FY2015 Annual Report
National Program 215—Pasture, Forage and Rangeland Systems

Introduction

The USDA-ARS National Program for Pasture, Forage and Rangeland Systems (NP215) had another productive year in 2015 in terms of scientific output, technology transfer activities and breadth of collaborations with partners and stakeholders across the US and around the world. Scientists in NP215 continue to make extraordinary impact in numerous diverse areas of research relating to the management of the Nation's natural resources, including the over 1B acres of rangelands and pasture lands.

In FY2015, NP215 continued implementing project plans that were developed from comprehensive stakeholder input gleaned from the NP215 national stakeholder workshop in 2012. The workshop brought stakeholders and the NP215 research community together to prioritize the scope and direction of research in NP215 and to discuss current and future areas of impact for stakeholders.

The overarching goal of NP 215 is:

> *To improve food and energy security while enhancing the natural resources base by developing and transferring economically viable and environmentally protective technologies for sustainable range, pasture, forage and turf production systems that are based on fundamental applications of ecological and agronomic processes, and that are flexible to mitigate and adapt to the uncertainties of changing climate and market conditions.*

Our Nation's range, pasture, and herbage-based forage and turf landscapes serve many critical functions. Farms and ranches produce high quality, nutritious, abundant, and safe food products, as well as fiber and wood products that are the basis of income for producers and their rural communities. Rural areas provide significant ecosystems services such as clean air, water, and wildlife habitat, and are a long-term repository for biodiversity. These systems comprise about half of the land surface of the United States and represent a large and diverse mix of ecological sites, including annual grasslands of California, tundra rangelands of Alaska, hot arid deserts of the Southwest, temperate deserts of the Pacific Northwest, semiarid cold deserts of the Great Basin, prairies of the Great Plains, humid native grasslands of the South and East, and pastures and hay fields within all 50 states from Hawaii to Maine and Alaska to Florida.

The United Nations estimates that two-thirds of the world's agricultural land is pasture, forage and rangelands that can sustainably produce high quality animal products, but are unsuitable for more sustained, intensive production of grains or vegetables for human consumption. Knowledge gained about the development of sustainable land management in the United States will aid people across the globe, and ARS research will be critical to meeting the food security demands of a projected 9+ billion people by 2050. In FY2015, the importance of these global applications was demonstrated by NP215 scientist collaborations with researchers from 27 countries in North America, South America, Asia, Europe, India, Australia, New Zealand, and Africa. Many of these international interactions continue long term and productive scientific relationships.

The Nation's 30-40 million acres of turf lands are found around our homes, schools, municipal and commercial buildings, in our parks, greenbelts and recreational areas, and along our roadsides, airports

and right-of-ways. These lands contribute to our well-being in many ways, including beautifying our towns and cities; enhancing property values; and providing vital environmental services such as erosion prevention, nutrient cycling, carbon sequestration and aquifer replenishment. These industries contribute an estimated $40 billion a year to the U.S. economy.

Pastures, forages and rangelands are the primary forage base for U.S. livestock grazing industries and are used by more than 60 million cattle and more than 8 million sheep and goats. Forage livestock systems contribute more than $100 billion in farm sales annually to the U.S. economy. The estimated value of alfalfa and other hay production is $13 billion, and is the third most valuable crop to U.S. agriculture, behind only corn and soybeans. In addition, hay exports from all U.S. ports has increased 34% during the 2002-2011 period to nearly 4M metric tons per year. The publicly owned rangelands in the western U.S. are also critically important, providing forage on 260 million acres for three million beef cattle and sheep raised on over 30,000 primarily family owned and operated ranches. Nearly 70% of dietary protein and 40% of dietary calories for the U.S. population are of animal origin, and forage resources are crucial for sustained efficient production of food animal products.

The ecosystem services provided by these lands are of increasing importance. Watersheds in upland range and pasture regions are essential sources of clean water for urban areas, irrigated agriculture, and recreation. These lands provide forage and habitat for numerous wildlife species, including 20 million deer, one-half-million pronghorn antelope, 400,000 elk, 55,000 feral horses and burros, and hundreds of additional animal and bird species. An array of additional demands are also placed on these natural resources, including mining, oil and natural gas production, camping, hiking, fishing, hunting, and other recreational activities. For example, Bureau of Land Management rangelands, primarily in the western U.S., supported over 1.5M hunters and over 40M visitors in 2011. Meeting these many demands requires an improved understanding of how basic ecological processes are affected by grazing livestock production, drought, climate change, forage management and harvest, and other conservation practices.

Of particular significance is the continued close working relationship between NP215 Scientists and technical staff with the Natural Resource Conservation Service. The NRCS provides technical support to the management of ~1B acres of private grazing lands. ARS scientific support in the development of conservation practices deployed by the NRCS, and the quantitative techniques employed in evaluation their effects, is critically important to the management of these natural resources.

Harvested and conserved forages provide a dietary resource for continuity of livestock production that is especially important during periods of cold or drought when nutrient rich plants are not available. Harvested and conserved forages also provide an important source of roughage and nutrients for dairy cattle in confined animal feeding operations. To meet this demand, nearly 200 million tons of forage crops are harvested each year from 73 million acres in the U.S., which is 24% of the cropland - providing about half the forage requirements of dairy cattle. The remainder, along with rangeland and pasture, supplies the forage needs of beef cattle, sheep, goats, horses, and other livestock. Increased forage and food animal production efficiencies are needed to ensure the competitiveness and sustainability of food animal producers and to improve domestic and international food security.

During FY 2015, 96 full-time scientists working at 23 locations across the U.S. actively engaged in more than 27 ARS-led and 204 cooperative research projects in NP215. ARS-lead projects were approved through the ARS Office of Scientific Quality Review in 2012, making FY2015 the third year

of implementation of these five-year projects. The gross fiscal year 2015 funding for NP215 was $47 million.

New additions to the NP215 team in 2015 were:

- **Dr. Serge Edme** joined the Grain, Forage & Bioenergy Research Unit, Lincoln, NE, in 2015 as a Research Geneticist working on switchgrass and other perennial grass species, breeding and genetics.
- **Dr. Corey Moffet** joined the Southern Plains Range Research Station, Woodward, OK. Dr. Moffet is a Research Rangeland Management Specialist, and came to ARS from the Samuel R. Noble Foundation.
- **Dr. J. Gonzalo Irisarri** from Cátedra de Forrajicultura, IFEVA, Facultad de Agronomía, Universidad de Buenos Aires, CONICET joined the Rangeland Resources Research Unit, Cheyenne, WY, as a visiting scientist for 2015. Dr. Irisarri's research used long-term data to produce a publication on grazing intensity regulating ANPP response to precipitation currently in press with *Ecological Applications*.
- **Dr. Yuanyuan Cao** was a visiting scientist in the Plant Science Research Unit in Saint Paul, MN. Dr. Cao is an Associate Professor in Microbiology at Anhui Agricultural University, in Hefei, Anhui in China, and her research with ARS focused on phenotyping alfalfa root architecture and characterizing diversity in symbiotic bacteria in alfalfa root nodules.
- **Dr. Huiqin He** of Yibin University, Yibin, China, was a visiting scientist in the Forage and Range Research Laboratory, Logan UT. Dr. He conducted meta-analysis of seeding success on pinyon-juniper reduction treatments in Utah.
- **Dr. Amanda Gearhart** has joined the Range and Meadow Forage Management Research Unit, Burns, OR, as a post-doc.
- **Dr. Alpana Joshi**, a post-doc from India, joined the Forage and Range Research Laboratory, Logan UT, to conduct research on cytology and genetic determinants of genetic stability in Kentucky bluegrass.
- **Dr. Cristiane Pilon** has recently joined the Dale Bumpers Small Farms Research Center in Booneville, AR as an Oak Ridge Institute for Science and Education **(**ORISE) postdoctoral research associate. Her research will focus on how grazing management and buffer strips affect soil erosion and nutrient and pathogen runoff from pastures. Dr. Pilon recently graduated from the Crop, Soil and Environmental Sciences Department at the University of Arkansas.
- **Dr. Amanda Ashworth** from the University of Tennessee Plant Sciences Department is an ORISE postdoctoral research associate on forage agronomy with the Dale Bumpers Small Farm Research Center in Booneville AR, in collaboration with the Poultry Production and Product Safety Research Unit, Fayetteville, AR.
- **Dr. Lauretta Ngere,** a quantitative geneticist from Texas A&M (originally from Nigeria), has joined the Dale Bumpers Small Farm Research Center in Booneville AR, as an ORISE postdoctoral research associate as well. She is working on developing improved ruminant animal management systems to enhance the productivity, efficiency and viability of animal production on low input farms.
- **Dr. Sandra Leanne Dillard** joined the Pasture Systems and Watershed Management Research Unit in University Park, PA as a post-doc research associate. Dr. Dillard completed her PhD at Auburn University and she is currently studying mitigation of methane emissions and increasing the economic sustainability of forage-based dairy systems.

- **Dr. Ana Roca-Fernandez** has also joined the Pasture Systems and Watershed Management Research Unit in University Park, PA as a post-doc. She completed her PhD at the University of Santiago de Compostela in Spain and will be conducting research on the effects of tannin-containing forages on ruminal fermentation and methane output of grazing dairy cows.

The following scientists retired from the ranks of NP215:

- **Dr. Stephen Alderman**, of the Forage Seed and Cereal Research Unit, Corvallis OR. Dr. Alderman was the lead scientist and plant pathologist assigned to develop disease control measures for cool season grass seed crops.
- **Dr. Dean Anderson** of the Rangeland Management Research Unit, Las Cruces, NM, after 40 years and a very successful scientific career.
- **Dr. Tony Svejcar,** Research Leader at the Range and Meadow Forage Management Research Unit, Burns, OR.
- The Plant Science Research Unit in Saint Paul, MN had three NP215 scientists retire in 2015: **Dr. Michael Russelle**, Soil Scientist, retired after 33 years of service to ARS. He was a Fellow of American Society of Agronomy and the Soil Science Society of America; **Dr. John Gronwald,** Plant Physiologist, retired after 36 years of Federal service. His recent work advanced alfalfa genomics using microarrays and RNA-seq to develop the first alfalfa gene index; **Dr. JoAnn Lamb**, Research Geneticist, retired after 23 years of service to ARS. Her research focused on developing alfalfa germplasm with novel traits. In 2013 she was awarded an Honorary Lifetime Membership in the North American Alfalfa Improvement Conference.

The distinguished record of service of these scientists is recognized world-wide, and they will be missed in NP215.

The following scientists in NP 215 received prominent awards in 2015:

- A paper authored by **Drs. Sayjro Kossi Nouwakpo and Mark A. Weltz** of the Great Basin Rangelands Research Center, Reno NV, received the Outstanding Youth Paper Award from the International Youth Forum on Soil and Water Conservation, Nanchang, China.
- **Dr. Bill Anderson** of the Crop Genetics and Breeding Research Unit, Tifton GA, was a 2015 Fellow of the American Society of Agronomy.
- **Dr. Jeff Herrick** of the Rangeland Management Research Unit, Las Cruces, NM, was named a Fellow of the Society for Range Management based on several decades of highly successful work in rangeland science.
- **Dr. Kris Havstad** of the Rangeland Management Research Unit, Las Cruces, NM, received the W.R. Chapline Research Award from the Society for Range Management.
- **Melinda Dornbusch** of the Plant Science Research Unit in Saint Paul, MN received the Civil Servant of the Year Award from the Federal Executive Board of Minnesota.
- **Dr. Joan Burke** of the Dale Bumpers Small Farm Research Center in Booneville, AR was awarded the ARS Southeast Area Technology Transfer Award for "Technology to Aid in the Control of Internal Parasites in Sheep and Goats."
- **Dr. Mary Beth Hall** of the Cell Wall Biology and Utilization Research Unit in Madison, WI received the Editor's Choice award for a paper published in the Journal of Dairy Science.

- **Dr. Howard Skinner** of the Pasture Systems and Watershed Management Research Unit in University Park, PA was named as a fellow of the Crop Science Society of America and American Society of Agronomy.

The quality and impact of NP 215 research was further evidenced in 2015 by following:

- Over 173 refereed journal articles published;
- Three new invention disclosures submitted;
- Seven current cooperative research and development agreements, and one new material transfer agreement with stakeholders;
- Administration or development of 18 collaborative web sites for partners in academia, other research organizations or non-government organizations, and stakeholders.

In 2015 NP 215 scientists participated in research collaborations with scientists in: Argentina, Austria, Brazil, Canada, China, Colombia, Czech Rep, Denmark, Ethiopia, France, India, Italy, Kazakhstan, Kenya, Mauritius, Mongolia, Namibia, Romania, Russia, Spain, Switzerland, United Kingdom, and Uruguay.

NP 215 Accomplishments for FY2015

This section summarizes 19 significant and high impact research results that address one of the 4 specific components of the FY 2013 – 2018 action plan for the NP 215. Each section summarizes accomplishments of individual research projects in NP 215. Of particular note are the many high impact accomplishments that address key problems facing management of the Nation's grazing lands. Units in the NP215 program have been nimble in directing research to develop conservation practices and pasture/forage management systems that solve critical problems, including controlling wildfire and erosion, enhancing habitat values for critical species including sage grouse, controlling invasive species such as cheatgrass, and development of ecologically based techniques for quantitatively assessing and monitoring land. Many of the programs summarized for FY 2015 include significant domestic and international collaborations with both industry and academia. These collaborations provide extraordinary opportunities to leverage funding and scientific expertise for USDA - ARS research by rapidly disseminating technology, which enhances the impact of ARS research programs.

Component 1. Improved Rangeland Management for Enhanced Livestock Production, Conservation, and Ecological Services

New grass variety released to improve grazing land management and drought tolerance. There is increasing interest in utilizing less productive agricultural lands (i.e., associated with increased drought, soil salinity, and low fertility) for grazing in the western U.S., it is difficult to establish grasses in these harsh environments. Thus, there is a critical need for winter hardy, early maturing grasses that establish rapidly and provide highly nutritional forage on western U.S. semiarid rangelands and non-irrigated pastures. ARS researchers at Logan, Utah, released a drought tolerant, winter hardy meadow bromegrass cultivar "Arsenal". On arid and semi-arid rangelands, Arsenal had 32% more seedlings establish than meadow bromegrass cultivars currently in use. Under similar conditions, Arsenal averaged 14, 66, and 5% increase in forage production over cultivars Cache, Regar, and MacBeth. Spring forage crude protein and digestibility were 17 and 12% greater than Cache and fiber 6% lower. Use of Arsenal is already expanding as ARS researchers in El Reno, OK have obtained plant variety protection and a license for the commercialization and marketing of the cultivar for Southern Plains rangelands. Arsenal (Plant Variety Protection No. 201500355) expands the use of meadow bromegrass from irrigated pastures to nonirrigated pastures and rangelands with =250 mm annual precipitation, providing livestock producers with high-yielding nutritious forage where less nutritious and lower yielding grasses were typically used.

Scientific bibliography of salinity developed. ARS scientists, the National Agricultural Library (NAL), and the Bureau of Land Management developed a bibliography of the worldwide, scientific literature on salinity sources, mobilization, and the transport of salts from rangelands to river systems, with particular emphasis on the Colorado River Basin. The bibliography allowed for a synthesis review on salinity transport from rangelands, describing how land management and conservation practices affect dissolved salt transport. The Bureau of Land Management and Bureau of Reclamation are using these documents to direct a multimillion dollar, multiyear research effort to develop cost-effective conservation practices to reduce salt loading within the Colorado River Basin.

Tools and techniques for multi-scale inventory, monitoring, and assessment. Standardized approaches for monitoring rangelands are needed to allow land managers and public land agencies to collect and share data that address numerous rangeland management and policy needs. ARS scientists in Las Cruces, NM led the implementation of core rangeland monitoring indicators, field methods, and sample design techniques within the BLM (including BLM's national guidance for monitoring solar and oil/gas development impacts and sage grouse habitat) and integration of BLM's monitoring efforts with the existing NRCS-NRI private-land monitoring program. Jornada scientists also created web-based tools for monitoring program design, data analysis and reporting, mobile and tablet-based data collection applications, and extensive training modules that are used by U.S. agencies and international partners. The inventory, monitoring, and assessment techniques and tools developed at the Jornada are providing managers and policy makers with information needed to manage resources at local to national scales over millions of acres of rangelands in the U.S. and around the world.

Delayed germination developed to overcome perennial bunchgrass seedling mortality. Invasion of sagebrush habitat by non-native annual grasses, such as cheatgrass, impacts about 60 million acres of western U.S. rangeland. Invasive annual grasses increase wildfire frequency, dramatically reducing livestock forage, eliminating habitat for wildlife (including the sage grouse), and costing taxpayers an estimated $3.0 billion a year in fire suppression activities. Replanting burned areas with desired perennial bunchgrasses is the most promising management action, however, seeding success is extremely low. ARS scientists determined that seeded perennial grasses typically germinate in fall, and then the seedlings experience a very high (up to 100%) freeze-associated overwinter mortality. To address this problem, ARS, in collaboration with private industry and conservationists, developed a hydrophobic seed coating that delays seed germination until spring, dramatically decreasing seedling mortality. Initial field results demonstrated that the seed coating improves seedling establishment and survival.

Native forbs improve rangeland biodiversity and pollinator efficiency on semiarid western U.S. rangelands. Forb species are critically needed to provide greater biodiversity, food, and habitat resources for native pollinators, birds (including sage-grouse), and wildlife in the Great Basin and Colorado Plateau Regions of the western U.S. However, few commercial seed sources of North American forbs are available for revegetation where precipitation is less than 350 mm (13.8 inches) per year, and those seeds that are available are typically wildland-collected. The amount of time and resources necessary to make wildland collections in suitable quantities results in high seed prices and variable seed quality, such that forbs have been under-represented in rangeland seeding mixes. Thus, ARS scientists in Logan UT have released pre-variety germplasms of native Searl's prairie clover designated as Fanny, Bonneville, and Carmel for commercial use in rangeland restoration. These germplasms are adapted to habitats with low annual precipitation (e.g. Bonneville [178 mm, 7.0 inches per year], Fanny [321 mm, 12.6 inches per year], and Carmel [347 mm, 13.6 inches per year]), and provide a genetically diverse array of Searl's prairie clover genotypes that biologically fix nitrogen as well as provide high quality food for wildlife and native pollinators. This germplasm provides a commercially available seed source for use in rangeland restoration.

Seasonal weather-related decision-making for cattle production in the Northern Great Plains. Ranching is a challenging and sometimes risky business, with cattle production (and associated enterprise income) largely being dependent on seasonal weather patterns and corresponding forage

production. To help reduce this risk, ARS scientists in Cheyenne, Wyoming, Fort Collins, Colorado, Mandan, North Dakota, and Miles City, Montana performed a multistate analysis of seasonal weather effects on cattle production across the Northern Great Plains (Wyoming, North Dakota, and Montana). Cool, wet springs and longer, cooler growing seasons increased cattle production across the Northern Great Plains. ARS is working with the USDA Regional Climate Hub to deliver knowledge of these seasonal weather influences on cattle production to land managers, providing them with increased enterprise flexibility needed to deal with variable forage production, matching animal demand to forage availability, through use of seasonal weather forecasts,. This type of science-based knowledge, practical information, management and conservation strategies and decision tools are critical to helping ranchers adapt to weather variability and changing climatic conditions.

The Lawson Aerator as a treatment for habitat restoration. Degraded big sagebrush/bunchgrass communities in the Great Basin provide very poor habitat and grazing resources for cattle and wildlife, including the sage grouse. ARS scientists mechanically treated old, degraded big sagebrush habitats in north-central Nevada using a Lawson Aerator. Pulled by a tractor, the Lawson Aerator consists of a heavy drum with blades that crush large, woody vegetation (such as declining sage brush and invading juniper), reduce soil compaction, and aerate the soil. When an area composed of 40% declining big sagebrush cover and desirable herbaceous vegetation at 1.3 plants per square meter was treated in the spring, it was converted to a habitat with 8.7 perennial grasses and 3.4 perennial forbs per square meter, and in the first year, a big sagebrush cover already at 5%. This innovative treatment has provided excellent wildlife and grazing values to the area.

Climate smart decision-making tools developed for Southwest U.S. land managers. Scientists across New Mexico, Arizona, Hawaii, Nevada, California, and Utah established a partnership to develop climate-smart decision-making tools in support of the USDA SW Regional Climate Hub. ARS scientists in Las Cruces and Cooperative Extension Agents in all six states worked together to translate scientific information into management resources and tools that are readily available to farmers, ranchers, foresters, and other stakeholders. Team members also met with counterparts in the U.S. Affiliated Islands of Guam and American Samoa that fostered closer ties to the SW Regional Climate Hub. This effort provided critical content to the SW Climate Hub in their effort to equip land managers with tools for adapting to changing climate.

Component 2: Develop Improved Pasture Technologies and Management Systems

High quality, cold-tolerant, grass variety released for improved management of humid temperate grazing systems. Livestock producers who use management-intensive grazing systems need improved grass varieties that are more long-lived in the pasture and of higher quality for growth and milk production. ARS scientists in Madison, Wisconsin, developed and released Hidden Valley meadow fescue to the public. This grass variety represents a significant improvement in forage quality over typical pasture forage varieties, as measured by increased fiber digestibility, combined with superior cold tolerance to survive throughout the humid temperate regions of the eastern U.S. and Canada. Seed was produced and distributed as requested to seed companies for further seed multiplication and commercialization. This variety is expected to fill a significant demand for a cold-tolerant, drought-tolerant, and high-quality grass for management intensive grazing systems in the North Central and Northeastern U.S.

Control of internal parasites in sheep. Alternatives to synthetic anthelmintics remain critical due to the prevalence of dewormer resistant parasites that cost farmers worldwide billions of dollars every year. Copper oxide wire particles (COWP) were determined to control barberpole worm, a worm that causes blood loss and death; recently two forms with different particle diameters appeared on the U.S. market for small ruminants to treat copper deficiency. Scientists at USDA, ARS in Booneville, AR, Louisiana State University, University of Arkansas, and Fort Valley State University determined that the smaller diameter particles reduced the percentage of barberpole worm better than the larger diameter, and reduced fecal egg counts in lambs, a sign of worm infection. This is the first report comparing copper oxide wire particles with two different particle diameter sizes on barberpole worm infection in lambs. There has been widespread interest by southeastern U.S. small ruminant producers and extension agents in the use of copper oxide for worm control, one of the few options remaining to sustain these industries. The results are important to organic and conventional farmers, poor resource farmers worldwide, extension specialists, and scientists with the aim of controlling barberpole worm in sheep and goats, which can save the industry lost income due to morbidity and mortality.

Use of a heat tolerant *Bos taurus* breed on tall fescue pastures. Reproduction in cows in the southeastern U.S. can be hampered by environmental factors such as the dominant forage, tall fescue, and heat stress, which costs the beef industry millions of dollars annually. Use of a tropically adapted Bos taurus beef breed, Romosinuano, that is more thermo-tolerant may allow for a tolerance to fescue toxins and improve production parameters on Arkansas pastures. Scientists from USDA, ARS Booneville, AR, Texas A&M, El Reno, OK and Clay Center, NE determined that the Romosinuano might be considered for inclusion in a breeding program due to direct favorable effects on calving and weaning rate, lower death losses and better stability compared with Angus, even considering the negative effects of tall fescue. These results provide information on potential genetics for cow-calf production on endophyte-infected tall fescue, information that is important to producers, extension agents, and scientists.

Isoflavones produced by clovers could enhance protein quality in ruminant diets. Hyper-ammonia producing bacteria in the rumen of grazing livestock can degrade protein and limit the quality of digested proteins and, therefore, have a negative impact on animal performance. An ARS scientist in Lexington, KY conducted a laboratory experiment and found that 'Cinnamon Plus' red clover contained enough of the phytoestrogen, biochanin a, to inhibit Clostridium sticklandii, a bovine ruminal hyper-

ammonia producing bacterium. A grazing trial is currently being conducted to verify if biochanin a supplemented to steers can enhance weight gain efficiency. This research could provide evidence that clovers in the diets of steers can inhibit the hyper-ammonia producing bacteria to an extent that provides an increase in average daily weight gain by the steers**.**

Identification of perennial grasses with high-yield potential for biofuel and forage production. The U.S. Department of Energy is seeking to decrease the nation's dependence on imported oil by developing renewable sources of bioenergy that can be produced from crops grown by U.S farmers. As part of that effort, USDA-ARS researchers worked with university researchers to study three species of perennial grasses (giant miscanthus, giant reed, and miscane) and compare their biomass yields under irrigated and non-irrigated conditions during the first three years after planting. Giant reed produced more biomass than the other two grasses in all three years regardless of irrigation, but was especially productive in the second and third years after planting. The research team also investigated the potential of these perennial grasses to help farmers minimize risk and maximize production efficiency by doubling as a food source for grazing livestock when necessary to meet changing market conditions. Nutritive value and energy content of the three grasses were compared during the first three years after planting, and results suggested that miscane and giant reed could potentially serve as livestock forages as well as bioenergy sources. However, giant reed is not currently recommended for planting, and feeding trials would be necessary before either species could actually be recommended for livestock consumption. This will impact farmers, scientists, and agency personnel because it can help identify perennial crops that potentially offer the highest yields of biomass for domestic energy production while possibly serving a dual-use option as livestock forage.

Component 3: Improved Harvested Forage Systems for Livestock, Bioenergy and Bioproducts

Molecular diagnostics of seed gall nematodes. Certain species of seed gall nematodes are regulated as quarantine pests by many countries because they attack wheat and other grasses, and they can carry bacteria toxic to livestock. Growers and regulatory officials face an enormous problem in that the existing molecular methods for distinguishing these nematodes are time consuming and occasionally inaccurate. Scientists from ARS and APHIS in Beltsville, Maryland, designed a new molecular diagnostic test that can rapidly detect and distinguish four different seed gall nematodes of wheat and grasses. This research is significant because the new assay is species-specific, highly sensitive, and faster to perform than existing molecular methods. This test will be useful for federal and state diagnostic labs, domestic and international research scientists, regulatory personnel, or extension agencies for identifying and preventing further damage caused by seed gall nematodes.

Reducing the carbon footprint of cellulosic ethanol. After producing ethanol from crop residues such as corn stover and straw, a slowly decomposing byproduct remains which is typically burned for energy recovery, but harvesting crop residues can result in decreased crop yields and soil carbon levels. ARS scientists in University Park, PA, in collaboration with university scientists, compared the current practice of burning this residue versus applying it back to the land. They found that although most prior studies recommend burning this material to generate electricity for the biorefinery, applying it to the land instead resulted in ethanol production systems with the lowest greenhouse gas (GHG) footprint, highest levels of soil carbon, and the greatest offset of GHG emissions. This finding could help the industry evaluate the different markets for byproducts produced at the biorefinery, considering both the economic and environmental impacts.

Improving the digestibility of forage grasses through cell wall modification. Grasses frequently have a lower digestibility compared to other forages such as alfalfa due to a strong cross-linked structure in grass cell walls. A major component of the cross-linking in grass cell walls is a phenolic compound called ferulic acid which produces ferulates. Ferulates in the cell wall become attached to lignin, creating a cross-linked network that reduces grass digestibility in dairy cows and other ruminants. ARS scientists in Madison, WI found a way to change the composition of the cell wall components in grasses, resulting in decreased ferulate attachments, fewer cross-linkages, and improved digestibility. Using modern genetic engineering tools, forage grasses can be modified to increase digestibility without inhibiting yield. Such increased digestibility has both economic and environmental benefits to U.S. dairy producers with the potential to save $350 million in feed costs and reduce the amount of manure produced by 2.8 million tons.

Component 4: Turf Improvement

Outdoor display educates the public on the importance and benefits of turfgrass. Turfgrass is under scrutiny for its requirements for water, fertilizer and pesticides, but is not often credited with the benefits it provides to the environment, economy and society. In some communities, turfgrass use is demonized and even targeted via turfgrass removal programs. In addition, the science behind turfgrass is not well recognized by the general public. To educate and inform the public about turfgrass, ARS scientists at the United States National Arboretum in Washington, District of Columbia, developed a new initiative entitled "Grass Roots". A 1.3 acre outdoor exhibit, the centerpiece of Grass Roots, was opened in late 2014 at the National Arboretum. The outdoor exhibit, along with associated web pages, has been very successful to date, with tens of thousands of visitors already enjoying the exhibit and learning from the displays. The Grass Roots Initiative is demonstrating the fundamentals of turfgrass, its value in landscapes, and the inherent scientific accomplishment to improve turfgrass and its management. This initiative has resulted in collaboration between USDA and turfgrass industry partners, and is making turfgrass benefits more visible to the general public, hence saving jobs and improving the environment.

Resistance to stem rust in Lolium perenne. Stem rust is the most significant disease problem for perennial ryegrass and tall fescue crops grown for seed production. A critical component to addressing this problem is the identification of germplasm with resistance to the disease. ARS researchers in Corvallis, Oregon, have identified individual plants of *Lolium perenne* displaying improved resistance to one pathotype of *Puccinia graminis* subsp. *graminicola* (stem rust pathogen). Progeny of the resistant plants were crossed with advanced breeding lines of turf-type perennial ryegrass and sent to collaborators at Rutgers University for evaluation. Selected progeny of our resistant plants crossed with well-adapted public forage types were successfully tested in field plots with a high level of naturally-occurring infection. These turf and forage selections will be very useful in creating improved germplasm resistant to stem rust to be used by Lolium breeders nationwide.

Outdoor display highlights the science of turfgrass development and management. Turfgrass is under scrutiny for its requirements for water, fertilizer and pesticides, but is not often credited with the benefits it provides to the environment, economy and society. In some communities, turfgrass use is demonized and even targeted via turfgrass removal programs. In addition, the science behind turfgrass is not well recognized by the general public. To educate and inform the public about turfgrass, ARS scientists at the United States National Arboretum in Washington, District of Columbia, developed a new initiative entitled "Grass Roots". A 1.3 acre outdoor exhibit, the centerpiece of Grass Roots, was opened in fall 2014 at the National Arboretum. The outdoor exhibit, along with associated web pages, has been very successful to date, with tens of thousands of visitors already enjoying the exhibit and learning from the displays. The Grass Roots Initiative will help make the value of turfgrass and landscapes, and the inherent scientific accomplishments, more visible to the general public, hence saving jobs and improving the environment.

Kentucky bluegrasses that require fewer inputs. Kentucky bluegrass is a species preferred by many homeowners, athletic field managers, park and grounds managers and golf course superintendents from the Mid-Atlantic to the Inner Mountain West. However, there are some concerns about using this species in a sustainable landscape because of its requirements for high water, fertilizer and pesticides inputs. ARS scientists at the United States National Arboretum, Washington, District of Columbia,

recently held trials to address these concerns by evaluating Kentucky bluegrass cultivars with much less inputs than typically used to maintain acceptable quality on a home lawn, park or golf course. Two years of data have shown that several new Kentucky bluegrass cultivars are producing acceptable quality with very little supplemental irrigation, fertilizer, and pesticides.