USDA AGRICULTURAL RESEARCH SERVICE

National Program 305
CROP PRODUCTION SYSTEMS

Action Plan [2013-2018]

INTRODUCTION
In 2011, U.S. farmers planted more than 330 million acres of commercial-scale grains, sugar, fruits, nuts, vegetables, and horticultural crops, with a commercial producer value that exceeded $210 billion. The wide variety of crops, their cropping systems, and the diverse geographic locations and climatic conditions of production provide a myriad of challenges for the farmer.

This national program builds upon other research within the Agricultural Research Service (ARS) that develops better crop varieties and devises ways to keep them safe from pests and diseases and applies that information to develop ways to bring those crops to the field and produce better yields with fewer amounts of fertilizers, pesticides, and herbicides. National Program 305, Crop Production, (NP 305) is the home of research dedicated to solving the field-scale challenges facing U.S. producers, including the critical area of plant pollinators.

Sustaining and enhancing economic viability of crop production as input costs—such as energy, water, nutrients, pest management, and labor—increase requires development of new, environmentally and worker safe technologies and production methods. Needs range from information to support decision tools, such as software, and improved devices, such as more efficient spray nozzles or accurate and reliable sensors for environmental factors. Further, this information and these devices need to be integrated into an overall production system for the specific crop and transferred to producers.

One important component of crop production is insect pollinators. Honey bees (*Apis mellifera*) are the pollinator most used for commercial crop pollination. Their health is threatened by a large number of pests, pathogens, pesticides, and poor nutrition. Honey bee populations continue to suffer, while the frequency of Colony Collapse Disorder (CCD) is increasing, further diminishing the number of honey bees. New techniques for management of honey bee diseases and pests are needed to maximize pollination, while safeguarding these resources. There is also a growing need for non-*Apis* bees (all bees other than honey bees) that effectively pollinate specialized crops or that are useful in greenhouse settings. Conservation of non-*Apis* crop pollinator species is needed.

GOALS
The primary goal of NP 305 is to enhance American agricultural crop productivity, efficiency, and sustainability, and ensure a high quality and safe supply of food, fiber, feed, ornamental, and industrial crops for the nation. As part of that goal, NP 305 seeks to maintain the health and encourage proper management of those bee species adapted for commercial pollination, which are critical to keeping U.S. crop production strong. NP 305 supports research to develop knowledge, strategies, systems, and technologies for a diversity of crops while increasing

environmental quality and worker safety. NP305 is the home for research dedicated to solving field scale challenges that face U.S. producers.

The Crop Production National Program is comprised of two major research components:
1) Integrated Sustainable Crop Production Systems; and
2) Bees and Pollination.

Though for organizational and administrative purposes most research projects and resources are assigned membership in one of these components, research projects and resources can contribute to the goals of both of the NP 305 components and other National Programs. Anticipated products for one problem statement are often critical to the success of research conducted under another.

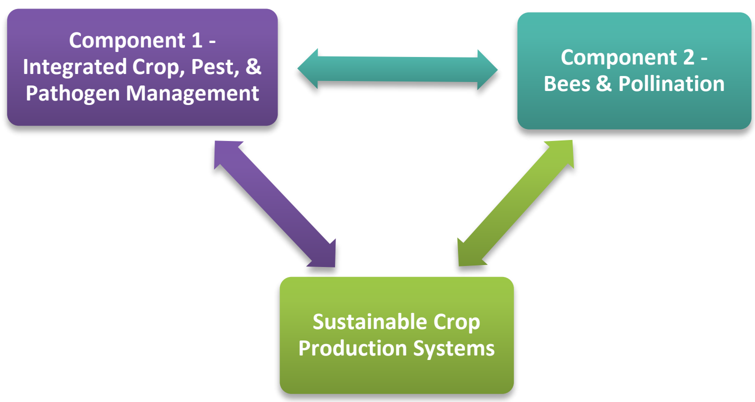

Figure 1: Relationship of NP305 program components.

NP 305 draws from other ARS National Programs, universities, and industries to adapt and incorporate technologies, approaches, and strategies to advance the Nation's crop production and enhance its international competitiveness. For example, research from NP 301, Plant Genetic Resources, Genomics and Genetic Improvement that develops improved crop varieties, and NP 303, Plant Diseases, that devises ways to keep crops safe from diseases is used by NP305 to develop integrated methods and strategies that increase yields with fewer amounts of fertilizers, pesticides, and herbicides. Research from NP211, Water Availability and Watershed Management, provides technology for managing water quality and quantity needed for agricultural production and ecosystem services. Production practices that promote stewardship of soil, efficient nutrient management, limiting impacts on air quality, and strategies for adaptation to the effects of changing weather patterns are available from NP212, Climate Change, Soils and Air Emissions. NP216, Agricultural System Competitiveness and Sustainability, is closely aligned with NP305 with research to develop integrated productivity, profitability, energy efficiency and natural resource stewardship.

RELATIONSHIP OF THIS NATIONAL PROGRAM TO THE ARS STRATEGIC PLAN

National Program 305 research outputs support the Actionable Strategies associated with the Performance Measure from the *2006-2011 ARS Strategic Plan,* Strategic Goal 2: Enhance the Competitiveness and Sustainability of Rural and Farm Economies, under Objective 2.2: Increase the Efficiency of Domestic Agriculture Production and Marketing Systems.

> **Performance Measure 2.2.3:** Expand, maintain, and protect our genetic resource base, increase our knowledge of genes, genomes, and biological processes, and provide

economically and environmentally sound technologies that will improve the production efficiency, health, and value of the Nation's crops.

Target: New technologies developed and used by ARS customers to increase production efficiency and enhance the economic value and quality of U.S. crop production while decreasing the environmental footprint of production systems.

COMPONENT 1: Integrated Sustainable Crop Production Systems

This component encompasses all ARS efforts to improve existing and/or develop new production systems for current and emerging crops. Production systems are highly complex and depend on the integration of multiple management components. Maintaining the profitability of production systems, while conserving energy and natural resources and promoting environmental sustainability, requires new cost-saving, higher-efficiency technologies, methods, and strategies. The ultimate goal of the development of these technologies, methods, and strategies is for their incorporation into new or existing production systems to increase sustainability, productivity, and profitability of the farming operation.

The focus of Component 1 research is on key factors that limit crop production in economically important agronomic and specialty crops grown in open-field or protected (greenhouse, shade house, high/low tunnel) crop production systems. Research optimizes the integration of biological factors (plants, pests, and beneficial organisms), physical factors (soil, water, sunlight, and nutrients), and/or machines at various scales, from within a plant to across a field. This research includes conventional high-input production agriculture, low-input systems, organic systems, and new crops. The needs of all different sizes and types of farming enterprises are considered; this includes field, greenhouse, orchard, and vineyard production platforms.

Research in Component 1 is expected to generate new knowledge, improved management strategies, new models and decision support aids, and new or improved sensors and equipment. These discoveries would be transferred to growers and extension specialists to apply in the field and to other researchers (Federal, State, university, and industry) to further advance research in sustainable crop production systems.

As crop production systems vary by plant type, geography, and use, the research in this Component is focused into five main research areas or Problem Statements, as listed below.

Problem Statement 1A: *Productive and Profitable Systems for Sustainable Production of Agronomic Crops.*

Problem Statement 1B: *Productive and Profitable Systems for Sustainable Production of Temperate Fruit and Nut Crops.*

Problem Statement 1C: *Productive and Profitable Systems for Sustainable Production of Tropical and Sub-Tropical Crops.*

Problem Statement 1D: *Productive and Profitable Systems for Sustainable Production of Ornamental, Nursery, and Protected Culture Crops.*

Problem Statement 1E: *New and Improved Mechanization and Spray Application Systems for Sustainable Crop Production*

The proposed research uses a systems approach combining three overlapping aspects of sustainable crop production:

- Horticultural and abiotic stress management;
- Pest and disease management; and
- Crop-quality management.

The inter-disciplinary nature of this research is required to understand critical crop management and production interactions. The goal is to develop a coordinated, national research program to improve crop management and quality and mitigate the impacts of insects and diseases to ensure consistent and profitable production of temperate fruit and tree nuts in the United States.

The research effort in Component 1 can be represented as shown in Figure 2 on the following page.

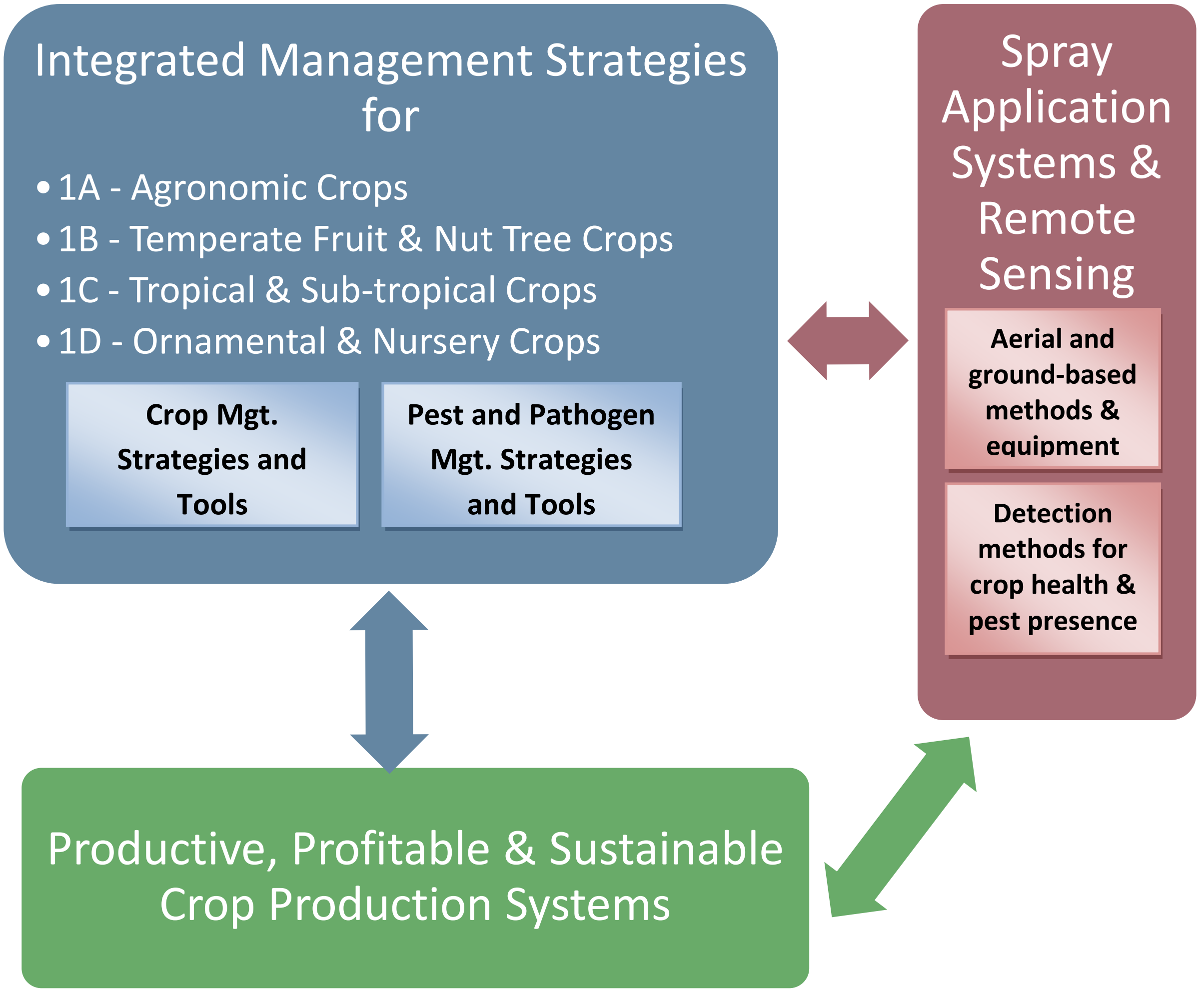

Figure 2: Integrated crop, pest, and pathogen management research flow diagram.

Problem Statement 1A: ***Productive and Profitable Systems for Sustainable Production of Agronomic Crops.***

For many years, the United States has continued to have the most productive agricultural system in the world. Much of this long-term success has been achieved through the development of economically and environmentally sustainable cropping systems. However, increased human population and demand for food security, loss of arable farmland due to urbanization, and reliance on agriculture to produce biofeedstocks along with food, feed, and fiber have led to increased demands on these cropping systems. Even with higher prices for some commodities, profitability is becoming more of a challenge because of rising production costs. Climate change adds another layer of complexity to agriculture because of its potential influence on the abundance and distribution of pests and shifts in crop-climate match. Such shifts, coupled with urban encroachment into traditional agricultural areas are already causing some agricultural production to move into less suitable regions and soil types. Meanwhile, farmers are faced with the daunting challenge of incorporating and integrating new technologies, such as improved crop genotypes, alternative crops, and new pest control strategies into modern cropping systems along with traditional commodity crops.

RESEARCH NEEDS:

- Optimization of profitable cropping systems that integrate food, feed, fiber, and fuel crops without negatively impacting the environment.
- Optimization of traditional, new, and alternative crop species and varieties for regionally variable climates, soils, and production practices.
- Improved knowledge of nutrient requirements and cycling within various cropping systems, and maximized and efficient use of additional inputs such as tillage and irrigation.
- Integrated pest management (IPM) systems that foresee and prevent the adaptation of pests within current and prospective production systems.
- Improved understanding of how components of production systems (e.g., tillage, soil types, planting dates, seeding rates, varieties, fertility, irrigation, environmental stresses, and pest management) interact and impact crop productivity and quality.

ANTICIPATED PRODUCTS:

1. Match crops (species and varieties) with regionally variable soil types for productive and profitable cropping systems.
2. Improved crop production systems based on understanding of crop production efficiencies, nutrient inputs, nutrient cycling and utilization patterns for various cropping systems.
3. Management practices that minimize the development of herbicide-resistant weeds and improve soil quality.
4. Integrated management systems for effective pest management and maximized yields.
5. Improved crop quality and productivity through understanding of interactions among rotations, tillage, soil types, planting dates, plant germplasm/variety, fertility, irrigation, and pest management.
6. Productive and profitable cropping systems capable of integrating crops for food, feed, fiber, and/or fuel.

POTENTIAL BENEFITS:

- U.S. agricultural systems are diversified, profitable, and sustainable, and produce crops of high quality.
- Farming communities remain economically sound and healthy and our nation has an abundant supply of food, feed, fiber, and biofuel.
- Knowledge of how cropping components interact and how those interactions impact crop production will inform farmers of best management practices and improve profitability.
- Knowledge of the minimum agricultural inputs needed to obtain a desired production level will lower production costs, minimize negative impacts on the environment, and help preserve of our natural resources.
- Farmers will know how best to utilize their lands to maximize diversity and productivity, as knowledge of new and alternative crops and varieties with respect to the soil types is developed.

- Farmers are aware of crop performance and cropping alternatives for their region and are better prepared to make adjustments to their cropping systems as climate change occurs.

Problem Statement 1B: *Productive and Profitable Systems for Sustainable Production of Temperate Fruit and Tree-Nut Crops.*

U.S. crop production systems for temperate fruit and tree-nuts have a critical need for novel management practices that not only minimize costly inputs, but also maintain and improve current production to help feed a growing national and global population. New knowledge and understanding of biological systems, new management tools, and ultimately effective technology transfer are needed to ensure continued global competitiveness of U.S. grape, berries, apple, peach, and pecan.

Crop production systems are challenged by an ever-increasing interface between urban and agricultural areas, decreasing availability of quality water, and unpredictable weather. More stringent labor, environmental, and pesticide regulations intended to lessen the adverse impacts from agriculture inevitably affect the cost of production. An integrated approach, grounded in scientific research, to simultaneously maximize crop yield and quality while reducing adverse environmental impacts, is needed to assure continued competitiveness of U.S. producers in the global marketplace and compliance with domestic and even potentially international regulations.

RESEARCH NEEDS:

- Increased knowledge of the effects of irrigation and nutrient management on floral regulation, root physiology, fruit development, and disease development.
- New knowledge of the biological foundation and environmental influences on plant architecture.
- Knowledge of the physiological and genetic bases of plant tolerance of abiotic stress (e.g., drought, heat, cold).
- Relationship of beneficial microbes (e.g., mycorrhizal fungi) to plant nutrient uptake including characterization of taxonomic and functional diversity.
- Characterization of the relationships between soil-management practices and biogeochemical cycles.
- Increased knowledge of the behavioral ecology and biology of invasive pests.
- Integration of chemical, biological, and/or cultural controls that target the most vulnerable stage of the pest or pathogen into crop production systems.
- Use of information on the epidemiology, pathogenesis, ecology, and population genetics of pathogens for the enhanced production of temperate fruit and nut crops.
- Improved understanding of the impact of environmental factors and crop management strategies on crop quality components.
- Methods for quality-component identification and characterization.
- Characterization of the effects of microclimatic factors on yield and crop quality.

ANTICIPATED PRODUCTS:

1. Enhanced crop management strategies for temperate fruit and tree nut crops utilizing improved understanding of the impact of physiological and abiotic stresses on crop yield and quality within the context of crop production systems. Examples include:
    - Canopy-management strategies that improve production efficiency, quality, and tolerance of abiotic stress to facilitate economic and environmental sustainability through resource-use efficiency, productivity, pest resistance, and orchard automation.
    - Nutrient management and floral regulation strategies that stabilize cropping within the orchard and over growing seasons.
    - Irrigation techniques that enhance crop quality and conserve water, while satisfying crop water need.
    - Mineral nutrient and soil-management strategies that minimize inputs and potentially-harmful outputs.
    - A computer-vision system that facilitates the automation of orchard tasks.
    - Analytical tools and instrumental analysis for monitoring and assessing crop quality as influenced by the crop production system.

2. Enhanced disease and pest management strategies for temperate fruit and tree nut crops derived from improved understanding of pest and pathogen interactions with crops within the context of crop production systems. Examples include:
    - Trapping/monitoring tools that minimize the spread of invasive pests to new areas.
    - Behaviorally based control strategies to both reduce insecticide inputs and increase profitability and sustainability.
    - Integrated pest management (IPM) programs that layer the most effective and economically sustainable chemical, biological, and cultural controls adapted to specific production systems.

POTENTIAL BENEFITS:

- Increased crop longevity and stability (i.e., longer intervals between replanting).
- Lower risk of crop loss from abiotic stress.
- Greater interannual stability of crop yield and quality (e.g., less alternate bearing).
- Improved crop quality.
- Water conservation.
- Reduced labor costs.
- Reduced material and application costs for pesticides.
- Lower risk of pest introductions into new areas.
- Lower risk of disease spread from nurseries to orchards/vineyards.
- More competitive perennial crop production systems for U.S. growers.
- New production areas for target crops.
- Better environmental stewardship.
- Improved sustainability of target crops.
- Transfer of technologies developed to other systems.

Problem Statement 1C: ***Productive and Profitable Systems for Sustainable Production of Tropical and Sub-Tropical Crops.***

Increased production of many tropical and subtropical fruit crops is hindered by a lack of basic information on how physiological, horticultural, environmental, entomological, and pathological variables, as well as management practices, affect fruit production systems and how these interact to influence harvestable yield and fruit quality. Development of efficient and sustainable production management systems using a holistic approach to study these variables, as well as the identification of superior cultivars and new crops based on performance within a production system, are of paramount importance to ensure the productivity and global competitiveness of the tropical and subtropical fruit industry in the United States.

RESEARCH NEEDS:

- Investigation and identification of horticultural and physiological factors limiting tree productivity and broader agro-environmental adaptation.
- Cultivar evaluation within a production system for enhanced input-use efficiencies to reduce production costs and increase crop productivity and adaptability.
- Evaluation of performance of superior cultivars and pollenizers within a production system for higher yield, fruit quality and other horticultural and physiological traits to enhance production efficiency and profitability.
- Evaluation within a production system of cultivars for superior adaptability for establishment under conditions of environmental and soil constraints to increase production efficiency and profitability.
- Sustainable cultural and pest management systems for improved crop production and fruit quality.
- Improved understanding of vector biology and interactions with crop hosts.
- Expanded understanding of impact of orchard design/layout on pest behavior and disease transmission.
- Improved/enhanced application of area-wide suppression/management of pests limiting export of crops.

ANTICIPATED PRODUCTS:

1. Production systems for tropical and sub-tropical crops with enhanced productivity, profitability, and sustainability. Examples include:
    - Performance assessment of cultivars in various production systems.
    - Improved crop production systems for new crops or cultivars.
    - Sustainable production systems for improved soil characteristics, fertility, productivity, and environmental quality.
    - Expanded markets for exotic fruits.
    - Guidelines for the management of pollenizers, pests, and pathogens of crops.

POTENTIAL BENEFITS:

- Improved efficiency of water and nutrient use, sustainability of soil quality, and health of tropical and subtropical crop production systems.
- Availability of improved production systems including new varieties, cultivars, and/or rootstocks.

- Increased and sustainable control of crop pests.
- Higher production efficiency and profitability of small farms.
- Reduced environmental impact of tropical and subtropical agricultural production.
- Stimulate growth in agricultural sector.

Problem Statement 1D: ***Productive and Profitable Systems for Sustainable Production of Ornamental, Nursery, and Protected Culture Crops.***

Production systems for nursery, greenhouse, and other protected culture crops offer control over the growth environment during production and, as a result, can achieve high yields, enhanced quality, and/or early production. However, the increased control in these horticultural systems comes at a cost of higher labor and fuel costs, increased reliance on substrates and inert materials, and an environment that enhances specific diseases and pests that are difficult to control. Within protected-culture (greenhouse, shadehouse, low/high tunnel), there are opportunities to improve water, nutrient, and substrate utilization; increase the use of mechanization; further develop integrated disease and pest management concepts; and significantly reduce the potential impact of crop production on the environment, while simultaneously preserving productivity and crop quality.

RESEARCH NEEDS:

- Determine the interactions of production components (water quality, quantity, and application; soil and substrate quality, physio-chemical properties, and substrate component management; mineral nutrition efficiency and water-use efficiency) and their impacts on crop quality and growth, plant health, effects on abiotic stress tolerance, and application technology:
- Methods and technologies to optimize on-farm and non-renewable resources and to integrate, where appropriate, natural biological cycles and controls to improve the sustainability and economic viability of protected-culture operations.
- New knowledge and technologies to assist growers in optimizing production within controlled-environment structures with respect to energy, labor, and agrichemical inputs.
- More accurate and more expansive/inclusive models to assist growers in using the right combination of production scheduling and energy inputs to produce profitable crops.
- New and innovative pathogen and pest management strategies to improve efficacy of control and worker safety while minimizing negative environmental impact.
- Greater knowledge of how cultural practices influence pest populations and their susceptibility to control measures.
- Greater knowledge of water-pathogen life cycles and pathogen suppression in recycled water.
- System-specific cultural management, including integration of strategically implemented sanitation and management practices that restrict pathogen build-up and spread, and new genetic material or plant varieties, to reduce crop susceptibility to pests during and after production.

ANTICIPATED PRODUCTS:

1. Enhanced crop management strategies for ornamental, nursery, and protected culture crops based on improved understanding of the impacts of physiological stresses, abiotic stresses, and crop environment on crop yield and quality within the context of crop production systems. Examples include:
   - New or modified components for floriculture and nursery substrates.
   - Guidelines to optimize the economical, physical, chemical, and biological impact of new and commonly used components in nursery and greenhouse substrates.
   - Guidelines for managing the interactions of nutrients, water, and substrates to enhance crop growth, product quality, and postharvest performance.
   - Innovative guidelines for implementing more economical and effective production practices (e.g. substrate construction, irrigation regimes, nutrient management, container design, etc.).
   - New molecular technologies and techniques for improving crop performance in production and post-harvest markets.
   - Optimized environmental controls for enhanced crop growth, input efficiency, product quality, and postharvest performance.
   - Expanded database of models for predicting energy requirements in protected culture and innovative guidelines for their implementation.

2. Enhanced disease and pest management strategies for ornamental, nursery, and protected culture crops based on improved understanding of pest and pathogen interactions with crops within the context of crop production systems. Examples include:
   - Improved pest and pathogen control strategies for both within-season and post-harvest application.
   - Effective and economical treatment for pathogens in recycled water.
   - New recommendations for cultural practices and enhanced pesticide performance.
   - Biological pesticides.
   - New decision support tools for disease and pest management.

POTENTIAL BENEFITS:

- New knowledge of the relationship between substrates, irrigation, and nutrition that will allow for savings by reducing costs of one or more of these inputs.
- New substrate components to increase the suite of materials from which to generate substrate blends will result in an expanded menu of choices for producers and, thus, more stable supply chains.
- New knowledge and technologies will allow growers to reduce the quantity of water needed for irrigating crops, improve the quality of irrigation water used and released from protected-horticulture systems, and lead to new strategies for managing water quality and quantity.
- New technologies in irrigation and greenhouse environmental control will help reduce labor costs, while adding production capacity, to help improve profitability.
- Expanded and refined models for energy requirements in protected-culture will allow for more efficient production scenarios to be considered by growers, thus increasing production efficiency and reducing energy costs.

- Greater understanding of the interaction between cultural practices and pest management will lead to reduced pesticide inputs and costs and safer work environments for employees.
- Reduced exposure to pest control agents and pesticides will mean healthier and more marketable plants and improved working conditions.
- Novel biological and natural pesticides will result in new markets for pesticide manufacturers, as well as reduced synthetic pesticide exposure to employees and consumers.

Problem Statement 1E: ***New and Improved Mechanization and Application Systems for Sustainable Crop Production.***

The detection, monitoring, and control of crop health and crop pests across the wide variety of cropping types and systems requires consideration of, and adaption to, a variety of influencing factors, including crop type and structure, pest type, environmental conditions, and chemical or alternative control inputs. A variety of application system types and methods are required to address the numerous and varied cropping systems within the United States. With rising operational and input costs, producers will need methods for rapid assessment of crop health and rapid detection of invasive pests that can be used in conjunction with improved application technologies. This would support timely management decisions and help to guide precision, targeted applications where needed to enhance overall efficiency and productivity while reducing environmental impact.

RESEARCH NEEDS:

- Improved understanding of deposition and transport mechanisms from conventional, alternative, and organic application systems crucial to reducing chemical inputs, minimizing environmental impact, and enhancing long-term sustainability in American agriculture.
- Improved understanding of spray atomization and drift from modern application systems.
- Increased understanding of on-target deposition and uniformity resulting from operational setups and application methods used in low-rate applications.
- New, improved, and optimized application equipment and methods to address the diversity in cropping systems and environmental factors.
- Drift Reduction Technologies to mitigate off-target movement for sustainable production programs.
- Precision, site-specific, application technologies and practices that maintain efficacy with reduced pesticide use.
- New or improved remote sensing methods including airborne and ground-based imaging and crop monitoring systems to identify crop structure, crop health, and emerging and invasive pests for optimum treatment effectiveness.
- High-quality research data using modern application systems and practices to guide regulatory decisions.
- Development and evaluation of testing equipment and methods that insure uniform pesticide application and label compliance.

ANTICIPATED PRODUCTS:

1. Aerial and ground-based application methods and equipment. Examples include:
   - Equipment and methods for performance measures of application uniformity and movement to provide guidance on optimum setup and operational parameters.
   - Guidance on use and setup of conventional systems for efficient and efficacious applications.
   - Updated and extended range spray nozzle models with improved Web and mobile platform-based decision support systems.
   - Improved variable-rate and alternative application systems that decrease environmental impact and minimize off-target losses.

2. Remote sensing and field detection methods to identify crop structure and health and emerging and invasive pests. Examples include:
   - New and improved technologies, such as manned and unmanned ground and aerial systems, for monitoring crop conditions and pest damage or presence to support precision application systems and crop management decisions.

3. Scientific data supporting application technologies and methods with significantly reduced spray drift to aid regulatory guidance and operational practices.

POTENTIAL BENEFITS:

- Readily available guidance on optimal equipment setups and operational practices will increase application efficiency and efficacy while minimizing adverse environmental impact.
- Lower rate application technologies and methods will increase application efficiency, thus providing for timely and cost-effective pest management.
- Research data from drift reduction technology evaluations will ensure the rapid acceptance and integration into standard application practices of those technologies with the potential to reduce drift.
- Precision variable rate applications will reduce overall field pesticide inputs by applying only in locations and in amounts needed for effective pest control.
- Rapid detection of spray drift, and environmental conditions that may promote spray drift, will allow applicators to rapidly adjust equipment and operational parameters.
- Data from completed research will provide a sound scientific foundation for regulatory agency decisions and policies.
- Remote sensing for affordable and rapid identification of crop pests for timely pest management will reduce overall loss of crop quality and yield.
- Data from integrated crop monitoring systems will allow rapid and timely assessment of crop growth stage and health to support crop management decisions.

COMPONENT 1 RESOURCES:

ARS projects in NP 305 address the research problems identified under Component 1 at the following locations (alphabetical by state). ARS lead scientists who are assigned to these projects include:

Location	Lead Scientist(s)
Davis, California	Baumgartner, Jiang
Ft. Pierce, Florida	Albano, McCollum
Byron, Georgia	Wood
Houma, Louisiana	Johnson
Beltsville, Maryland	Baligar
Morris, Minnesota	Gesch
Poplarville, Mississippi	Copes
Stoneville, Mississippi	Thomson, Reddy
Wooster, Ohio	Frantz, Derksen, Zhu
Corvallis, Oregon	Bryla, Lee
Mayaguez, Puerto Rica	Goenaga
College Station, Texas	Hoffmann
Kearneysville, West Virginia	Tworkoski, Takeda

COMPONENT 2: Bees and Pollination

In the United States, managed bees are vital to the production of more than 90 crops including almonds, apples, cherries, berries, melons, and sunflowers. Maintaining the health and practicing proper management of the few species of bees that have been adapted for commercial pollination are critical to keeping U.S. agricultural production strong. The honey bee (*Apis mellifera*) is the main commercial (and a versatile) pollinator. In the United States, the honey bee pollinates crops with an added value in the billions of dollars (and of course produces honey).

The health and well-being of honey bees, colonies, and their queens are threatened by a large number of pests (including other insects and parasitic mites), pathogens, pesticides, and poor nutrition. Therefore, the long-term viability of the honey bee industry and the production of crops dependant on their pollination is likewise threatened. The *Varroa destructor* parasitic mite remains the primary threat to honey bee health. While ARS researchers are developing *Varroa* control agents, resistant bee lines, and diets to improve bee nutrition, further research and development is needed. The gut pathogen *Nosema ceranae* (parasitic fungi) also poses a large threat to honey bees; new control products are needed as is epidemiology research to help prevent spread of the pathogen. Other issues of concern, which can be severe, are American foulbrood disease and the small hive beetle (SHB), which attacks honey bee colonies and destroys bee products.

First reported in 2006, unexplained losses of managed honey bee colonies called Colony Collapse Disorder (CCD) has become a major threat to bees. CCD is a complex syndrome that has proven to be hard to define and combat. Though ARS research has shown that a number of factors are associated with CCD—including parasites, pathogens, poor nutrition, pesticides, bee management practices, habitat fragmentation, and agricultural practices—no single factor or pattern of factors definitively leads to CCD. Additional research on the inter-relationships of these factors is needed to increase understanding and develop effective prevention and mitigation strategies. ARS heads the CCD Steering Committee, whose 2007 Action Plan (available at www.ars.usda.gov/is/br/ccd/ccd_actionplan.pdf) calls for survey and sample data collection, the development of mitigation and preventive measures, and research to identify factors affecting honey bee health—including attempts to recreate CCD symptomology. The committee's latest progress report (2011) can be found at www.ars.usda.gov/is/br/ccd/ccdprogressreport2011.pdf. A new Action Plan will be created in October 2012.

ARS is partnering with other agencies to work on this complex problem. For example the USDA National Institute of Food and Agriculture (NIFA) has funded a "Coordinated Agricultural Project (CAP)," the Bee Informed Partnership (http://beeinformed.org), that endeavors to decrease the number of managed honey bee colonies that collapse each winter by helping to determine which management practices are working best to sustain honey bees and their hives. The Bee Informed Partnership also examines various data collections to assess pest and disease levels in an effort to bridge the gap between research and application. Since 2007, The Bee Informed Partnership has joined ARS and the Apiary Inspectors of America to carry out annual surveys of winter losses of managed honey bee colonies.

There is also concern about sub-lethal effects, such as exposure to pesticides that can lower honey bees' resistance to pests and pathogens. A recent study suggests that some pesticides might increase the levels of infection of the *Nosema* gut pathogen in individual bees. ARS scientists continue to examine whether such sub-lethal effects correlate with or contribute to bee health problems and CCD.

There is also a growing need for non-*Apis* bees (all bees besides honey bees) that effectively pollinate certain crops, such as alfalfa or berries, or are useful in greenhouse settings. Non-*Apis* bees are also critical components of our ecosystems and land restoration efforts in the United States. While there is only one species of managed honey bee (*Apis mellifera*), there are close to 4,000 species of native North American bees. In light of CCD, the contribution of these non-*Apis* bee pollinators to plant and crop production takes on special importance. Yet, the taxonomy of these bees is still unclear making identifying these bees correctly a challenge. With this vast number of species, better identification methods are needed to aid conservation efforts.

Species of interest for crop pollination include the alfalfa leaf-cutting bee (*Megachile rotundata*), the alkali bee (*Nomia melanderi*), the blue orchard bee (*Osmia lignaria*), and bumble bees species (*Bombus* spp.). To maintain the productivity and health of these non-*Apis* bees and expand their use in crop production, a better understanding of their biological requirements and behaviors is needed, as is research on their parasites, disease, and nutritional needs (forage).

Component 2 is focused into five main research areas or Problem Statements, as listed below.

Problem Statement 2A: *Bee Management—Improving Bee Nutrition and Performance*

Problem Statement 2B: *Bee Health—Mitigating the Impacts of Pathogens, Pests, and Pesticides*

Problem Statement 2C: *Maximizing Bee Pollination and Quantifying Bee Forage Requirements*

Problem Statement 2D: *Conserving Bee Diversity and Improving Bee Taxonomy*

The interrelationships of these problem statements are shown in Figure 3 on the following page.

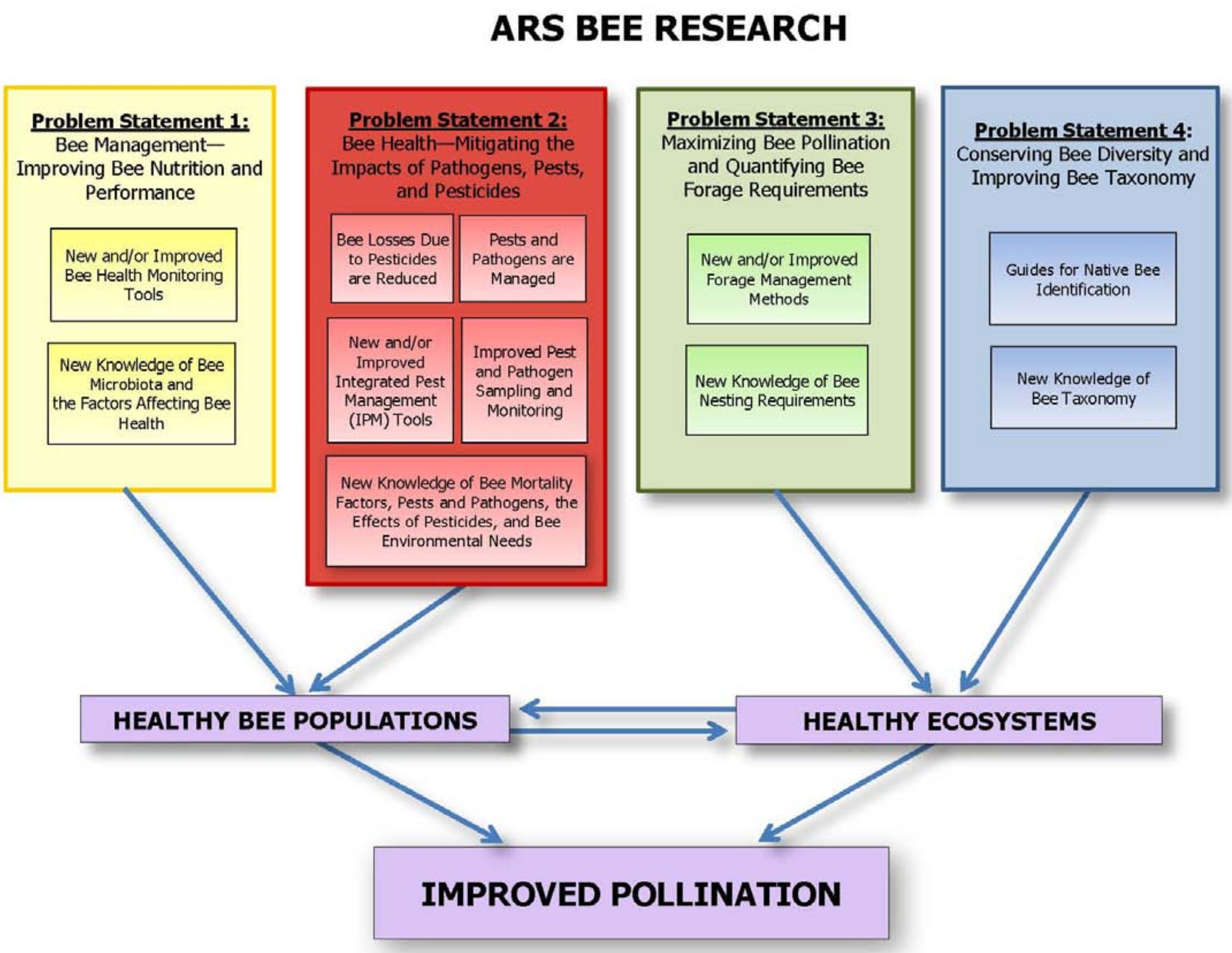

Figure 3. Relationships of ARS bee research Problem Statements.

Problem Statement 2A: ***Bee Management—Improving Bee Nutrition and Performance***

The abundance and quality of food as well as weather and storage conditions during dormancy can affect bee activity, longevity, reproductive capacity, immunity, and resilience, but further work is needed to quantify how nutrition and environmental conditions affect these parameters of bee performance and health. This is true for honey bees (colonies), as well as non-*Apis* bees, such as bumble bees (colonies) and alfalfa leaf-cutting bees (solitary). Honey bees collect nectar and pollen from flowers, then use beneficial microbes to ferment and store them, creating what is known as “bee bread.” These microbes also help process and digest this “bee bread.” Such microbes might also confer benefits to bee and colony health, nutrition, and disease resistance, and they also occur in the guts of many other bee species.

The antimicrobial properties of fungicides and other pesticides used to control plant pathogens during bloom might alter the microbial composition of bee bread and/or bee guts so understanding bee nutritional microbiology may help growers to choose fungicides and pesticides that limit pollinators’ risk. Furthermore, the role of nutrition in immune response, queen performance and longevity, and the resilience of bee colonies (hives) to stress are also largely unknown. Impacts on bee colony health and activity are usually measured by intermittent in-person inspections of hives (static) which can disrupt normal hive activity and new methods that will collect continuous data without such disruptions are needed.

RESEARCH NEEDS:
- Identification of core microbes associated with bee nutrition.
- Identification of environmental factors that can compromise community diversity and structure.
- Understanding the nutritional and environmental (e.g., temperature and humidity) requirements for bee and colony health, including overwinter survival.
- Characterization of the nutritional values of various pollens, including honey bee pollen, before and after it is stored in hives or nests.
- Identification of nutritional factors that promote queen longevity and health, as well as increase mating success.
- Characterization of the native diet of bumble bees and alkali bees.
- Development of remote and continuous methods for monitoring hive health; this both prevents any interference with hive activity and provides more accurate data to beekeepers.

ANTICIPATED PRODUCTS:
1. Characterization of microbial communities needed to maintain bee health and the effects of pesticides and antibiotics on these communities.
2. Knowledge on the environmental and nutritional needs of bees for improved longevity, reproduction rates, and winter survival.
3. New methods for continuous monitoring of bee health and activity which is needed for preventative and/or evasive action.

POTENTIAL BENEFITS:

- Improved overwintering survival of honey bee colonies and bumble bee queens.
- Recommendations for beekeepers on bee nutritional requirements for health maintenance, high overwinter survival, and high reproductive capacity.
- Recommendations for regulatory agencies and agronomists on the evaluation of the risks posed to pollinators by fungicides and agricultural antibiotics.
- Methods for both beekeepers and bee researchers to readily monitor honey bee hive productivity and health.
- An improved understanding of how plant community (and pollen) diversity affects bee population growth.

Problem Statement 2B: *Bee Health—Mitigating the Impacts of Pathogens, Pests, and Pesticides*

Parasites, pests (whether native or invasive), and pesticides are critical factors that negatively influence bee health and survival. Honey bees are strongly impacted by parasitic invasive mites (varroa and tracheal), small hive beetles, viruses, nosema, larval pathogens, and nest depredators (which ransack nests). Overwintering colony losses have risen due to CCD and in order to combat this phenomenon, the inter-relationships of the aforementioned factors need to be better understood. Solitary bees are most adversely affected by chalkbrood disease and parasitoid wasps. Understanding the effects pests and pathogens have on bees as well as bees' natural defense mechanisms is important for the development of new control method and strategies and to mitigate potential threats to bees from the establishment of additional invasive species. Pesticide exposure is the most important abiotic stressor that affects the success of all pollinators, including bees. Bees are among the insects that are most sensitive to the toxic effects of pesticides, but the impacts of sub-lethal and chronic exposure to pesticides are poorly understood. Mitigating damage caused by these natural and man-made factors requires detailed knowledge of their impacts and sustained multi-disciplinary efforts to devise appropriate strategies.

RESEARCH NEEDS:

- Optimization of diagnostic protocols for bee pathogens, e.g., viruses, nosema, and crithidia.
- Identification of the effects of pathogens (e.g., chalkbrood, foulbrood bacteria, and *nosema*) and pests (e.g., varroa and tracheal mites, solitary hive beetle, and solitary bee parasitoids) on bees and develop means for control.
- Characterization of pathogen transmission mechanisms.
- Using an epidemiological approach, identification of causes for bee declines.
- Identification of the genetic basis of bee immune traits and enhance immunity.
- Investigation of microbial interactions and their effects on bee health.
- Determine and mitigate the sub-lethal, chronic, and acute impacts of pesticides on bees.
- Determine the effects of environment on immunity.

ANTICIPATED PRODUCTS:

1. New sampling and diagnostic methods for bee pests and diseases.
2. Information that will improve pesticides' risk assessments.
3. Identification of environmental effects associated with bee declines.
4. New knowledge and/or tools, such as bee stocks and traits and their associated management techniques, that provide a foundation for improved IPM strategies for pest and disease control.

POTENTIAL BENEFITS:

- Tools for regulating the spread of novel or newly virulent pathogens.
- Improved control of bee-specific pests and diseases.
- Improved bee health and overwintering survival.
- Non-chemical control strategies for varroa mites.
- Preserved and improved pollinator germplasm.

Problem Statement 2C: *Maximizing Bee Pollination and Quantifying Bee Forage Requirements*

In managed bees that provide crop pollination services, reproduction and colony size or population are often suboptimal for pollination; this may be even more so for non-*Apis* bees. Research is needed to determine the optimum number of bees for deployment in various crops (maximum pollination), balanced with adequate provision of floral resources (forage) for the bees. More research is needed to identify optimal bee population enhancement strategies, such as increasing the length of time forage is available and its total amount (and the optimal forage type). Such research will help to evaluate the effect of land management practices on bees, such as grazing practices in rangelands, and to assure the sustainability of areas that are suitable to build-up bee populations. Also, the health, well-being, and productivity of bee populations and crop pollination could be improved with a better understanding of how bees should be distributed and for non-*Apis* bees, with better quality nesting materials and sites. This would make both beekeeping and pollination services more reliable and economical.

RESEARCH NEEDS:

- Investigation of plants and planting strategies to supply forage before and after crop pollination.
- Determination of pollinator density and distribution in crops to optimize yields.
- Improvements in nesting conditions for solitary bees.

ANTICIPATED PRODUCTS:

1. Methods to improve forage management and nesting conditions to increase bee populations.
2. Recommendations for pollinator deployment to optimize crop yield.

POTENTIAL BENEFITS:
- Improved availability of bees for crop pollination.
- Improved bee production rates for bees used in pollination services, making beekeeping more economical.
- Conserved native bee abundance within agricultural and rangeland areas.

Problem Statement 2D: *Conserving Bee Diversity and Improving Bee Taxonomy*

Native bee populations are critical natural resources that need to be conserved. There is growing concern that these vital resources may be in jeopardy. While recent bumble bee research documents severe declines in some species, there is a lack of understanding of the declines of other native bees. Inventory and monitoring efforts, assessments of population sustainability, and studies of the effects of altered habitats are needed to determine the extent of species decline and as precursors to remedial efforts. Many important groups of pollinators remain in a state of taxonomic chaos and accurately identifying them, given the approximately 4,000 species of bees in the United States, is difficult. Formal revisions and user-friendly Web-based identification guides are required to remove this impediment.

RESEARCH NEEDS:
- Improvements to taxonomy and evaluation of bee biodiversity to assist with conservation efforts.
- Monitoring of bee diversity and abundance, development of methods to assess conservation priorities, and evaluation of the effects of altered habitat on bee declines.

ANTICIPATED PRODUCTS:
1. Guides for bee identification.
2. New knowledge of bee taxonomy.

POTENTIAL BENEFITS:
- Improved conservation of pollinators.
- Knowledge about the diversity and distribution of pollinators in the western United States.
- Means for conservationists and land managers to identify bees.

COMPONENT 2 RESOURCES:

Ten ARS projects that are coded to National Program 305 address the research problems identified under Component 2, at the following locations:

Location	Lead Scientist(s)
Tucson, Arizona	DeGrandi-Hoffman, Gloria
Baton Rouge, Louisiana	Danka, Robert & Rinderer, Thomas
Beltsville, Maryland	Evans, Jay
Weslaco, Texas*	Meikle, William
Logan, Utah	James, Rosalind

*Location has been proposed for closure