USDA Agricultural Research Service

National Program 216-- Sustainable Agricultural Systems Research Action Plan 2018-2022

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Contents

National Program 216
Sustainable Agricultural Systems Research
2018-2022 Action Plan

Vision

Integrated solutions for agriculture enabling greater productivity, profitability, and natural resource enhancement.

Mission

The mission of National Program 216 (NP 216) is to build the science-based foundations for farming systems of the future using a systems approach without bias for particular science discipline. Producers will be equipped with actionable genetic and management *options* offering multiple routes to achieving the four goals of sustainable agriculture: 1) desired quantity and quality of yields, 2) economic viability and competitiveness, 3) environmental enhancement, and 4) quality of life for rural populations and society as a whole.

This transdisciplinary research effort integrates information and technology. New configurations of practices will be identified that integrate on-farm resources with knowledge of natural ecosystem processes to reduce the need for purchased inputs, thus reducing production costs and risk. Technological advances that include precision management, automation, and decision support tools are investigated to increase production efficiencies and enhance environmental benefits. The resulting diverse, improved agricultural systems will support the long-term financial viability, competitiveness, and sustainability of farms and rural communities, and increase food, feed, and fiber security for the U.S. and the world.

Relationship of this National Program to the USDA Strategic Goals for FY2018-2022

This Action Plan outlines research that supports three objectives in the USDA under Strategic Goal 5 Strengthen the stewardship of private lands through technology and research:

- Objective 5.1: Enhance conservation planning with science-based tools and information.
- Objective 5.2: Promote productive working lands.
- Objective 5.3: Enhance productive agricultural landscapes.

Relationship of this National Program to the USDA Resource, Education, and Economics (REE) Action Plan

This Action Plan outlines research that supports the 2014 REE Action Plan

- Goal 2: Responding to climate and energy needs
  - Subgoal 2a Responding to climate variability
  - Subgoal 2b Bioenergy/biofuels and biobased products

- Goal 3: Sustainable Use of Natural Resources
    - Subgoal 3B Landscape-scale conservation, management and resiliency.

Relationship of this National Program to the ARS Strategic Plan
This Action Plan outlines research that supports the 2012-2017 ARS Strategic Plan Strategic Goal Area 2 - Natural Resources and Sustainable Agricultural Systems, Goal 2.6 Develop integrated solutions to solve challenges related to agricultural system productivity, profitability, energy efficiency, and natural resource stewardship.

- Performance Measure 1.2.6: Develop integrated solutions to solve challenges related to agricultural system productivity, profitability, energy efficiency, and natural resource stewardship.

Introduction

The National Research Council report titled *Toward Sustainable Agricultural Systems in the 21st Century* provides a foundation for National Program 216. The report identifies four goals that define sustainable agriculture:

- Satisfy human, food, feed and fiber needs, and contribute to biofuel needs
- Sustain the economic viability of agriculture
- Enhance environmental quality and the resource base
- Enhance the quality of life for farmers, farm workers, and society as a whole

Simultaneously achieving these goals requires a systems approach. The NP 216 program will use a systems framework that defines production as a function of the interactions of genetics with environment and management (GxExM). The expansion of the traditional GxE interaction to include M highlights opportunities for management to enhance performance of genetic resources under varying environmental conditions. Feedback from producers and stakeholders about GxExM is universally favorable as this is how they "view the world". Additionally, products delivered to consumers are viewed as a function of (GxExM)P where P is post-processing, socio-economic factors including price and consumer preferences such as nutritional value and food safety.

Customers and Stakeholders for this program include farmers, consultants, biofuel industry, state agencies, commodity organizations, nongovernmental organizations (NGO's), the Natural Resources Conservation Service (NRCS), the Farm Service Agency (FSA), the Foreign Agricultural Service (FAS), the Risk Management Agency (RMA), the Environmental Protection Agency (EPA), the Department of Energy (DOE), and other action agencies and organizations.

This program will continuously build a vision for sustainable production systems of the future.

Goal

The goal of the Sustainable Agricultural Systems Research Program (NP 216) is to utilize transdisciplinary research teams to develop and integrate information from a diverse set of technologies around the genetics x environment x management (G x E x M) concept to develop and evaluate practices that optimize production efficiency, productivity, profitability, energy efficiency, resilience, and natural resource enhancement for agricultural systems across the United States.

Research results and products will be delivered to stakeholders through local and regional technology transfer events; through websites; through application development for personal devices; and various publications. The forms of delivery will include regional, and local stakeholder meetings (which include written handouts as either fact sheets or proceedings) and national presentations of findings each year. Other forms of delivery of research results and findings will include extension publications, field day books, annual reports, extension newsletters, proceedings and refereed journal manuscripts.

Data and metadata collected for NP 216 research will be made openly available and accessible via data management systems operated by ARS and where appropriate, collaborating organizations. It is ARS policy that only data that has been scientifically vetted be released, to ensure that the highest standards of data quality data are met.

Approach

The 216 National Program is organized into three components:

- Building Agroecosystems for Intensive, Resilient Production via GxExM
- Increasing Efficiency of Agroecosystems
- Achieving Agroecosystem Potential

These three component areas focus on what can be implemented to improve production efficiency within the field, what can be done to limit the offsite impact and enhance ecosystem services, identify the limitations to productivity, sustainability, and resilience of agricultural systems, and integrate knowledge gleaned to optimize agricultural systems at the field and farm scale.

Component 1. Building Agroecosystems for Intensive, Resilient Production via GxExM

There is a need to intensify production and maximize ecosystem services per unit area of land due to increased demand for food and fiber products and a decreasing availability of land for agroecosystems. Holistic agroecosystem solutions are sought to avoid unintended consequences of management decisions. The complexity of agroecosystems is such that integration and synthesis of research results is needed to build multifunctional landscapes of the future. The long term consequences of production system decisions, changing precipitation and temperature patterns, and the effects of policy on decision-making are of increasing concern and thus, ongoing efforts to assess the sustainability of existing and proposed future systems are needed, coincident with efforts to further enable greater efficiency and productivity. Projects contributing to the ARS Long Term Agroecosystem Research network (LTAR) are directly focused on such questions. The research of Component 1 will address combinations of viable *options* for building GxExM-based systems solutions using agroecological principles.

Problem Statement 1A. Sustainable & resilient cropping systems
The GxExM perspective on cropping systems provides a foundation from which to develop and evaluate agricultural strategies that link combinations of variables such as planting practices, tillage, rotations, cover crops, nutrient management, water management, other conservation practices, adaptation to biotic and abiotic factors that may limit production; efficient practices that lead to better economic returns; and enhanced ecosystem services. The development of viable management practice options is expected to enable producers to meet production demands, make continuous profit over multiple growing seasons, while enhancing the natural resources base.

Research Focus
ARS will conduct research to develop strategies to increase production and selected non-provisioning ecosystem services while increasing socio-economic performance of cropping systems.

Anticipated Products
- Guidelines for cropping systems that include cover crops and conservation tillage across dryland moisture regimes for reduced yield risks; enhanced soil structure, soil organic matter, microbial activity, and nutrient cycling.
- Assessment and communication of the impact of selected crop rotation practices intended to reduce populations of weeds, diseases, and invertebrate pests; increase success rates in establishment of new crop stands; and increase longevity of new stands.
- Identification, elucidation and communication of agroecological principles that have the greatest impacts of grain and forage cropping systems and ecosystem services.

- Quantification of the influence of destabilizing forces on sustainability, including: weather variability; degrading or declining soil quality; human demand for non-agricultural water use; and demand for nutritious and safe food.
- Technologies and management strategies that improve productivity, enhance soil and water conservation, improve efficiency of nutrient cycling, and support food safety and nutritional security goals in grain-based and horticultural cropping systems.
- Viable options for alternative crops and management practices for introduction into existing dryland rotation systems.
- Sustainable and resilient cropping systems derived from site-specific GxExM frameworks.
- Identification of crop rotations, irrigation systems, plant populations, row orientations, and row spacing(s) best adapted for sustainable peanut-based agriculture systems.
- Complete development of a new database to improve quality, accessibility, and utility of Ecological Site Description (ESD) information nationwide, and collaborate with NRCS to complete national population of ESD information.
- Guidance for the use of sustainable crop production strategies for irrigated crop production systems.
- A tool box of high-value management practices for sustainable field management of intensive dryland rotations.

Potential Benefits

- Meet the needs of producers for comprehensive management strategies that have greater relevance than historical single goal-focused research efforts.
- Greater potential for sustainable systems by enlarging capacity to meet yield, profit and environmental enhancement goals.
- Reduced impacts of agriculture on environment.
- Increased soil health.
- Improved water quality, reduced air emissions.
- Habitats more conducive to pollinators and wildlife.
- Reduced production input amounts and costs.
- Sustainable intensification of cropping systems on spatially variable landscapes and soils.
- Abiotic and biotic stress-resilient edible legume production systems.

Problem Statement 1B. Sustainable & resilient grazing land systems

There is a need to understand and enable sustainable intensification of agricultural systems for regions where rangeland and integrated crop/livestock operations exist. Such systems include variable attributes of land (E), and forage, crops and livestock (G). The producer introduces strategies (M) for agricultural production and economic viability while ensuring ecosystem services. This includes opportunities to expand the GxExM concept to explicitly embrace dynamics of mixed species ecosystems used for grazing systems.

Research Focus
ARS will conduct research to develop strategies for increased production and enhancement of selected non-provisioning ecosystem services while increasing economic performance of grazing and pasture lands systems.

Anticipated Products

- Comprehensive management strategies with greater relevance to local systems than historical single goal-focused research efforts.
- A decision guide for evaluating rangeland and pastureland health.
- Impacts of projected climate variability on dairy and beef production systems and adaptation strategies.

Potential Benefits

- Better information and tools for risk management.
- Greater potential for sustainable agriculture by increasing capacity to meet yield, profit and environmental enhancement goals.
- Increased soil health.
- Improved water quality, reduced air emissions.
- Habitats more conducive to pollinators and wildlife.
- Reduced production input amounts and costs.
- Safeguards to ensure that research-driven, new production systems provide are sustainable.

Problem Statement 1C. Integrated/Diverse Cropping & Livestock Systems
Producers may choose to establish relatively uncommon agricultural practices to improve resilience and address environmental or economic resource concerns. Practices such as the inclusion of livestock or poultry within a cropping system, or other combinations that deviate from standard farming operations are of interest. Diversified systems will be investigated to quantify how they may offer increased productivity with lowered economic costs, while determining their ability to provide greater environmental benefits and ecosystem services when compared to traditional cropping or livestock/poultry operations.

Research Focus
ARS will conduct research to develop approaches for integrated/diverse agricultural systems that reduce production risks, improve producer economic returns and enhance ecosystem services.

Anticipated Products

- Guidelines for developing resilient, sustainable integrated agricultural systems.
- Strategies to enhance ecosystem services from integrated agricultural systems
- Comparisons of system productivity and efficiency between integrated and non-integrated systems.

- Alternative livestock-cropping systems that promote soil and water quality, and reduce the prevalence and persistence of antibiotic resistant (AR) microorganisms at the systems level.
- Diversified cropping systems that include mixed cropping, provide year-round vegetative cover, habitats for arthropod natural enemies and pollinators, and mitigate crop metal toxicity and/or persistence of antimicrobial resistance in integrated crop-livestock production systems.
- Consequences of trade-offs between management for ecosystem services and specific economic attributes in an integrated crop-livestock system as compared to those outcomes as they occur in a single enterprise conventional system.
- Integrated crop-livestock production systems that have reduced off-farm inputs, improved water and nutrient use efficiencies, reduced contaminant export, and diversified economic opportunities.
- Resilient soil that meets integrated crop-livestock production needs and provides essential ecosystem services.
- Options for integrated agricultural systems that reduce production risks, and enhance economic viability and ecosystem services under extreme weather conditions.
- Quantified sustainability of cattle production systems in areas of the United States (and many areas of the world) that are suited to grassland and rangeland production.
- Improved sustainable intensification strategies of crop and integrated crop-livestock systems for farm systems, watersheds, and landscapes.
- Databases for modeling enterprise management options for integrated crop-livestock production systems.

Potential Benefits

- Reduced environmental risk from transport of contaminants from agricultural operations, and thus greater protection of air, water, and soil quality and livestock health and production.
- Opportunities for landowners to raise productivity.
- Increased agroecosystem productivity, resilience, and viability.
- Sustainable Agricultural Systems for the Northern Great Plains.
- Resilient agricultural systems of the southeastern U.S..
- Gulf Atlantic Coastal Plain cropping systems that enhance productivity, efficiency, and resiliency of agroecosystems.
- Sustainable intensification of crop and integrated crop-livestock systems at multiple scales.

Problem Statement 1D. Long Term Agroecosystem Research (LTAR) network

The ARS LTAR network was established to assess and enable greater sustainability of working lands. The LTAR network research is organized around topics of sustainability relevant to local, regional and national consequence, relying upon long-term databases, cross-site experiments, and computational modeling to tie experimental and monitoring conclusions for a broader vision of the future of agriculture for the United States.

A significant component that sets LTAR network apart from other long-term research infrastructures is the Common Experiment. This experiment is conducted within each LTAR site, and in community across the LTARs as a unifying experiment. For this, two production schemes are studied and analyzed, with one being the crop or livestock operation that is currently in-use for the particular region ("business as usual"), and an innovative, research-driven agricultural crop or livestock system that is "aspirational." These comparisons enable scientific evaluation of the long term sustainability of the traditional agricultural approaches to be deeply analyzed and modeled, and compared to the aspirational approach. Outcomes from the LTARs will provide a national perspective on viable G and M approaches with demonstrated long-term agroecosystem sustainability, to bring to the producer community.

Research Focus

ARS will operate and maintain the LTAR network using scientifically vetted technologies and practices to assess and enable the long term sustainability of U.S. production systems. Contributing projects will submit relevant data with appropriate metadata to the LTAR Information Ecosystem.

Anticipated Products

- Techniques to extrapolate results from field-scale research to larger scale watersheds and regions, such that the findings at field scale are made more applicable to wider regions.
- Calibration and validation of models and sensing technology to use with local and strategic decision making.
- Updates to good agricultural practices and toolkits.
- Sustainability metrics appropriate for local production systems.
- Quality controlled and assessed data from a variety of spatial and temporal scales.

Potential Benefits

- Better decision-making criterion for risk management through:
  - Insights to the consequences of producer decisions on immediate and long-term production, producer economics, and environment.
  - Insights to the consequences of policy decisions on immediate and long-term production, producer economics, and environment.
  - Insights to the consequences of changing climate on immediate and long term-production, producer economics, and environment.
  - Resilient and climate smart agriculture.
- Safeguards to ensure that research-driven, new production systems are sustainable.

ARS Locations Contributing Resources to Component 1

Akron, CO	Columbia, MO
Ames, IA	Corvallis, OR
Auburn, AL	Dawson, GA
Beltsville, MD	Las Cruces, NM

Lincoln, NE
Mandan, ND
Maricopa, AZ
Mississippi State, MS
Orono, ME
Pendleton, OR
Pullman, WA
West Lafayette, IN
Raleigh, NC
Salinas, CA
Sidney, MT
Stoneville, MS
Temple, TX
Tifton, GA
University Park, PA

Component 2. Increasing Efficiencies for Agroecosystem Sustainability

Increasing efficiency creates pathways toward sustainable systems, as efficiency contributes to the goals of profitability and reduced effects on natural resources via fewer losses of inputs. Efficient amounts, timing, and placement of inputs also contributes to greater productivity as over-application can reduce yields. However, efficiency of agroecosystems is not an easily defined endpoint due to tradeoffs between the cost of production and the efficient use of fertilizers, pesticides, and natural resources, e.g., water and light. The ability to compare different systems and incorporate insights from each into technologies (Problem Statement 2b) and decision support tools (Problem Statement 2c) can provide producers and landowners with a rigorous framework for assessing viable options for building agroecosystems. Producers often ask about the cost of incorporating different practices, and thus the economics of production (Problem Statement 2a) must be incorporated into the research framework. The outcomes of such efforts are guidelines for viable technology options for a system, the cost to implement the technologies, and the impact of the technology on the efficiency within the G x E x M framework.

Enabling sustainability is accelerated when research provides estimates of cost and expected return from different agricultural systems, options for technology available for producers to consider, and a framework for evaluating the options. A framework becomes apparent via G x E x M as this mirrors how producers view production. The wide variation of agricultural production systems across the United States poses challenges to the development of universal decision support tools. However, research findings combined with guidelines for decision-making and user-friendly simulation models for “what if” scenario projections are expected to provide rigorous steps towards increasing the efficiency and profitability of American agriculture.

Problem Statement 2a. Production Economics

The economic assessment of systems and components of agricultural systems is often the first question that producers ask about an alternative system. Within the context of GxExM, the cost of a specific management practice and the expected return from its use, compared to the cost and return of the current system, are criteria for decision making. To ensure the livelihood of producers, this component becomes a necessary aspect to link the technologies (Problem Statement 2b) into the decision context (Problem Statement 2c).

Research Focus

ARS will investigate potential tradeoffs of the cost of implementation and expected return of GxExM options within existing systems.

Anticipated Products

- Economic assessments of the viability of different production systems.

- Compare the production risks among agricultural systems within a given agroclimatic region.
- Evaluate effects of extreme weather events on risk factors of different agricultural systems.

Potential Benefits

- Framework for assessment of risk within the context of ecosystem services and economic return.
- Increased economic viability.
- Reduced risk for production systems.

Problem Statement 2b. Technologies to Enhance Efficiency

Increasing the sustainability of agricultural systems requires more efficient use of all inputs. Within the G x E x M framework, this focuses on the E x M interactions to quantify the effects of different management practices and the resulting interactions with the environment. Management practices can range from the types and rates of fertilizers, plant spacing, water management practices, residue management, pest management, and interfacings with all aspects of precision agriculture. The question that remains, however, is how to utilize the available technological resources to enhance the sustainability of agricultural systems and further develop technologies that enable resilience for these systems.

Technologies with the potential to enhance efficiency across a range of agricultural systems are especially promising as we move further into the future of the digital age of agriculture. The technologies encompass all of the components in the G x E x M concept. Technologies are considered to be part of the M component and would include methods that enhance water management (drainage and irrigation), fertilizer application, weed control, pest management, tillage and cover crops management. The needs for technology to be addressed focus on how we can use tools to help define the efficient use of these technologies relative to production and ecosystem services. Precision agriculture employs technologies to quantify the spatial variation within fields, and the use of these technologies need to be tested as a tool to decrease the temporal variation of yields within fields.

One large knowledge gap is the utilization of the next generation tools for the application of remote sensing technologies to detect crop stress, and estimate crop growth, phenology, and productivity. This leads to a need for the development of tools that utilize remote sensing to enhance application of precision technologies for increased production efficiency. These technologies are envisioned to provide spatial and temporal understanding of how G can be assessed in the G x E x M framework and how changes in G and M interact to increase efficiency.

Research Focus

ARS will conduct research to develop, assess and provide guidelines for the effective use of technologies that will advance the efficiency of agricultural systems.

Anticipated Products

- Strategies to increase production efficiency for water, nutrient, and light use.
- Information to aid in the assessment of the viability and efficiency of different technology options for different agroecosystems.
- Evaluation of the utility of precision agriculture techniques.
- Development and assessment of remote sensing methodologies to quantify cropping systems for growth, phenology, and productivity.
- Identification of technologies that can increase crop or animal production efficiency.
- Identification of methods that can enhance soil function.
- Identification of methods that can enhance capability to stabilize production across all sectors of U.S. agriculture.

Potential Benefits

- Increased efficiency of natural resource utilization.
- Increased sustainability of the soil resource and enhanced soil function.
- Greater stability of production across all sectors of U.S. agriculture.
- Increased capability of producers to identify and select alternative practices.
- Increased capacity of management systems to offset the impacts of extreme weather events.
- Frameworks to evaluate different technologies for their effectiveness at improving efficiency.
- Decision support tools that include the capacity to evaluate the consequences of management actions on the environment.

Problem Statement 2c. Decision support

Information to guide producers and landowners requires synthesis across research efforts and a framework for integrating this information into a context that has value to the user. The goal is to provide the information in a way the user can use and provide them with the capacity to inform decisions that meet their production and sustainability goals. The knowledge required for this problem area is to develop the decision framework in the context of sustainable pathways for agricultural systems. The challenge will be to design the framework for sustainability metrics to provide information for producers and landowners to utilize. Effective decision support tools focus on synthesis of information in a way to show alternatives and place information in the context of all of the objectives of the decision-maker. Within the context of GxExM, the focus needs to be on site-specific identification of the potential and most relevant and impactful alternatives of G and M for a given production system. The research being conducted must emphasize that agricultural systems are site-dependent and an evaluation of agricultural systems must consider the specific environment (e.g., soils and climate) before determining how G and M can be evaluated.

Addressing the complex problem of decision support requires an understanding of the agroecosystem over the scales of field, farm, and landscape. The development and use of sustainability metrics for decision-making will vary among scales and will be affected by the spatial and temporal dynamics of each agricultural system. The research will focus on the development of a decision support framework using sustainability metrics of different agricultural systems. These efforts will require an evaluation of the impact of current and future climate scenarios on the sustainability of agricultural systems. A primary question to be addressed will be to determine how changes of resilience will impact sustainability within the context of multiple endpoints. The analysis requires synthesis across research locations to share results, ideas, and approaches.

Research Focus

ARS will develop and assess decision support tools and options for GxExM decision-making criteria that will enable producers and strategic decision makers to develop more informed short term and long-term strategies for sustainability.

Anticipated Products

- Decision support tools that optimize multiple endpoint goals.
- Decision support tools that enable exploration of options for resilience and sustainability.
- Identification of techniques that enable the quantification of tradeoffs among system components.
- Development of a research structure for the sharing of information among locations to develop effective strategies for decision support.

Potential Benefits

- Information will be provided to producers and landowners to help guide decisions to enhance resilience in their production systems.
- Information will be provided to producers and landowners to help guide decisions to enhance sustainability in their production systems.
- Development of an infrastructure for sharing information to increase the value of multi-location and multi-disciplinary research in ARS.

ARS Locations Contributing Resources to Component 2

Akron, CO
Ames, IA
Auburn, AL
Beltsville, MD
Columbia, MO
Corvallis, OR
Dawson, GA
Las Cruces, NM
Lincoln, NE
Mandan, ND
Maricopa, AZ
Mississippi State, MS
Orono, ME
Pendleton, OR
Pullman, WA
Raleigh, NC
Salinas, CA
Sidney, MT
Stoneville, MS
Temple, TX
Tifton, GA
University Park, PA
West Lafayette, IN

Component 3. Achieving Agrocosystem Potential

Questions regarding how the genetic makeup of specific varieties informs management practices and how these enable producers to reach the full production potential are emerging. Although there is a compelling need to increase the production potential of crops, there is an equally compelling need to close the gap between what is possible (yield potential) and what is often achieved (farmer yield). New tools are transforming our ability to reduce this value, known as yield gap. Traditional and advanced breeding techniques combined with rapid phenotyping methods will continue to increase potential yields and to select varieties that are better adapted to specific environments and management strategies, while advances in electrical, mechanical, chemical and biological tools (remote sensing, GPS, variable rate applicators, unmanned aerial vehicles (UAV), agrochemical inputs, etc.) help close the yield gap. However, the science behind the application of these technologies, and further, the science of decision-making to meet sustainability goals needs strengthening. Precision agriculture, cropping systems, grazing systems, and development of predictive models have a role.

Enhancing ecosystem services and reducing the effects of farming on the environment are goals of sustainable agriculture. Specifically, reducing the use of agrochemicals, managing crop residues, sequestering carbon, and improving water use efficiency lead to improved soil health and decreased off-site movement of chemicals, nutrients, and soil. While these practices may improve production efficiency by reducing costs, they can also exacerbate pest populations. Therefore, a deeper understanding of how tradeoffs between improving efficiency and associated environmental outcomes can be optimized and predicted is needed.

Agroecosystems must be poised to adapt to changing climate. Several strategies that contribute to increased efficiency (reduced tillage, increasing soil carbon, targeted use of agrochemicals) may also facilitate resiliency and adaptation to changing climate. Research contributing to the USDA Climate Hubs, the Agricultural Modeling Intercomparison and Improvement Project (AgMIP), and LTAR aspirational scenarios will promote regional climate resiliency.

Agroecosystem potential may have a regional component. For example, germplasm developed to be optimally productive in the humid southeast United States will not perform nearly as well as in the semi-arid great basin. However, the opposite is also true. For example, the discovery of microbiomes that help mitigate drought stress may be simultaneously important to dryland agroecosystems in the Pacific Northwest and to arid agroecosystems in the southwest United States. Therefore, multi-location, multi-disciplinary research efforts, including those that contribute to ARS Greenhouse gas Reductions through Agricultural Carbon Enhancement network (GRACEnet), Agricultural Antimicrobial Resistance (AgAR), Nutrient Use and Outcome network (NUOnet), Resilient Economic Agricultural Practices (REAP), biochar network (CHARnet), Conservation Effects Assessment Project (CEAP) and LTAR will improve cropping outcomes, provide ecosystems services, and ultimately advance agroecosystem potential by fostering collaborations, synthesizing and standardizing data, sharing resources, and developing expertise.

Problem Statement 3a. Sustaining Intensified Production

Across all agricultural systems, a primary goal is to increase and sustain production for an abundant supply of safe, nutritious food, feed, and high-quality fiber. Accomplishing this goal is increasingly difficult as available land area shrinks and natural resources become more limited. Given the limited amount of land available for agriculture, the path towards increasing and sustaining production lies in increasing the yields that producers obtain under specific environments and management practices. Thus, implementation of the GxExM framework can begin to explore ways to optimize interactions to achieve agricultural potential. A yield gap approach addresses all factors affecting crop yields and also identifies when these factors affect yield during the growing season. The concept of yield gap also applies to livestock systems.

Yield gaps are often not fully attributable to individual environmental or genetic factors. Therefore, multi-location, transdisciplinary approaches are essential to identify the collective causes of yield gaps for different agricultural systems and to broaden efforts beyond the scale of individual fields. Research on factors that limit plant health and growth including stress tolerance, nutrient use efficiency, and disease resistance is needed, including the development and evaluation of novel germplasm. Likewise, an evaluation of practices that enhance productivity such as precision agriculture, targeted use of agrochemicals and soil amendments, and resource management strategies is also needed. Research advances on these and other related topics will facilitate the development and implementation of systems-appropriate management practices that optimize production and reduce yield gaps. Systems-level approaches that integrate agricultural operations within farms, across farms, and across economic/social structures within a local and regional community should be pursued.

Research Focus

ARS will conduct research to understand factors and processes contributing to yield gaps and identify solutions that ameliorate these restraints.

Anticipated Products

- Catalog of causes of yield gaps across agroecosystems.
- Development of germplasm that is resilient towards abiotic and biotic stress.
- Development of germplasm that is adapted to a changing climate.
- Synthesis of potential management practices that decrease the yield gap and enhance sustainability in the different agroecosystems.
- Synthesis of information that could increase productivity in different agroecosystems.

Potential Benefits

- Enhanced productivity.
- Stabilized production and decreased environmental impact across a range of agroecosystems.

- Increased resilience to climate change and climate variation.
- Decreased yield gaps of cropping, grazing, and livestock production systems.
- Increased farm profitability.

Problem Statement 3b. Enhancing ecosystem services

Ecosystem services include a broad spectrum of environmental, cultural, and community benefits resulting from properly-functioning ecosystems. These benefits are divided into provisioning (production of food, fiber, and energy), regulating (environmental quality), supporting (nutrient cycling, soil health), and cultural services, including those that support rural livelihoods. Because past research has focused on how to improve upon an individual type of ecosystem service, knowledge that integrates or optimizes these four aspects of ecosystem services is lacking. Transdisciplinary GxExM approaches are required to achieve a more holistic understanding of how management practices simultaneously affect myriad agroecosystem services. Likewise, tradeoffs between production, environmental, and economic goals must be defined and quantified across landscapes.

Research that develops comprehensive management strategies and technologies to enhance ecosystem services is needed. This may include cropping practices that specifically improve water quality, air quality, and soil health. To reduce off-site transport of nutrients and agrochemicals, strategies that reduce inputs by using targeted application or increased nutrient use efficiency should be developed. Research that improves soil management practices to increase water holding capacity and limit runoff and erosion will also limit off-site transport of nutrients, agrochemicals, and soil. Research investigations may include evaluation of targeted deployment of soil amendments, such as biochar, compost, and manure. The identification of crop rotations that increase soil carbon, enable better management of weeds, and control populations of insect and plant pathogens may also reduce agrochemical inputs, improve soil health, and sequester carbon. To jointly optimize multiple ecosystem services, evaluations of the tradeoffs between production, environmental, and economic goals are also needed.

Research Focus

ARS will conduct research to develop comprehensive management strategies and technologies to enhance ecosystem services.

Anticipated Products

- Meta-analyses of different agricultural systems that provide a quantitative assessment of the tradeoffs among ecosystem services.
- Crop and grassland management practices that are optimized to deliver simultaneous ecosystem services.
- Novel soil amendments, including novel chemical and biological products.
- Expanded ARS GRACEnet, AgAR, NUOnet, REAP, LTAR, CHARnet, and CEAP databases.

Potential Benefits

- Sustainable agricultural systems.
- Increased system resilience.
- Improved water and air quality.
- Improved soil health.
- Sustainable control of pest populations and pathogens.
- Economically-resilient rural communities.

Problem Statement 3c. Enabling decision support for sustainability

Defining the tradeoffs between strategies that optimize production, and strategies that optimize environmental goals is the emphasis of the research articulated under Problem Statement 3b. Achieving an acceptable solution for ecosystem services will require the development and expansion of decision support tools that can address the complex interactions leading to the intended and unintended consequences of operator actions, changing climate, changing policies and changing markets. Decision support tools must be capable of quantifying GxExM interactions for different agricultural systems. Decision support tools may include the development, expansion, and implementation of models, lists of viable options for management practices, guidelines on the implementation of technologies and practices, and indices of sustainability. The outcomes of these efforts will provide producers and landowners with tools to help guide decisions toward sustainable outcomes.

The development of information on how a broad-spectrum of agricultural practices collectively affects ecosystem services on a regional and national scale is needed. Although one-practice, one-field, one-farm investigations are useful, it is imperative that the results from these studies are extrapolated beyond that scale. This information will support decision making tools that producers can use to better manage and optimize practices to simultaneously meet production and environmental goals. The need for research includes knowledge that quantifies how components of agricultural systems interact with each other to affect particular ecosystem services. However, to quantify progress towards environmental goals, the development and application of metrics for sustainability is also needed, including the development of sustainability indices for water, air, and soil quality. In general, the technology required to address this complexity is a “big data” problem because it will require computational systems capable of evaluating interactions over a range of spatial and temporal scales. While the development or expansion of models, best management practices, guidelines and indices is paramount, the dissemination and implementation of decision support tools is also a vital component.

Research Focus

ARS will conduct research to develop decision support technologies that will help guide decisions toward sustainable system outcomes.

Anticipated Products

- New or improved models that predict how management strategies impact production and environmental outcomes.
- Development and communication of best management practices or guidelines for sustainable production.
- Decision support tools that utilize data from precision agriculture technologies, including UAVs and remote sensors.
- Development, calibration, and validation of process-based models.
- Development of decision support tools that evaluate G x E x M management scenarios in response to changing climates.
- Decision support tools and software to evaluate environmental quality or crop and soil health.

Potential Benefits

- Increased predictability of how production practices impact ecosystem services.
- Improved assessment of ecosystem services.
- Implementation of best management practices and guidelines.
- Improved profitability from precision farming.
- Reduced risk.
- Improved sustainability.

ARS Locations Contributing Resources to Component 3

Akron, CO
Ames, IA
Auburn, AL
Beltsville, MD
Corvallis, OR
Dawson, GA
Las Cruces, NM
Lincoln, NE
Mandan, ND
Maricopa, AZ
Mississippi State, MS
Orono, ME
Pendleton, OR
Salinas, CA
Temple, TX
Tifton, GA
University Park, PA
West Lafayette, IN