newest and one of the more complex rules introduced and little was available with regards to consistent or mandatory training. In response to the Produce Safety Rule, an increased number of wholesale buyers are asking more fruit and vegetable growers to have a third-party audit before they will purchase produce from their farms. The third-party audits are very expensive (\$900-\$10,000 depending on the size of the farm and the number of different crops grown) and this cost is mostly associated with travel and travel time as there are no Indiana based auditors.

What has been done

The Indiana State Department of Health, in collaboration with Purdue University developed extensive training protocols to meet FDAs new Standards for the Growing, Harvesting, Packing, and Holding of Produce for Human Consumption. To address the possibility of establishing an Indiana based third party audit system, Purdue worked with consultants (New Venture Advisors) to conduct a needs and feasibility study. This study involved growers, regulatory agencies (ISDH, ISDA), buyers, and Purdue Extension and the results indicated that a third-party audit system was feasible in Indiana. By combining several Hatch projects and previously funded USDA research with FDA funding, Indiana was able to administer the regulatory compliance of the Produce Rule of FSMA. Part of this training included an educational component to help growers learn about FSMA and the Produce Rule as well as teaching the Produce Safety Alliance Good Agricultural Practices Training that all growers who are covered by the Produce Rule need to take to be compliant (this replaced the previous GAPs A-Z training that was developed and offered by Purdue Extension).

Results

A total of 22 PSA GAPs trainings with a total of 260 people receiving certificates of completion from the Association of Food and Drug Officials were delivered since November 2016. Although funding has not been received to make a third-party audit system viable in Indiana, Purdue has been offering on-site farm visits and performing mock audits on farms to help them prepare for a third party audit. To date, Purdue has assisted 7 farms (who were doing a third-party audit for the first time) to pass their audit on the first attempt.

Global Food Security and Hunger

Title

Calcium signaling in pig oocytes

Research

Zoltan Machaty, Animal Sciences

Outcome

120 - GF 1.3 - # of increased efficiencies (i.e. (% pregnant), or increases in yield/unit (bushels/acre; lbs. product (meat, protein, milk) per animal; lbs. feed per gain).

Issue

Foundational information is needed to improve the efficiency of swine oocyte activation methods especially in assisted reproductive technologies such as in vitro fertilization or somatic cell nuclear transfer. Despite its significance, the complete mechanism of the fertilization calcium signal has never been characterized--in particular, repetitive calcium signaling. Cloning by nuclear transfer of genetically modified cells is the only method on hand for making pigs with specific genetic modifications. However, our inability to properly activate the oocyte reconstructed during nuclear transfer is one of the reasons for the extreme inefficiency of nuclear transfer procedures. Because we don't know the

underlying mechanism that mediates calcium signaling in fertilized oocytes we are not able to artificially induce the repetitive signals. Increasing our knowledge of how the sperm triggers the oscillatory calcium signals will enhance our abilities to more precisely control the process of signaling during embryo production in the laboratory.

What has been done

The project has focused on how to trigger repetitive calcium signaling in the oocyte's cytoplasm. Each elevation in the intracellular calcium concentration is followed by a calcium influx across the oocyte's plasma membrane. The team has been investigating the molecular identity of the components of the entry pathway to identify the molecules that are responsible for the generation of calcium entry across the plasma membrane. They have also been determining whether the calcium influx serves simply to replenish the calcium stores or whether it is also responsible for the activation of critical signaling pathways required for complete oocyte activation. Defining the mechanism and functions of calcium entry has deepened the knowledge about oocyte physiology and may also help improve the efficiency of a number of assisted reproductive technologies such as in vitro fertilization and somatic cell nuclear transfer.

Results

The team previously demonstrated that store-operated calcium entry across the egg plasma membrane is essential for normal fertilization. STIM1 was shown to be a protein located in the membrane of the intracellular stores known as the endoplasmic reticulum, and it is able to detect calcium levels in the stores. The calcium influx channels were shown to be made of Orai1 proteins. Using Fluorescence Resonance Energy Transfer (FRET) it was shown that changes occur in the eggs following sperm-egg fusion, indicating that fertilization is associated with repetitive interaction between STIM1 and Orai1. Appropriate inhibitors were applied to strengthen the notion that STIM1 and Orai1 proteins are essential to sustain the fertilization calcium signal in pig oocytes. In addition, the role of magnesium in the regulation of the calcium signal was demonstrated. A series of experiments showed that magnesium blocks calcium entry, probably by inhibiting the kinase domain of the TRPM channel, which in turn blocks store-operated calcium entry. This supports the major hypothesis that store-operated calcium entry mediated by STIM1 and Orai1 proteins is essential to sustain the sperm-induced calcium signal during fertilization in pig eggs.

Title

Interfacial Engineering for Enhanced Food Quality and Security

Research

Carlos Corvalan, Food Science

Outcome

303 - GF 2.1 - # New or improved innovations developed for food enterprises

Issue

Food dispersions, such as gels, foams and emulsions, are major components of the human and animal diet. Examples of common food dispersions are jam, beer, whipped cream, dressings, mayonnaise, butter, spreads, and margarine. Food dispersions constitute a multi-billion dollar part of the modern food industry that will benefit from advancing the understanding of the properties, dynamics and rheology of interfaces. New knowledge and innovative computational tools that result from this effort will help address some of the most critical issues regarding interfacial processes that are essential to control the creation and stabilization of structures in food dispersions. It can also have a direct impact in the area of nutrition and health because interfacial properties strongly influence the dynamics by which foods interact with the gastrointestinal tract. By expanding our fundamental knowledge of interfacial phenomena, and improving the realistic representation of important interfacial processes in computer models, it is expected that this research will help design formulation and processing strategies for the production of food dispersions with higher nutritive value manufactured with greater efficiency benefiting human health and enhancing food security.

What has been done

The project focused on foams (dispersion of bubbles), emulsions (dispersion of droplets), and suspensions (dispersion of solids), which are major components of the human diet.

- 1) Research efforts focused on assessing the influence of formulation on the interfacial dynamics of food dispersions in order to enhance their stability and process-ability. The team completed and published new findings on the effects of surface-active molecules (surfactants) adsorbed on the surface of foam bubbles and emulsion droplets. These studies were carried on using formulations representative of both commercial surfactant additives (e.g. sorbitan and sucrose esters) and surfactant naturally present in foods (e.g. lecithin, proteins and polysaccharides).
- 2) Investigations continue on the bulk and interfacial rheology of food dispersion in order to assess the extent to which rheology can be modulated to optimize food processing. In 2018 new findings were published on the rheological properties of starch suspensions.
- 3) Another study on the importance of structural changes during the formation of nanoparticles made from maize amylose/beta-lactoglobulin/alpha-linoleic acid was developed and published.

Results

- 1) Surfactant results: The findings show that surfactant properties can be modulated to extend the lifespan of micropores nucleated at fluid-fluid interfaces because surfactants render the interfaces more elastic in their response to stresses (1 publication). Ultimately these results may enable food processors to design surfactant formulations to delay the coarsening of foams and emulsions improving their process-ability and increasing their shelf-life (1 publication).
- 2) Rheological results: The findings demonstrate that the swelling of starch granules is modulated by the degree of crosslinking in the starch network (1 publication). The gained knowledge enabled the formulation of an accurate mechanistic models to predict and control the swelling kinetics of starch suspensions (1 publication). The proposed model for starch swelling accounts for entropy of mixing, enthalpy of water-starch interaction and viscoelastic rheological forces.
- 3) The new insight into the structure of this amphipathic ternary nanoparticle is important to technologies for encapsulation of bioactive and aromatic compounds in food suspensions. Encapsulation cloaks the bioactive and aromatic compounds with a protective food-grade shell barrier that preserves them during processing, provides the ability to control their release for maximum effectiveness, and increases their solubility and bioavailability enhancing their health and nutritional value (1 book chapter).

Title

Purdue Wine Grape Team toasts to the 100th Indiana Winery and a \$600 million Economic Impact

Research & Extension

Christian Butzke, Bruce Bordelon, Katie Barnett, Jill Blume

Outcome

1 - GF 2.3 - # Innovations adopted in food enterprises including production, allied services, processing, and distribution

Issue

Indiana has a vibrant and growing wine industry that contributes significantly to the economic wealth of our State and enhances the lives and livelihoods of its residents and visitors. Between 1991, when the program was established, and 2018, more than 100 new wineries opened statewide. As wine grape production has increased in Indiana, growers and vintners demand up-to-date information on new grape cultivars, sustainability and pest management, winemaking techniques and marketing strategies.

What has been done

The Purdue Wine Grape Team (PWGT) conducted research that led to the selection of grape cultivars that match Indiana's growing conditions while exhibiting improved fruit quality. Wine production practices have been improved through winery consultations and analytical services. Extension workshops have been designed to engage stakeholders across the state and deliver the latest scientific information in viticulture and enology. The PWGT teaches Wine Appreciation to 250+ students as well as the upper level classes Commercial Grape and Wine Production and Commercial Food and Beverage Fermentations. The integrated Extension campaign Try on Traminette created an Indiana signature wine by utilizing the team's winegrowing, winemaking and wine marketing expertise. In 2018, the PWGT organized the 14th Vintage Indiana wine festival in Indianapolis, which attracted more than 8,000 wine consumers, and the 27th Indy International Wine Competition. With almost 2,000 entries it is the largest scientifically

organized event of its kind in the U.S. In 2018, the PWGT led the preparation of an independent Economic Impact Study of the Indiana wine industry that documented the significance of the team's efforts.

Results

According to the latest estimates, the Indiana wine industry now contributes more than \$600 million annually to the State's economy. Grape and wine production continues to be the fastest growing segment of Indiana value-added agriculture and agri-tourism. The Purdue Wine Grape Team engages with the Midwestern wine industries through Extension, research, marketing and promotion activities. Through Purdue's leadership, Indiana's wine grape acreage has increased 50% in the past ten years. Annual wine production surpassed 1.5 million gallons (8 million bottles) in 2018, a 30-fold increase since the PWGT began its efforts. Indiana wine sales are growing by more than 18% every year. The PWGT provides transformational Extension and research leadership for viticulture and enology programs nationwide. Wineries are the number one agri-tourism destination in Indiana with 630,000 annual visitors who spend \$94 million, while wine has emerged as a showcase for a valued-added agricultural product crafted in Indiana that sustains 3,900 jobs and \$120 million in paid wages.

Title

Poultry Production Systems and Well-being: Sustainability for Tomorrow

Research

Marisa Erasmus, Animal Sciences

Outcome

5 - DISEASES 1.6 - # of projects related to preventing poultry diseases and disease management

Issue

Public and consumer interest in animal well-being continues to increase along with concerns over food safety. A major welfare concern in the commercial turkey industry is that of skeletal integrity and footpad condition, specifically footpad dermatitis (lesions or inflammation of the footpad). Litter type and stocking density (the amount of space available per animal or average body weight per unit of space) are two major factors affecting footpad health and well-being of commercial turkeys. Although stocking density is recognized as an important factor influencing turkey well-being, there is little scientific evidence to support the use of a particular stocking density. Furthermore, the type of management protocol used also has a major impact on turkey well-being. In the commercial egg industry, there is movement away from conventional cage systems to alternative housing systems such as aviaries and enriched cages. However, scientific evidence regarding the impacts of these alternative systems on production, egg quality, food safety and animal well-being is lacking. Heat stress is an important poultry health and welfare issue, resulting in major economic losses. Little information is available regarding the effects of heat stress on broiler chicken behavior and core body temperature (CBT).

What has been done

The objectives of this study were to examine changes in broiler chicken behavior and CBT as a result of heat stress. Mixed-sex broiler chickens were housed in groups of 15 in 2 littered floor pens. At 34 days, data loggers (iButtons) were surgically implanted in 10 males and 10 females to continuously record CBT. Birds were maintained under thermoneutral conditions ($22.5 \pm 0.1^\circ\text{C}$) until 42 days, when cyclic heat stress (HS) was imposed. The HS cycle consisted of increasing the temperature from thermoneutral conditions to a mild HS period ($26.3 \pm 0.1^\circ\text{C}$), followed by a moderate ($30.1 \pm 0.1^\circ\text{C}$) and hot ($34.5 \pm 0.2^\circ\text{C}$) period. Each period was maintained for 1 h. Cyclic HS was repeated daily from days 42 to 45. Overhead video cameras recorded behavior on days 39 and 40 (pre-HS) and 42 and 43 (HS). Behavior (sitting, standing, drinking, eating, preening, dustbathing, walking and out of view) was analyzed using 10-min instantaneous sampling for the 17 h light period for focal birds with iButtons ($n=6$ males, 5 females) and birds without iButtons ($n=5$ males, $n=4$ females). The occurrence of panting was also recorded. All procedures were carried out in accordance with the guidelines of the Purdue University Institutional Animal Care and Use Committee. Data were analyzed using the GLIMMIX and MIXED procedures (SAS 9.4).

Results

The proportion of observations in which birds preened was higher pre-Heat Stress (HS) (0.07 ± 0.009) than during HS (0.05 ± 0.009 ; $P=0.01$) and was higher for females (0.07 ± 0.009) than males (0.05 ± 0.009 , $P=0.048$). Males (0.76 ± 0.02) sat more than females (0.70 ± 0.02 , $P=0.03$) and birds with iButtons sat less than birds without iButtons (0.76 ± 0.02 vs. 0.70 ± 0.02 , $P=0.02$). The proportion of observations that birds were out of view differed between pre-HS and HS periods (0.017 ± 0.008 vs. 0.05 ± 0.008 , $P=0.008$), males and females (0.02 ± 0.009 vs. 0.05 ± 0.008 , $P=0.01$), and birds with and without iButtons (0.05 ± 0.007 vs. 0.02 ± 0.009 , $P=0.03$). Core body temperature (CBT) differed among HS periods, males and females, behavioral categories and when birds were panting vs. not. CBT increased with increasing ambient temperature (thermoneutral: 41.33 ± 0.05 degrees C, mild: 41.92 ± 0.08 degrees C, moderate: 42.46 ± 0.08 degrees C, hot: 43.22 ± 0.08 degrees C; $P < 0.001$). Female CBT was higher than male CBT (42.53 ± 0.06 vs. 42.17 ± 0.06 , $P < 0.0001$). CBT was higher when birds were out of view, which typically occurred when birds were under the drinker (42.62 ± 0.06 degrees C, $P < 0.001$) than when birds were preening (42.35 ± 0.06 degrees C), sitting (42.38 ± 0.03 degrees C) and standing (42.28 ± 0.06 degrees C). CBT was also higher when birds were panting (42.44 ± 0.06 degrees C) than when birds were not panting (42.26 ± 0.06 degrees C, $P < 0.0001$). HS significantly affected broiler chicken behavior, with birds spending less time preening during HS. CBT differed depending on the behavior birds were performing. Further research is needed to identify early changes in behavior associated with increasing ambient temperature and CBT

Title

Neonicotinoid seed treatments in Bt maize: balancing contributions to insect resistance management with impacts on soil health

Research

Christian Krupke, Entomology

Outcome

5 - Data 2.1 - # of discoveries, innovations, technologies and technology transfer related to improving data, data reconciliation, improving insights, enhancing data collaboration

Issue

The European corn borer (ECB) (*Ostrinia nubilalis*) and western corn rootworm (WCR) (*Diabrotica virgifera virgifera*) account for over \$1 billion each in control costs and grain losses annually. Research conducted by this multi-state committee was used to develop models predicting the rates of resistance evolution and efficacy of refuge in preventing resistance. This led to the Integrated Pest Management (IPM) approach that used a 20% independent refuge planting; however, as genetically modified (GM) technology has evolved, so has IPM. Recently deployed GM corn hybrids use multiple genes that target ECB and WCR. The IPM plan for these hybrids requires a smaller refuge, and seed mixtures (Bt and non-BT) are now being deployed. The models supporting these IRM modifications were constructed using the best information available, but a number of assumptions had to be made. These assumptions must be tested and research conducted to move them from assumptions to quantified variables. Furthermore, information is needed on the economics of this evolving technology at the field, farm, and regional levels. Addressing these knowledge gaps forms the basis for several objectives of the project. The long-term goal of our research is to develop sustainable ways to manage the corn insect pest complex.

What has been done

The relationship between pest management technologies and the agricultural environment was investigated. The committee worked on 3 objectives. First, they assessed the need, efficacy and pest management window of seed treatment insecticides, primarily neonicotinoids, to control secondary below-ground insect pests. They evaluated the possible effects of insecticidal seed coatings on non-target beneficial insects.

Second, they investigated the ecology, biology, evolution, genetics, and behavior of corn arthropods. In 2018, they characterized the dispersal of adult WCR and lepidopteran pests, and assessed its implications for integrated pest management (IPM) and for resistance development, spread, and mitigation.

Third, they employed diverse delivery methods to disseminate information related to sustainable management of corn arthropod pests. 1) Establish an NC-205 video library website with permanent high quality versions of IPM videos for open online access and download to computer and portable electronic devices. 2) Produce and deploy a comprehensive IPM system for cost-effective prevention, early detection, rapid diagnosis, and mitigation of new and emerging corn

pests that links all stakeholders who have common interests in pest detection and management. 3) Develop an array of IPM and IRM distance education workshops.

Results

First, they found that neonicotinoids that were applied to corn are consistently found in nearby waterways and this has implications for the aquatic organisms that live there, including unintended mortality. A publication in the Journal of Applied Ecology, demonstrated that dusts originating from seed treatments applied to corn seeds move over a wide proportion of the environment, covering most of the state of Indiana. This means that non-target exposure of honey bees and other pollinators is likely and in some cases lethal. Second, another publication demonstrated that WCR in refuge/Bt environments tend to mate close to where they feed and that the current levels of refuge beetles produced in fields are likely insufficient to contribute towards delaying resistance significantly. Third, a video was developed as a unique method to disseminate information. The video is meant to provide a jumping-off point for future work that reaches out to corn producers and pest managers in educating them about how and when to prevent resistance development.

Title

Utilizing reflectance spectroscopy to assess plant responses to biotic and abiotic stress

Research

John Couture, Entomology

Outcome

11 - GF 2.5 - # New diagnostic systems

Issue

Reflectance spectroscopy is emerging as a promising tool with potential applications in agricultural management because it is a non-destructive, rapid, and a relatively low-cost approach to monitoring vegetation status. In vegetation, reflectance spectroscopy relies on the interaction of light with plant chemical and structural composition and water content. Reflection of light in the visible (400-700 nm), near-infrared (NIR, 700-1100), and short-wave infrared (SWIR, 1100-2400 nm) can provide a comprehensive assessment of both shifts in visual symptoms (e.g., pigments, leaf color) and the underlying biochemical (e.g., nutrient composition, secondary metabolism) and physiological (e.g., photosynthetic activity, water relations) responses to disease or stress. Spectroscopy can also aid in the retrieval of plant traits, and has been utilized to predict a wide range of plant biochemical constituents and physiological processes based on the optical properties of foliage, including concentrations of nutrients and secondary metabolites and leaf structural and morphological composition and plant physiological status or specific physiological processes. To date, the applications of spectroscopy in agriculture have largely focused on disease detection through classification strategies, development of narrow- or broad-band disease indices, or relating vegetation indices sensitive to plant stress with plant disease status. Hyperspectral data is also utilized for classification of plant varieties and genotypes. Less is known about the ability of hyperspectral data to classify differences in plant stress responses between stressors that produces similar physiological effects, an emergent outcome of the proposed research. The use of hyperspectral data to detect specific biochemical and physiological responses to disease in crop systems is less explored and represents a promising and novel approach for not only the classification of disease status via spectral profiles, but also non-destructively quantifying responses of plants to stress.

What has been done

The goal of this research is to evaluate the ability of hyperspectral data as a potential tool for plant management of agricultural and natural areas. Specifically, determine the ability of spectroscopy to: 1) Detect asymptomatic responses by plants to biotic and abiotic stress, i.e., before the occurrence of visual symptoms. 2) Identify specific biochemical and physiological responses by plants to biotic and abiotic stress that allow spectral information to detect stress. 3) Determine the ability of hyperspectral data to accurately classify multiple different stressors, alone and in combination. 4) Determine that ability of hyperspectral data to achieve points 1, 2, and 3 accurately across multiple plant developmental stages. 4) Evaluate the ability of field-based approaches for points 1, 2, 3, and 4 across multiple measurement scales.

Results

The following has been accomplished through the use of hyperspectral data: 1) Monitored seasonal variation in wheat nitrogen under different fertilization application rates; 2) Monitored nitrogen in wheat as a breeding tool to assess nitrogen use efficiency; 3) Tracked wheat defense responses to Hessian fly infestation; 4) Quantified specific physiological responses of maize to water stress and are working to use these data in a high-throughput, trait-based breeding approach for yield-stability under water stress; 5) Detected western corn root worm infestation in maize, with implications for the monitoring development of Bt-resistance; 6) Quantified specific physiological responses of high-value hardwood species in response to biotic and abiotic stress; 7) Quantified physiological responses of lettuce to common stressors in a protected agrosystem; and 8) Quantified the impact of different agronomic management practices on the chemical profiles of industrial hemp (THC, CBD, etc.).

Title

Elucidating the microbial mechanisms mediating plant productivity in specialty crop systems

Research

Lori Hoagland, Horticulture

Outcome

120 - GF 1.3a - # of increased efficiencies (i.e. (% pregnant), or increases in yield/unit (bushels/acre; lbs. product (meat, protein, milk) per animal; lbs. feed per gain).

Issue

Nitrogen (N) is generally the most limiting nutrient in specialty crop systems and growers apply substantial amounts of fertilizer to meet plant needs. Only 50 percent of N is utilized by most crops. The unused N leaches to the environment causing serious environmental problems. This leaching is a major contributor to the growing hypoxic zone in the Gulf of Mexico. Organic fertility amendments (i.e. compost and cover crops) have potential to help reduce N loss, though meeting crop N needs with these amendments is more challenging. The soil N cycle is largely mediated by microorganisms, and learning more about the ecology of this system and how it is impacted by alternative fertility amendments has potential to increase crop N uptake and reduce N loss.

What has been done

Soil quality (or health) is now widely regarded as essential for maintaining plant and environmental health, but the direct mechanisms mediating these beneficial relationships are less clear. Research conducted as a part of this project supports the results of previous studies demonstrating that soil quality can be improved by amending soil with organic substrates. Moreover, results demonstrate that the composition and amount of these substrates can alter the structure of soil microbial communities that interact with plants to help them withstand biotic and abiotic stress.

Results

Over the course of this project, several experiments were conducted at Purdue research stations and on-farm trials throughout the Midwest to quantify the effects of various types of fertility amendments on N cycling and crop productivity in vegetable cropping systems. Results of these studies confirm that both amendment composition and site-specific soil and environmental factors are key factors affecting the soil N cycle. In particular, amendments derived from organic sources increased microbial activity and the activity of key microbial genes steering the N cycle relative to amendments derived from inorganic sources. This indicates that application of organic amendments could reduce nutrient loss if incorporation of the amendments are timed appropriately. Microbes with genes controlling the N cycle were also more abundant in the plant rhizosphere than bulk soil, indicating that plants can play a significant role in steering the soil N cycle. Finally, in addition to affecting plant growth, nutrient availability also affected the susceptibility of plants to pathogens and insect pests, indicating that pest dynamics are intimately related to nutrient management strategies.

Title

Pesticide Applicators in Indiana Gain Knowledge and Intend to Adopt Recommended Practices of Dicamba

Extension

William Johnson, Cheri Janssen, Fred Whitford, Greg Bossaer, Joseph Ikley, John Obermeyer, David Scott, Walter Sell, Amanda Mosiman, Amy Alka, Amy Thompson, Andrew Martin, Andrew Westfall, Ashley Adair, Austin Pearson, William Horan, Bob Bruner, Brad Kohlhagen, Bryan Overstreet, Corey Roser, Courtney Schmidt, Courtney Stierwalt, Crystal Van Pelt, Curtis Campbell, Curt Emanuel, Dana Gadeken, Danielle Walker, David Osborne, Edward Farris, Elysia Rodgers, Eugene Matzat, Hans Schmitz, Jorge Benitez, James Wolff, Jeffrey Burbrink, Jeffery Hermes, Jenna Nees, James Luzar, Jodie Thomas, John Woodmansee, Jon Charlesworth, Kamile Brawner, Karen Mitchell, Kelly Heckaman, Kenneth Eck, Kristine Medic, Krista Pullen, Kyle Weaver, Larry Temple, Lonnie Mason, Luis Santiago, Lyndsay Ploehn, Mark Carter, Mary Rodenhuis, Megan Voyles, Nicholas Held, Nicole Witkowski, Ophelia Davis, Paul Marcellino, Phillip Cox, Phil Woolery, Richard Beckort, Robert Yoder, Roy Ballard, Sadie Davis, Sara Dzimianski, Sarah Hanson, Daniel Gabbard, Simon Kafari, Steven Engleking, Valerie Clingerman, Will Schakel, Julie Huetteman

Outcome

19,381 - ANR Horticulture - NIFA GF 1.4 - # of participants adopting best practices and technologies resulting in increased yield, reduced inputs, increased efficiency, increased economic return, and/or conservation of resources

Issue

Many herbicide-resistant weeds affect soybean production. Johnson (2018) estimates costs to control marestail is \$20/acre, giant ragweed \$30/acre, and waterhemp and Palmer Amaranth \$50/acre. Many growers are reluctant to return to more intensive, tillage practices. In some situations, cover crops can help reduce overwintering weed populations, but results can be erratic. Some growers are migrating to short-term solutions strictly through utilizing new GMO seed technologies, versus adopting longer-term best management practices, which might include cover crops, pre-emergent residual herbicide applications, and utilizing a variety of herbicide mode of actions along with post emergent herbicide applications. Dicamba containing herbicides are good for managing these weeds but these herbicides have been under review by pesticide regulatory officials in Indiana and other states for damage related to chemical drift. In 2017, 2,708 dicamba drift issues had been reported to State Departments of Agriculture or Chemists Office across 25 soybean-growing states (Bradley, 2017). In Indiana the State Chemist Office conducted 257 drift investigations, compared to between 74 and 92 in the previous four years. Of the investigations, 129 (50%) were related to dicamba, as compared to just 3 to 8 dicamba investigations in the previous four years. In the fall of 2017, the Indiana Pesticide Review Board classified all pesticide products containing at least 6.5% dicamba, as Restricted Use Pesticides (RUPs) in Indiana and can only be sold to certified applicators. At the same time, the Environment Protection Agency (EPA) reached an agreement with Monsanto, BASF and DuPont on measures to further minimize the potential for drift to damage neighboring crops from the use of dicamba formulations used to control weeds in genetically modified cotton and soybeans. New requirements for the use of dicamba over the top (application to growing plants) will allow farmers to make informed choices for seed purchases for the 2018 growing season. As a result of steep increases in drift complaints across the country, the EPA and the manufacturers of dicamba products created federal label-mandated training requirements for 2018 for users of Engenia, FeXapan, or Xtendimax in 2018.

What has been done

The Office of the Indiana State Chemist and Purdue Extension delivered 193 one-hour training sessions in person and via webinar from January 1 to April 30, 2018 to users of dicamba products and other interested in the dicamba regulations. Instruction focused on practices to reduce drift and volatilization, including buffers, wind direction and speed, application timing, temperature, rain, recordkeeping, nozzles, boom height, ground speed, sprayer cleaning and spray volumes for application of dicamba products. There were 5,669 private pesticide applicators, currently certified in Indiana, who attended the training.

Results

In many of the training sessions, program evaluations were conducted. A survey was distributed at the end of the training for attendees to complete. A total of 3,898 evaluations were collected for statewide compilation. Evaluations were from 78 counties, across the 10 geographic areas and 5 districts of Indiana. Responses (n=3722) on acreage showed that half of the attendees (50%) reported having over 1,000 acres which they farm or advise.

Based on paired t-test analysis of the retrospective pretest evaluation data, gains in knowledge of the dicamba issues and practices among the attendees were statistically significant regarding dicamba application: 1) decreasing drift, 2) decreasing volatilization, 3) buffers of at least 110 feet, 4) wind direction toward sensitive crops, 5) wind speed between 3 and 10 mph, 6) rainfall forecast within 24 hours, and 7) regulatory authority of drift complaints. Responses about knowledge for all topics showed a shift from before to after. The knowledge levels of none and some decreased, and the knowledge levels of much to expert increased. At the conclusion of the training, attendees (n=3,579) showed accurate knowledge of: 1) proper boom height (98.8%), 2) causes and effects of dicamba volatilization (85.7%), and 3) locating dicamba sensitive crops (82%). Attendees indicated actions they are planning to take in 2018. The largest number of attendees indicated that they would: 1) Maintain required records (75.6%), 2) Review updated dicamba regulations (75.4%), 3) Prepare a checklist for spray day (72.4%), 4) Inventory sprayer nozzles (63.4%), and 5) Survey nearby dicamba sensitive crops (62.2%). On each of these items there were 10%-18% of responses from attendees who indicated these actions did not apply to them. Training attendees were asked about the importance of dicamba. From 3,662 attendees, 69.8% indicated that having dicamba technology available is very to extremely important. Attendees indicated how what they learned in the training would benefit them and their operation. They found the training helpful to them. Many expressed desire to do it right, be more aware, be careful, follow the label and regulations, communicate with neighbors, and apply what they learned in their operation this year or in the future. Others expressed that it confirmed their feelings or convinced them to avoid applying dicamba. These increases in knowledge and intentions to adopt recommended practices related to dicamba among Indiana's private pesticide applicators and others in agriculture may contribute to improved safety and compliance with regulations and containing drift complaints and other issues related to dicamba use in current and future growing seasons.

Title

Indiana agricultural producers adopt practices resulting in increased return and decreased costs per acre

Extension

Alyssa Besser, Amy Alka, Andrew Martin, Andrew Westfall, Ann Kline, Ashley Adair, Austin Pearson, Beth Vansickle, William Johnson, Brad Kohlhagen, Brad Shelton, Bryan Overstreet, Bryan Young, Christopher Hurt, Corey Gerber, Courtney Stierwalt, Crystal Van Pelt, Curt Emanuel, David Osborne, Don Carlson, Edward Farris, Elysia Rodgers, Eugene Matzat, Fred Whitford, Gary Tragesser, James Camberato, James Wolff, Jason Tower, Jeff Boyer, Jeffrey Burbrink, Jeffery Hermes, Jill Andrew-Richards, Jim Beaty, Joel Wahlman, John Hawley, John Obermeyer, John Woodmansee, Jon Charlesworth, Jonathan Ferris, Justin Curley, Kamile Brawner, Karen Mitchell, Katherine Rainey, Keith Johnson, Kelly Heckaman, Kelly Pearson, Kenneth Eck, Kristine Medic, Kyle Weaver, Larry Temple, Lenny Farlee, Lonnie Mason, Mark Carter, Mary Rodenhuis, Mitchell Tuinstra, Nicholas Minton, Nicole Witkowski, Phil Woolery, Richard Beckort, Robert Nielsen, Robert Yoder, Ron Rathfon, Ronald Lemenager, Shaun Casteel, Stephen Boyer, Steven Engleking, Will Schakel, William Horan, Julie Huetteman

Outcome

17,466 - GF 1.4.a - # Of producers indicating adoption of recommended practices

Issue

There are 56,800 farming operations in Indiana. 97% of Indiana farms are family-owned. Of Indiana's roughly 23.3 million acres of land, 84% of it is farms, forests and woodland. Corn (\$3.16 billion) and soybeans (\$2.84 billion) account for the largest value of sales for Indiana's commodities. Successful and sustainable production requires attention to a vast array of variables, including, but not limited to, soil health, water availability and access, prevalence of weeds, insects, invasive species, and diseases, and seasonal and weather variability. The need for access to and understanding of new technologies and management is great for Indiana's producers and the future of crop production. It is prudent for Indiana to protect its resources and support productivity of the land, farms, and operations.

What has been done

Seven Purdue Agricultural Centers (PACs) Field Day events provided 35 hours of educational activities on many topics, including wildlife and woodlot management, forage and beef cow management, corn and soybeans, herbicide and weed management, putting a sprayer on the road, UAVs/drones, soil fertility economic outlook, cash rent options, integrated pest management, pollinator protection, and crops pathology. Continuing Education Units (CEUs) for Certified Crop

Advisors, Continuing Certification Hours (CCHs) for Indiana Commercial Pesticide Applicators, and Private Applicator Recertification Program (PARP) credits were available. 12 external partners and 44 funders provided a total of \$15,525 in support of the events. A total of 1,032 adults participated in the seven events. 437 (42% response rate) participants completed the post-survey. 34% indicated they currently farm/advise over 1,000 acres, 24% farm 101 to 500 acres, 17% don't farm, 13% farm 501 to 1,000 acres, and 10% farm 100 acres or less. Respondents live in 63 of Indiana's counties, and 9 from out of state. Largest numbers were from these counties with 10 or more each: Randolph, LaPorte, Tippecanoe, Porter, St. Joseph, Ripley, Whitley, Wayne, Huntington, Jay, Jasper, Jennings, Kosciusko, Jefferson, Pulaski, and White.

Results

Participants found Field Day useful, with 75% indicating it was extremely or very useful. Participants indicated they would apply information to their farm/operation. Most common included: 1) drones/UAVs, 2) equipment, 3) weed management, 4) diseases, 5) pesticides, and 6) insects. A few comments of information participants planned to apply to their operation included: the different uses of UAVs and the possible future use of them, doing a better job of taking care of equipment, water hemp control options, difference between sudden death syndrome and brown stem rot, and being more careful of over spray to protect bee population.

There were 35% (n=73) of returning respondents who indicated they had adopted a new, recommended practice for their farm/operation since last year's event. Most frequently reported practices that were adopted included: 1) using sulfur on beans, 2) pesticide application, 3) no till / cover crops, 4) scouting, and 5) seeds. Some 19% (n=39) indicated their operation's financial position since last year's event had improved. Improvements were: 1) 46% (n=21) had increased dollar return per acre due to adopted recommended practices, and 2) 50% (n=24) had reduced costs per acre due to adopted recommended practices. Field Days, as reported by participants are useful and applicable, and by returning participants reporting adoption of new, recommended practices, can help contribute to improved productivity, yield, environmental stewardship, and financial management for farms and operations across Indiana.

Title

Purdue Extension trains applicators for safe and effective pesticide use

Extension

Fred Whitford, Cheri Janssen, ANR Educators, Julie Huetteman

Outcome

3,483 - GF 2.7 - # People trained in early detection and rapid response of plant pest, animal pests and diseases

Issue

In 2016, Indiana had 57,500 farms with 14,700,000 acres of land. (Indiana Agricultural Statistics 2016-2017, USDA, NASS). Corn was the leading source of income for Indiana farmers and amounted to \$3.16 billion. Soybeans were second at \$2.84 billion. Farmers and agribusiness personnel including fertilizer and chemical dealers, seed and company agronomists and crop consultants, need up-to-date information on pest populations, outbreaks, and management strategies, pesticide label changes, safety and environmental issues related to pest control, and the use and application of pesticides, for safe use of pesticides and herbicides. Appropriate application of pesticides is extremely important for our food systems, environment, health, wildlife, and water supply.

What has been done

PARP (Private Applicator Recertification Program) is a training program for private pesticide applicators who need to keep their certification current. Private applicator permits last five years. In that five years, private applicators are required to attend three recertification programs or take the pesticide or fertilizer certification exam. A private applicator may attend recertification programs hosted by Purdue Extension based in the counties across Indiana. Recertification programs are at least two hours in length and include presentations on fertilizer and/or pesticide-related topics. Each program includes an approved regulatory topic. A private applicator can attend and receive credit for a recertification program in any county, not just their home county. There are 11,784 PARP certificates managed per year in Indiana by the Purdue Pesticide Program. Purdue Extension provided 208 PARP trainings in the past year. To keep PARP certification current, 6,390 farmers attended these trainings. Regulatory and elective training topics were selected

and presented to match local needs at the county. Topics included dicamba, pollinator protection, herbicides, weeds, drift watch, recordkeeping, cover crops, soil health, pests, nitrogen, plus many others. The Office of the Indiana State Chemist, charged with administering several agricultural laws involving animal feeds, fertilizers, pesticides and seeds to ensure truth-in-labeling, food safety, user safety and the protection of our environment, manages the 14,930 commercial applicator certificates in all categories. In the past year, for the agricultural pest management category there were 2,702 certified commercial applicators, and 2,158 for agricultural fertilizer application. A total of 700 training programs were approved last year for commercial applicator continuing certification hours (CCHs).Purdue Extension provided many of these trainings. While agriculture is a large part of those programs, it is not nearly the whole. Turf management, ornamental pest management, right of way, forest pest management and professional pest control all benefit from Purdue Extension (and Extension programs all over the country). Extension is not only a part of the initial training programs but plays a huge part in recertification programs. Extension Specialists in weed science, entomology, turfgrass and many others are critical to the recertification programs for commercial applicators.

Results

Application of pesticides is regulated to ensure safe and appropriate use. Those who administer pesticides, herbicides, and fertilizers, must complete training and pass tests to be certified. They obtain certification initially and then participate in ongoing training to keep current. Purdue Extension provides training opportunities throughout the year at locations across the state. Depending on the training program, participants may receive credit toward their recertification for private applicator (PARP), or commercial applicator continuing credit hours (CCHs).

Responses of the training participants reflect the variety of topics provided across Indiana. Here is a sampling of actions they plan to take as a result of the training: 1) they will be making changes to their farm practices, 2) they will adopt agronomic practices to assist in reducing cost and increasing dollar return per acre, 3) they will take precautions and safety measures recommended in the program, 4) they will likely have more group discussions with farm co-owners, and with people who rent the farm, 5) they intend to utilize herbicide mode-of-action charts to make herbicide decisions, and 6) they will monitor weed height more closely to ensure effectiveness of herbicide applications.

Participants stated the benefits they received: 1) the training helped their understanding of safety practices, 2) the program helped them understand the importance of recordkeeping, 3) they learned something new about temperature inversions, droplet size and drift, rust, grain storage insects, keeping records, and soybean cyst nematode races, 4) they increased their knowledge of management strategies for weed control, disease control, insect control, and pesticide control related to pollinators, and 5) they feel comfortable knowing how and when to plant cover crops correctly.

The availability and delivery of ongoing training provided by Purdue Extension makes it possible for individuals to keep their certification and helps Indiana to have better informed farmers and agribusiness personnel more likely to make economically and environmentally sound decisions for safe and appropriate application of pesticides.

Human, Family, and Community, Health and Well-being

Title

Business Retention and Expansion

Extension

Tanya Hall, Lionel Beaulieu, Michael Wilcox, Heather Strohm, Hans Schmitz, Emily Del Real, Melinda Grismer, Mark Kepler, Kristi Whitacre

Outcome

357 - # of key stakeholders engaged and active in community and economic development locally, countywide and regionally

Issue

Existing businesses and the local workforce are key barometers of community economic health (as a place to live, work and play). Research shows that small businesses are the major drivers of job growth. In Indiana, 85% of all existing businesses employ less than 100 people. They are the often-overlooked growth machine of the state and the ones most

likely to add new jobs to their portfolio. Business retention and expansion is critical for communities as it provides the cultural aspect, quality of life, and longevity necessary for the economy.

What has been done

Purdue Extension Business Retention and Expansion (BR&E) is intended to help focus the energies of community stakeholders on economic assets that exist in their cities, counties and regions, making them stronger and more resilient over time. The program helps local communities understand issues related to their economy, and makes local officials aware of business needs and resulting expansion strategies. A strong relationship among community stakeholders (businesses, residents, local leaders/officials) helps communities understand local business needs and respond, so that businesses grow, stay and become more committed to the community. Special attention is given to small businesses that employ between two to 99 employees, otherwise known as Stage 1 and Stage 2 firms. BR&E communities learn: 1) How to approach business retention and expansion, 2) Models for business visitations and surveys, 3) Tracking feedback and response, and 4) Fostering and strengthening business alliances. In 12-18 months building capacity among local leadership is key and is accomplished through development and implementation of a local task force. Purdue Extension supports these communities throughout, including developing survey questions, analyzing results, writing final reports and helping to present findings to the community. Research and data are provided to the local task force to help them identify, design, implement and evaluate strategies to strengthen businesses and industries. Purdue Extension takes the lead for the first cycle, then after 12-18 months, the local task force coordinator takes the lead and begins a second cycle of BR&E, targeting a different business sector (e.g., agriculture, manufacturing, retail sector or downtown businesses). Which companies are targeted in each cycle is up to the local task force. BR&E started a couple years ago with a pilot program in Parke County. During 2018, more communities have been added, and Purdue Extension delivered over 30 sessions in Knox, Owen, Fulton, Posey and Vanderburgh Counties.

Results

From the pilot program in Parke County, BR&E has harnessed community support of ten task force members and one full-time coordinator. Members conducted business visits and will complete the results report on identifying red flags and opportunities for growth. During the process, a community readiness assessment was conducted to gauge the support of the community and leverage additional resources as needed. Parke County completed the first cycle of BR&E, and the coordinator stated The company visits allowed insight for the task force which is creating more energy in the community to support local businesses. A strong relationship with the businesses is invaluable. The task force coordinator, began Cycle 2 of the BR&E program, with support from Purdue Extension with curriculum, data, resources and monthly connection. In Owen County, BR&E participants organized a task force, studied data about their county, identified local business participants, conducted interviews, analyzed results and responded to opportunities that resulted from the interviews. They compiled their final report to communicate the story of the local economy to the public. They will wrap up their first BR&E cycle in January 2019. Other Counties are in process of reviewing data and compiling results. Each local BR&E program runs in cycles to continue the dialogue with businesses in the community, in an ongoing effort toward economic sustainability.

Title

Training a Cadre of Facilitators through Facilitative Leadership

Extension

Kris Parker, Tamara Ogle, Kara Salazar, Carmen DeRusha, John Orick, Kristi Whitacre, Patricia Keating, Emily Toner, Jodee Ellett, Tanya Hall

Outcome

821 - NC - # of participants reporting new leadership roles and opportunities undertaken

Issue

Community professionals in fields such as Extension, philanthropy, local government, state government, and natural resources seek facilitation skills training to be able to lead participatory meetings, discussions, and decision-making processes.

What has been done

Purdue Extension taught the Facilitative Leadership workshop twice in Indiana to 37 participants. Each workshop includes a 90-minute webinar and 27 hours of face-to-face instruction scheduled over three days. Participants lead a 10-minute discussion. They plan and lead a 45-minute group facilitation using tools taught in the workshop. Each participant gives and receives feedback to fellow classmates in their small group.

Results

The one-year follow-up survey was completed by 11 of 22 participants. As a result of the training, and in the year following: 1) Eight participants took on new leadership roles, 2) 117 volunteer hours were completed using facilitation skills, a \$2,776 value based on Independent Sector for 2017, 3) participants facilitated groups for the creation of five plans, four of which were adopted and three implemented, 4) 14 partnerships were created, and 5) \$68,000 was leveraged as a result of facilitating activities. 100% of participants said the workshop was extremely or very valuable to their work, community, or volunteer efforts.

Title

Strengthening Community by Strengthening Families

Extension

Barbara Beaulieu, Debora Arseneau, Megan Broughton, Janice Dougan, Elizabeth Beiersdorfer, Teri Hornberger, Brian Howell, Jennifer Monarch, Mandy Medbourn, Terri Newcom, Abby Sweet Morgan, Joni Muchler, Monica Nagele, Amber Noll, Marcia Parcell, Sarah Richer, Marilyn Sink, Alice Smith, Tammy Walker, Lisa Wilson, Samantha Williams, Amanda Galloway, Courtney Stierwalt, Nancy Hudson, Amber Barks

Outcome

6,517 - NIFA FCS1.HCFD1 - # of individuals who learn about healthy child and/or family development

Issue

In Indiana, there are over 400,000 youth ages 10 to 14. This age cohort is subject to social and emotional changes, greater academic challenges, and biological changes. They face academic challenges, seek more independence from their families, and experience increased episodes of sadness or depression which could lead to poor grades, alcohol/drug use, unsafe sex, and other risky behaviors. Parenting can be a very stressful responsibility, however, high levels of stress that persist for extended periods in families can negatively affect a child.

What has been done

Focusing on one of the human development programs provided by Purdue Extension, Strengthening Families Program: For Parents and Youth 10 to 14 (SFP: 10-14), is an evidence-based parent, youth and family skills-building curriculum that: 1) prevents teen substance abuse and other behavior problems, 2) strengthens parent/youth communication skills, 3) increases academic success in youth, and 4) prevents violence and aggressive behavior at home and at school. In seven two-hour sessions, separate sessions for youth and parents are followed by joint family sessions. Youth learn about peer pressure resistance, reducing stress, finding family values, problem solving, goal setting, and resisting substance use. Parents learn what it is like to be a current youth, how to love but set limits, develop family rules and establish consequences, encourage good behavior, build bridges between youth and parents, and protect youth against substance use. The joint session allows families to bond by participating in learning game activities, and projects, such as making a family, identifying family members strengths, strengthening communication skills, and increasing problem-solving skills. There were 96 adults and 92 youth enrolled in 12 programs held in 12 counties during 2017-2018. Program post-/pre-reflective evaluations were completed and data collected from 49 adults and 50 youth.

Results

Post-/pre-reflective assessments for youth showed positive changes in knowledge and actions. Almost twice as many youth indicated they had family meetings (a tool introduced in the program) some or most of the time after the program. There was a 54% increase in youth who indicated they could do things to help themselves feel better when under stress, and in knowing a step to take to reach their goals. 96% of youth responded positively to these: 1) appreciating things parents/caregivers do for me, 2) knowing qualities important in a true friend, 3) feeling truly loved and respected by

parents/caregivers. 94% of youth know what their parents/caregiver think about drugs and alcohol. Youth indicated the most valuable things they learned were: 1) how to handle stress, 2) choosing friends, and 2) resisting peer pressure. Sample comments were: 1) I have learned how I could get out of being peer pressured. I now also know how to deal with stress without yelling and getting mad. I also know now how my parents feel when they have to deal with me. I now know what a good friend is like. 2) To understand my decisions not only affect myself but others as well. Parent assessments showed improvements from pre to post for: 1) I often tell my child how I feel when he or she misbehaves (79% increase). 2) I wait to deal with problems with my child until I have cooled down (73% increase). Parent most valuable things learned were: using I messages, listening to their youth, and understanding their youths stress. Parent comments included: 1) I have been practicing the things that I learned during the Strengthening Families classes and it works! 2) My kids are listening better and responding to my coaching, and I am able to no longer lose my temper. Our home is much calmer and peaceful. 3) One parent stated, Everything has been amazing! The change in my home has made life so much better. I am going to make sure my family never goes back to how we use to function. 4) The program contained many valuable lessons about enhancing our understanding of our youths perspective in order to use ways to make our relationships better and in turn, improve our family. We also really like the family meeting time, especially writing down what was agreed upon. Positive changes made by parents and youth involved in SFP: 10-14 will help improve the time they spend together communicating, working to achieve individual and family goals, and establishing rules and consequences. These skills will help strengthen families and arm youth with valuable life skills. Close relationships, working toward goals and dreams, and having skills to reduce peer pressure are important elements that can help youth resist substance use and abuse. When parents are actively engaged in their children's lives, children are likely to have better academic performance, higher graduation rates, and fewer behavioral problems.

Title

Helping Hoosiers Prevent Heart Disease

Extension

Stephanie Woodcox, Lisa Cangany, Jay Christiansen, Abigail Creigh, Linda Curley, Peggy Ehlers, Jaclyn Franks, Allison Goshorn, Molly Hunt, Jane Horner, Nancy Hudson, Gracie Marlatt, Joanne Lytton, Mandy Medbourn, Joni Muchler, Terri Newcom, Amber Noll, Susan Peterson, Megan Peterson, Tonya Short, Demarcus Sneed, Beth Switzer, Elizabeth Richards

Outcome

179 - # of participants identified dietary recommendations for eating and preparing more heart-healthy meals

Issue

Heart disease is the number one cause of death among men and women across the nation. Each year, about 610,000 Americans die from heart disease, accounting for nearly 1 out of every 4 deaths. Heart disease and stroke cost the U.S. an estimated \$1 billion each day in health care services, medications costs and lost productivity. Heart disease is also the number one cause of death for Indiana. 39% of adults in Indiana have had their cholesterol checked and been told by a healthcare professional that it is high, 32% have had their blood pressure checked by a healthcare professional and been told it is high, and 33% are considered obese, a body mass index (BMI) greater than 30. High cholesterol, high blood pressure, and being overweight or obese are all risk factors for heart disease.

What has been done

Purdue Extension provides education to adults about heart disease and ways to reduce risk for this and other chronic health conditions. Through delivery of Be Heart Smart, Extension Educators help participants identify and monitor controllable risk factors for heart disease, encouraging them to make simple changes to their daily routine that can improve their heart health. Be Heart Smart is offered as a series of four, 1-hour classes. Topics covered during the program include risk factors, cholesterol and blood pressure guidelines, heart-healthy eating plan, stress reduction techniques, and tips on to talk to your healthcare provider. Each lesson provides participants with suggested action items to incorporate heart-healthy behaviors to start making a difference. Be Heart Smart was presented 32 times during the 2017-2018 program year, reaching 286 individuals. Of those reporting, participants of the program were mainly female (72%), aged 61 years or older (40%), and White (89%). The majority (69%) of Be Heart Smart participants are concerned they are at-risk for heart problems. Over half (58%) indicated having a family history of heart disease.

More than one in ten (13%) participants has been diagnosed with heart disease, indicating that they are still in need of education on how to improve their heart health and manage/monitor their risk factors.

Results

There was a statistically significant improvement in knowledge by participants on these topics: identifying the most common cause of heart disease, categorizing risk factors as controllable versus uncontrollable, defining a healthy blood pressure and body mass index, understanding how to decrease sodium in the diet including the DASH Eating Plan, describing benefits of physical activity, and practicing techniques to reduce stress. Prior to the first lesson, 69% could correctly identify controllable risk factors for heart disease. At the conclusion of the program, 86% could correctly identify such risk factors. As a result of the program, participants indicated they intend to make behavior changes to help reduce their risk for heart disease: 1) 92% said they would monitor controllable risk factors for heart disease such as blood pressure and cholesterol, 2) 85% said they intend to increase daily physical activity, and 3) 87% intend to employ stress reduction techniques when needed. Participant feedback indicates the program was well-received and beneficial. Comments included: 1) the education received helped me realize how important being aware of any [health] problems can help me live a longer and healthy life, 2) the content increased my understanding of many of the terms and words I have heard all of the time, 3) it was motivating to take more control of my health, and 4) the program gives me more ideas on eating better and [increasing] physical activity. The findings suggest that after the program, adults are more knowledgeable about risk factors for heart disease, strategies to prevent or reduce personal risk of heart disease, and can incorporate heart-healthy behaviors into their daily activities.

Title

4-H STEM programs prepare youth for careers in Science and Math

Extension

Renee McKee and 4-H and Youth Development Educators

Outcome

666 - # of youth that would like a job that uses science

Issue

U.S. youth are lacking in the fields of science and mathematics. Data from the 2015 Program for International Student Assessment (PISA), show U.S. 15-year-olds as just above average in science literacy and below average in math literacy compared to 72 countries. STEM education is very important, and youth need more opportunities to be involved to increase their mastery level in science and mathematics.

What has been done

Indiana 4-H Youth Development provides educational programming focused on STEM learning and potential future careers. With over 800 youth in 38 different programs across the state participating in a variety of learning opportunities, Indiana youth were provided diverse experiences to excite them to learn and explore via STEM. During the FY 2017-18 program year, 40% (300 youth) of STEM program participants were new to 4-H, noting that this was their first time attending a 4-H event.

Results

Indiana 4-H offers STEM programming that interests and engages youth beyond the classroom. Over 80% of STEM program participants reported learning new things about engineering and over 90% learned new things about science during 4-H programs. As we look toward our youth becoming the future workforce, 76% of 4-H STEM program participants said they would like a job that uses science (666 youth grades 4-12) and 70% would like a job that uses engineering (605 youth grades 4-12). It is through Indiana 4-H programs that youth learn how science can help solve everyday problem - with 80% of participants identifying that they learned this skill during their program. Indiana 2017-2018 4-H STEM program participants reported the following: 1) 73% Ask questions about how things work, 2) 85% Try new things to see how they will work, 3) 69% Compare how different things work, 4) 60% Take things apart to see how they work, 5) 76% Come up with ideas for how to build new things. The future workplace and occupations need not only

content competent employees, but also employees who have the critical skills to identify problems, construct solutions, and innovate. Indiana 4-H STEM programs provided a learning environment to develop and foster these skills.

Title

4-H Programs Train Youth in Food Safety and Animal Well-being

Extension

Renee McKee, Courtney Stierwalt, and 4-H and Youth Development Educators

Outcome

19,540 - # of youth certified in Youth for the Quality Care of Animals (YQCA)

Issue

Youth may not be aware of practices for maintaining a healthy animal. It is important that with 4-H programming involving animals, the youth are armed with knowledge of quality care for animal well-being and for the safety of our food.

What has been done

Youth for the Quality Care of Animals (YQCA) is a national multi-species quality assurance program for youth ages 8 to 21 that was implemented by the Indiana 4-H Youth Development Program in 2018 after pilot testing during 2017. YQCA is designed as an annual education and certification program focused on food safety, animal well-being and character awareness for youth producing and/or showing pigs, beef cattle, dairy cattle, sheep, goats, market rabbits, and poultry. The program was been designed by extension specialists and national livestock program managers to ensure it is accurate, current and relevant to the needs of the animal industry and shows and is appropriate for youth. There were 98 Purdue Extension staff certified to provide training and they conducted programs across Indiana's 92 counties. Certification was also possible via web-based instruction.

Results

YQCA was added as a programmatic expectation for all Indiana 4-H members in grades 3-12 who exhibited any livestock species addressed by the training. At the end of the instruction period there were 19,540 Indiana 4-H members certified in YQCA. A total of 13,280 participated in instructor-led face-to-face meetings which often included hands-on activities to enhance participant experiences. There were 6,260 youth who opted to complete the program via web-based instruction which required passing a series of three quizzes to earn the YQCA certification. Acquiring these skills help the youth and their animal, but also address the safety of available meat products in the community.

Title

Digital Ready Businesses – Helping Rural Businesses Compete in the Digital Economy

Extension

Roberto Gallardo, Emily Del Real, Annette Lawler, Heather Strohm, Tanya Hall, Kristi Whitacre, Mary Foell, George Okantey, Monet Kees, Nicholas Held, William Horan, Janet Reed, Crystal Van Pelt, Amanda Galloway, Kirsta Pullen, Hans Schmitz, Julie Rigrish, Cheyanne Geideman

Outcome

2,845,980 - NC 13 - \$ value of grants and resources leveraged/generated by communities

Issue

As the digital economy continues to expand, having an online presence is critical for any business to remain competitive. Rural businesses and entrepreneurs are no exception. A robust, well designed online presence helps rural businesses compete and expand their markets beyond their small local communities/regions.

What has been done

Purdue Extension, in partnership with the Purdue Center for Regional Development (PCRD), is providing critical information and technical support that is designed to expand broadband access and adoption by rural households, business and rural communities in Indiana. In order to help make rural entrepreneurs and small businesses more competitive, Purdue Extension developed the Digital Ready Business curriculum. This curriculum consists of eight face-to-face 1-hour workshops. During 2018, seventeen educators were trained to launch the program delivering 32 workshops reaching 92 entrepreneurs, business owners, and employees throughout Indiana. Expansion is under development to add an online version which will be available initially through an app, and later on a website.

Results

Over the past year, the Purdue Extension and PCRD partnership has realized a number of significant achievements. First, the team completed one of the most extensive studies ever conducted on the benefits/costs of providing broadband to rural households in Indiana. It is this study that prompted Indiana Governor Holcomb to pursue a \$100M investment to expand broadband to unserved areas of the state. Second, in-depth state of broadband reports produced for four regions (encompassing over 24 counties), resulted in formation of broadband task forces working to address gaps in broadband access and utilization in targeted geographic areas of Indiana. Third, Extension and PCRD have teamed up with the Indiana Office of Community and Rural Affairs to develop and implement \$45,550 in Rural Broadband Planning Grants for five communities. Extension also secured a \$65,000 USDA grant to provide and support training and technical assistance for businesses in three counties to implement digital strategies. Fourth, with Digital Ready Business helping small Indiana businesses and entrepreneurs expand their online presence, knowledge gained by participants exceeded 90% for all eight curriculum modules, including business intelligence, email marketing, planning a website, and social media analytics. Likewise, more than 75% of participants reported they were likely/very likely to apply knowledge learned.

Title

Mental Health and Well-Being in Midwestern Latino Youth: A Resilience Approach

Research

Zoe Taylor, Human Development and Family Studies

Outcome

5 - HHS 3.1 - # of discoveries, innovations, technologies related to Culture and Diversity

Issue

Adolescents can be vulnerable to mental health problems, and this appears especially so for Latino in the U.S. Also, Latino youth in rural communities remain woefully understudied and may be particularly vulnerable to health disparities such as poor mental health (Umaña-Taylor, 2009; Wickrama, Elder, & Abraham, 2007). Additionally, identifying protective factors that have potential to mitigate the magnitude of the stress response may reduce the probability of experiencing mental health problems during adolescence (Shonkoff, Boyce, & McEwen, 2009). Mitigating consequences of such challenges, and fostering systems that promote positive mental health, may be one of the most significant ways to promote well-being and long-term success of Latino youth.

What has been done

The objective of the research is to document the effects of contextual stressors (e.g., discrimination, poverty) on the mental health and well-being of Latino youth in the Midwest, to identify resilience factors (e.g., self-regulation and supportive parenting) that have the potential to buffer or counteract such stressors, and measure the effect of stress on the hypothalamus, pituitary gland and adrenal glands, which are the organs that produce hormones that control the human physiological reaction to stress.

Results

Results of the study with Latino families with a fifth-grade child living in the Midwest suggest that effortful control (a resilience factor which is related to self-regulation of emotional reaction or behavior) may help counteract contextual risks commonly experienced by Latino youth. The study of ego-resiliency (how individuals adapt to environmental stressors, conflict, and change), showed that a supportive family (resilience factor) helped youth develop stronger ego-

resiliency and reduced incidence of depressive problems, and, this persisted over time, suggesting it may have long-term effects on reducing depressive problems in Latino youth. Researchers studied the cortisol awakening response (which is an increase in production of the hormone cortisol within 30 minutes after awakening, and believed to be a preparation for stress for the day) of the hypothalamic-pituitary-adrenal system in 119 preadolescent Latino youth and found that youth with both stronger cortisol awakening response and effortful control, had fewer depressive programs. Hence, physiological processes and individual resilience traits were shown to help counter depressive problems in Latino youth. These results may have a positive impact on public health issues relating to Latino youth through informing policy and directing future intervention efforts targeted at reducing stress and health disparities in this population.

Natural Resources and the Environment

Title

Soundscape analysis for biodiversity, behavioral patterns of animals, dynamics of weather and climate, and human activities

Research

Bryan Pijanowski, Forestry and Natural Resources

Outcome

21 - NRE 1.2 # New relevant databases, monitoring systems, and inventories managed or under development

Issue

Understanding the impacts that humans have on ecosystems is challenging. Central to this challenge has been the inability of researchers to develop a universal measure of both ecosystem health and human activities for a place. Soundscape measures have the potential to capture a locations' biodiversity, behavioral patterns of animals, the short-term and long-term dynamics of weather and climate, and various human activities simultaneously. Past work in the area of acoustics has focused on how animals use sound to communicate or how noise impacts human health and behavior. This work will characterize, for the first time, how soundscapes vary across time, space and human disturbance intensities. This will lead to better understanding of ecosystem dynamics, spatial variability of ecosystems and potentially how humans might affect ecosystem quality.

What has been done

The research project focused on 1) converting soundscape recordings to acoustic metrics that reflect the diversity and intensity of sounds occurring at a location; 2) using these metrics to analyze spatial-temporal patterns that are reflective of human disturbance (e.g., land use patterns) at a location and 3) providing this information to potential users via online database management tools. Within ecosystem and across ecosystem analyses formed a majority of the research proposed here. The impact of this work can be summarized by focusing on three main target audiences that our project has focused on: a) the general public; b) the scientific community and c) natural resource managers. Goal 1 (metrics) focused on the scientific community, goal 2 (application of our metrics) focused on natural resource managers and goal 3 (provide information to users) focused on all three. These goals were accomplished through a) creation of high quality educational materials such as an IMAX film, citizen science project, summer camp program and online learning web site; b) development of new software tools that are provided to researchers in a hands-on workshop environment and c) the formation of partnerships with parks and research facilities around the world that use information for management decisions.

Results

Through a citizen scientist app, there are now over 2500 users that upload their soundscapes and sentiment data to the website for use in a) building an understanding of the importance of listening/observing our surroundings and b) for the team to understand the linkages between the types of sounds people hear and their emotional reaction to them. The website contains millions of recordings which are available online for people to listen to and this is an easy to use, easily accessible form for many to connect to our research. The team's work has also been showcased on major news media

outlets during this reporting period, including CNN, New York Times Magazine, Science News, Business Week, Nova, NPR Science Friday, BBC World News Service, and NBC Today Show as well as numerous online news outlets (e.g., Wired Magazine, Huffington Post). Our IMAX film, *Global Soundscapes: A Mission to Record the Earth* is now in 14 theaters in the U.S., Canada and Germany. An outside evaluator has ranked the film second among 12 assessed in the area of science education. More than 10 journal articles have been published per year on various aspects of soundscape dynamics and their linkages to natural (e.g., hurricanes) and anthropogenic stressors (e.g., deforestation). This team is helping to define this very new field in terms basic and applied areas of research. Publication venues are top tier in the field, including: *Landscape Ecology*, *Global Environmental Change*, *Ecological Informatics*, *Freshwater Biology*, *Auk*, *Journal of Biogeography*, *Biotropica*, *International Journal of Science Education*, *Journal of the Acoustical Society of America*, among others. Over 7 keynote addresses have been delivered during this reporting period that summarize the work. We have also hosted 11 hands-on workshops that have involved over 117 scientists from 15 universities in the US, Canada, Costa Rica, Brunei, Australia and Mongolia. Natural Resource Managers. We have now partnered with over 25 natural resource parks and protected areas around the country and world. These include: Hustai National Park (Mongolia), Chingaza Natural National Park (Colombia), Le Selva Research Station (Costa Rica), Chiricahua National Monument (Arizona), Crane Trust (Nebraska), and the Wells National Estuarine Research Reserve. Our partnerships have also included those in national or regional offices of the National Park Service and NOAA and some national/international conservation groups (Conservation International, Institute Alexander von Humboldt, Colombia). These partnerships have evolved into many separate projects including some that are not Purdue driven (thus they adopt the technologies and paradigms) and this to us represents a change in behavior which we sought.

Title

Beneficial Reuse of Residuals and Reclaimed Water: Impact on Soil Ecosystem and Human Health

Research

Linda Lee, Agronomy

Outcome

11 - NRE 1.3 # Viable technologies developed or modified for detection and characterization

Issue

Biosolids can be extremely beneficial to enhance soil quality and soil fertility. Use of these organic materials, derived from wastewater treatment operations, for agriculture, raise concerns among public and regulatory community. Sound science is needed in order to properly evaluate the risks to the ecosystem and human health so that biosolids may continue to serve a beneficial purpose rather than be destined for landfills. Our ability to assess such risks is often hindered by a lack of data typically used for evaluating risk or an inappropriate use of the data typically used because the behavior of many potentially toxic inorganic trace elements, and pharmaceuticals and personal care products (TORCs) do not follow previously used paradigms for predicting risk. The primary goal of this research is to optimize the use of municipal biosolid for land reclamation and provide the needed environmental fate data (leaching, persistence, and plant uptake) on the trace organics towards enhancing risk assessment protective of human and environmental health.

What has been done

An evaluation is being conducted of the 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 the environmental and health risk-based effects of their application at a watershed scale. 2) The team also evaluated the uses and associated agronomic and environmental benefits for residuals in agricultural and urban systems. The team conducted an evaluation on the fate of perfluoroalkyl acids (PFAAs) in waste-based fertilizers including biosolid-based materials and composted city wastes (yard trimmings, food wastes, food packaging, etc.). PFAA occurrence was quantified in numerous waste-based fertilizers. The concentration of PFAAs present in the pore-water that can be transported or taken up by plants was quantified. 3) Additional pot studies were initiated this past year with basil, green bean, kale, Swiss chard and turnip grown in soils mixed with a subset of composted materials and analyzed for azithromycin (antibiotic), carbamazepine (anticonvulsant), miconazole (antifungal), triclocarban and triclosan (antimicrobials) and some selected PFAAs.

Results

On the fate of perfluoroalkyl acids (PFAAs) in waste-based fertilizers: On average about 50% or more of the PFAA present in the fertilizers was found in the pore-water. PFAA pore-water concentrations were generally proportional to the initial concentration in the fertilizer. 2) As to how PFAA levels change with different post treatment processes: PFAA concentration tended to decrease in fertilizers where biosolids were blended with other materials, most likely due to a dilution effect. Fertilizer exposed to either composting or heat-treatment appeared to have increased PFAA concentrations after the treatment process. 3) In the pot studies initiated this past year with basil, green bean, kale, Swiss chard and turnip, a preliminary greenhouse study showed that for the five trace organics targeted, (all personal care products and pharmaceuticals), all were taken up into all of the edible parts of plants to some extent at a high application rate (8X recommended rate). Of the four compounds targeted, only triclosan degraded substantially with a half-life of approximately 115 days. The other compounds showed little or essentially no degradation within the 180-day period. Preliminary comparisons with previous literature suggest that the biosolids matrix limits the bioavailability, thus microbial degradation, of these compounds relative to systems where the compounds of interest is added artificially.

Title

Fire effects within group shelterwood systems on regeneration response and residual timber quality

Research

Michael Saunders, Forestry and Natural Resources

Outcome

7 - NRE 1.4 - # Viable prevention, control and intervention strategies

Issue

Oak species have been on the decline for several decades due in part to harvesting practices, failure of nut production (mast), increased wildlife pressure (deer), land-use change, and invasive species. Many scientists have concluded that we are dangerously close to the large-scale loss of oak species by more shade-tolerant tree species such as maple species and American beech. Silvicultural systems have been developed to successfully regenerate oak in uniform age distributions. While these systems are effective, they are often done in areas that go beyond the spatial scale of management activities on many private holdings. New regeneration systems that can be applied at smaller, sub-stand-level spatial scales and that may be more attractive to private landowners are needed. Hybrid silvicultural systems based on natural disturbance dynamics, may be one such alternative. One such hybrid system, an expanding group shelterwood system, is commonly used in Europe for oak regeneration, has been successfully applied to Northeastern mixed-conifer forests, and is now being utilized in several parts of the eastern oak forest by the U.S. Forest Service and other researchers. However, none of these efforts include the use of prescribed fire, which is a key ecological process that promoted oak dominance in these stands over the past two centuries, but has been generally avoided by private landowners because of liability concerns and misinformation regarding its effect on stand timber values.

What has been done

Two ongoing long-term, forest management experiments, NWSC Crane experiment and the Hardwood Ecosystem Experiment, are incorporating the use of prescribed fire to not only track regeneration response to prescribed fire, but also quantify the damage to overstory trees resulting from its use. In addition, over 100 U.S. Forest Service stands, from Missouri to eastern Kentucky, have been inventoried in a retrospective study of prescribed fire on overstory timber volume and value. The team has been 1) Comparing the interacting effects of prescribed fire and expanding gap-based harvesting on short-term tree regeneration response; and 2) Monitoring the influence of prescribed fire, used as a regeneration tool, on residual overstory tree timber quality within shelterwood regeneration systems; and 3) Developing empirical models of expected damage to timber value with increasing prescribed fire intensity and/or frequency.

Results

1) Early results suggest that the combination of prescribed fire and gap-based harvesting techniques hold promise to increase regeneration of oak species, but the benefit will depend highly upon site conditions. The technique is likely to be more successful on dry sites, often with south- or west-facing aspects, than more moist north- or east-facing sites,

and regeneration response will vary spatially. Competitive oak regeneration, in the short-term, is likely not going to occur inside gaps, but on the northern, western and eastern flanks of gaps. Prescribed fires offer an additional benefit to create understory conditions that favor germination of acorns from small mammal caches, which could lead to more oak recruitment in the long-term with repeated burnings.

2) In total, over 200 overstory trees are now being monitored across 16 sites that have had a single prescribed fire. There has been comprehensive analysis of the short-term effects, although the study design has been published and analysis for two sites has been completed. Those results suggested that there was minimal damage to overstory trees, as none died or received a reduction in U.S. Forest Service tree grade.

3) For empirical models of expected damage to timber value with prescribed fire, losses to overstory timber volume and value is likely to vary regionally with edaphic factors and the prescribed intent of the surface fire. Inventories from the Hoosier National Forest in Indiana suggest that prescribed fire will wound up to 50% of the trees, but the relative volume loss is <3% and grade changes are 2-7%. In the Mark Twain National Forest in Missouri (Mann, M.S. thesis, in prep.), prescribed fires are more intense leading to higher wounding rates (up to 70%) and grade loss (up to 45%). Economic damage is likely in this system, but further work is needed to verify patterns seen "on the stump" to actual lumber recovery and value at the timber mill.

Title

Forest Management for the Private Woodland Owner - Helping landowners connect to forestry information and assistance

Extension

Lenny Farlee, Ron Rathfon, Brian MacGowan

Outcome

43 - NRE 1.13 - # Projects focused on understanding of the roles of humans, plants and/or animals

Issue

It is always good to know how programs impact actions and outcomes over time. Because forest management often happens over long timelines, many landowners will not immediately implement management practices after attending a course, so follow-up surveys, which may contact people several years after attending the course, provide a picture of the knowledge change and actions taken by attendees.

What has been done

The Forestry and Natural Resources Extension team surveyed 296 past participants (2007-2015) of the Forest Management for the Private Woodland Owner workshop presented by Ron Rathfon and Lenny Farlee. The workshop provides a broad overview of forest biology, management and sources of information and assistance for landowners. The course is composed of 8 three-hour evening sessions and two half-day field tours. Over 180 responses were received from past participants.

Results

As a result of taking the course in previous years, participants self-reported increases in: 1) knowledge about their woodlands (53%), 2) awareness of groups and organizations that offer information (80%), 3) understanding of where to find professionals who can help manage their woodlands (74%), 4) extent their woodland management decisions are informed by long-term planning (53%), and 5) trust in Purdue Extension as a source of information (34%). Three out of four respondents controlled invasive species on their woodlands in the previous 5 years. 97% indicated the course influenced them to control invasive plants in their woodlands with over half strongly influenced. Similarly, the course influenced 82% to some degree to use the services of a professional forester. Responses included: Participation in the Forest Management for the Private Woodland Owner course was important in helping me determine management objectives for my woodlands (Somewhat agree=35.7% Strongly agree=46.5%). Management of my woodlands improved because of what I learned in the Forest Management for the Private Woodland Owner course (somewhat agree=34.6% strongly agree=41.6%). In the last 5 years, these activities occurred on the woodlands they owned: 1) Hiked/walked (94.67%), 2) Viewed wildlife (90.53%), 3) Controlled invasive species (73.37%), 4) Applied herbicide, pesticides or fertilizers (56.8%), 5) Wildlife/fish habitat improvement projects (e.g., constructed brush piles, planted native shrubs or wildflowers) (53.25%), 6) Prepared land and/or planted trees (49%), 7) Conducted a timber harvest (25.44%), 8) Fished

(23.67%), and 9) Controlled/prescribed fire (10.65%). Comments included: 1) This was a very good program for the beginning forest owner. We have learned a great deal from it and the materials that we received. Thanks! 2) The class I attended in Rochester, IN was excellent and the instructor was terrific. He did a great job. I give him an A+. 3) I would like to receive Indiana Woodland Steward and the class last year was excellent! 4) We really enjoyed this course. Our place is just a get way for us. All of the woods are on a hill. 5) I would eagerly attend more short classes on forestry management. 6) I am interested in returning my entire farm to woodland. 7) I now have the resources and renewed interest in maintaining our forest and passing that information on to my son and grandson. 8) I would recommend this class to other landowners. 9) Extremely grateful for this class. If I had to register a complaint it would only be that I felt the whitetail deer was given a lot of blame for tree damage. If I had to put a value on this class I would say I've got \$1000 worth. Thanks again.

Title

Conservation Partnership Tree Planting Training

Extension

Lenny Farlee, Brian Beheler, Stephen Boyer

Outcome

220 - NIFA CC 2.3 - # of participants adopt recommended adaptation strategies for natural resources management

Issue

USDA programs provide incentives and planning assistance for landowners wishing to implement conservation practices like tree planting, forest stand improvement, and invasive plant species management. USDA Natural Resources Conservation Service and Soil and Water Conservation District employees are often the first contact and a primary source of technical advice and assistance to these landowners. Providing training in science-based management techniques and strategies for these practices may improve the success rate for these practices, and provide the employees more confidence to recommend these practices to landowners. Extension educators also are a primary contact point for local landowner questions regarding natural resource management. Providing training to extension educators expands their knowledge base and provides them with contact points to refer clients to sources of professional assistance.

What has been done

Purdue Forestry and Natural Resources Extension has provided natural resources management training to Indiana Conservation Partnership members for several years. In 2018, two Conservation Tree Planting training days were held at Martell Forest and NEPAC for Conservation Partnership members.

Results

68 Conservation Partnership members participated and 47 returned program surveys. 83 to 94% of participants indicated they planned to speak with landowners about information provided during the program. 100% indicated the program was useful or somewhat useful for making decisions or taking action on conservation tree planting. 33 to 35% reported improved knowledge for tree planting topics including site evaluation and preparation, planting techniques, weed control, and post-planting management. Comments included: 1) hands-on tree planting was a valuable learning experience, 2) hands-on tree planting was helpful and beneficial, 3) this was a fantastic training, 4) A+ it was great hands-on!!!

Sustainable Energy

Title

Biocatalytic Processing for Renewable Resource Utilization

Research

Outcome

6 - SE 4.1 - # New technologies developed

Issue

Federal mandates for the production and use of advanced biofuels has increased the importance of developing technologies to reduce costs and improve efficiencies for cellulose-to-fuel production processes. Technologies that reduce the costs associated with generating fermentable sugars from plant biomass, (e.g., pretreatment and hydrolysis), can have immediate and substantial impacts. Costs associated with cellulose hydrolyzing enzymes are an order of magnitude more expensive than starch-degrading enzymes.

What has been done

The project goal is to develop fundamental knowledge of molecular and engineering processes required for sustainable conversion of renewable resources to transportation fuels and value-added products reducing the carbon footprint of agriculture and industry. The research is identifying lower cost technologies and enhancing the economics of transforming renewable resources to value-added and low carbon footprint molecules. A second objective relates to the application of bio-separation and enzyme technologies, developed for conversion of cellulose to biofuels to the rapid and cost-effective detection of food pathogens. Researchers are studying the impact of plant cell wall structure on its catalytic or bio-catalytic processing into molecules that serve as precursors or end products for use as transportation fuels; carrying out fundamental studies on catalytic mechanisms by which transformations may occur using either enzyme, chemical or microbial (fermentative) catalysts, and developing biochemical processes for effective transformation of plant cell tissues into identifiable alcohol, aldehyde, and aromatic molecules.

Results

For cellulose conversion, liquefaction of biomass that combines modeling of particulate material into pellets and pellets into liquefied biomass material has been initiated. A combination of fluid, solids and particles systems computational models, together with fundamental measurements of innate properties of corn stover particles are being used to define an envelope of processing conditions that lead to pumpable slurries of biomass materials at concentrations between 20% and 30%. For catalytic process, further research has proven beneficial effects of using non-catalytic proteins to block adsorption of enzymes onto lignin, thereby reducing the amount of cellulases by a factor of 5x to 10x required to carry out hydrolysis of cellulose in liquid hot water pretreated corn stover, hardwood and sugarcane bagasse. For biochemical processes, researchers developed a method to recover lactic acid from food waste at optimized conditions and accounted for understudied factors that influence yield (RedCorn and Engelberth 2018). Researchers quantified glycogen production potential from waste activated sludge employing enhanced biophosphorus removal techniques (RedCorn and Engelberth, 2018). In terms of food processing, researchers compared potential avenues for upgrading food waste and determined that higher value potential could be achieved from recovering a niche product rather than processing the waste via anaerobic digestion (RedCorn, Fatemi, and Engelberth, 2018). Researchers quantified the volume of lutein and zeaxanthin in distiller's dried grains with solubles (DDGS) and determined there was a non-trivial quantity and that further study is required to determine a cost-effective recovery method (Li and Engelberth, 2018). These research findings can help build understanding for more cost-effective technologies for biofuel production.

Title

Global Change and the Challenges of Sustainably Feeding a Growing Planet

Research

Tom Hertel, Agricultural Economics

Outcome

74 - SE 5.6 - # Policy makers increased knowledge of decision models

Issue

Since the 2007/2008 commodity crisis, there has been a resurgence of interest in sustainability of the world food system and its contributions to feeding the population and ensuring environmental sustainability of the planet. The number of people which the world must feed is expected to increase by another 2 billion by 2050 (Bloom 2011). When coupled with significant nutritional improvements for the 2.1 billion people currently living on less than \$2/day (World Bank 2008, p.1), this translates into a very substantial rise in the demand for agricultural production. Food and Agriculture Organization of the United Nations (FAO) estimates increased demand at 70% of current production, with a figure nearer 100% in developing countries (Bruinsma 2009, p.2). Over the past century, global agriculture has managed to offer a growing population an improved diet, primarily by increasing productivity on existing cropland. In addition, agriculture and forestry are increasingly envisioned as key sectors for climate change mitigation policy. When combined, farming and land use change - much of it induced by agriculture - currently account for about one-third of global greenhouse gas emissions (Baumert, Herzog, and Pershing 2005). If incorporated into global climate policy, these sectors could contribute up to half of all mitigation in the near term, at modest carbon prices (Golub et al. 2009). Any serious attempt to curtail these emissions will involve changes in the way farming is conducted and place limits on expansion of farming - particularly in the tropics, where most of the agricultural land conversion has come at the expense of forests. Limiting the conversion of forests to agricultural lands is critical to preserving biodiversity on the planet (Green et al. 2005). These factors will restrict the potential for agricultural expansion with growing global demands. Finally, agriculture and forestry are likely to be the economic sectors whose productivity is most sharply affected by climate change (Lobell, Schlenker, and Costa-Roberts 2011; Schlenker and Roberts 2009). This will shift the pattern of global comparative advantage in agriculture (Reilly et al. 2007) and may reduce productivity of farming in precisely those regions of the world where poverty and malnutrition are most prevalent (Hertel, Burke, and Lobell, 2010), while increasing yield variability and vulnerability of the poor (Ahmed, Diffenbaugh, and Hertel, 2009).

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 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 economic factors altogether. Improving predictions and developing coherent policy recommendations which account for dynamic interplay between these forces is a high priority. To improve on the current state of knowledge and policies, the project has these objectives: 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 impact of uncertainty in climate impacts, change mitigation policies and energy prices on both optimal and observed land use change at global scale. 3) Assess impact of future water shortages on global food production, trade and land use. 4) Assess impacts of these global changes on world food prices, food security, livelihoods and poverty in developing countries.

Results

Researchers assessed the need for public investments in research and development (R&D) over the 21st century in light of the very long lag between such investments and U.S. agricultural productivity outcomes, and considerable uncertainty in future population, income and bioenergy growth, and climate impact. R&D has been the major driver of U.S. farm productivity growth since WWII, yet spending has recently leveled off and has even been declining. Failing to invest today in improvements of agricultural productivity cannot be simply corrected a few decades later if the world finds itself short of food. Researchers computed the optimal path of agricultural R&D spending over the 21st century for each Shared Socioeconomic Pathway, along with valuation of regrets associated with investment decision-making. Regret is minimized to find a robust optimal R&D pathway that factors in key uncertainties and the lag in productivity response to R&D. Results indicate that the whole of impact by uncertainty on R&D is greater than the sum of its individual parts. Uncertainty in future population was the dominant impact on optimal R&D expenditure path. The robust solution suggests that the optimal R&D spending strategy is very close to the one that will increase agricultural productivity fast enough to feed the world under the most populous scenario. It also suggests that society should accelerate R&D spending up to mid-century, thereafter moderating this growth rate. These computation results may help in decision-making to support R&D for agriculture productivity to feed the population of the planet.