FY2018 Annual Report
National Program 215—Grass Forages and Rangeland Agroecosystems

Introduction

The USDA-ARS National Program for Grass Forages and Rangelands Agroecosystems (NP215) had another productive year in 2018 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 more than 1B acres of rangelands and pasture lands.

Vision

Healthy, productive rangelands, pastures, forage cropping systems, and green spaces that support rural prosperity, food security, and earth's ecology.

Mission

The mission of the National Program is to provide research results that can be used to improve management decision making and enhance the utility, function, and performance of rangelands, pastures, forage, and turf agroecosystems while enhancing environmental and ecosystem services.

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 FY2018, the importance of these global applications was demonstrated by NP215 scientist collaborations with researchers in Argentina, Australia, Brazil, Canada, China, Colombia, Denmark, Ethiopia, France, Germany, Greece, Ireland, Jordan, Kazakhstan, Kenya, Mexico, New Zealand, Russia, Ukraine, United Kingdom, and Uruguay. 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 rights-of-way. 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 $15 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 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 is 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 ~1 billion 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 2018, 90 full-time scientists working at 21 locations across the U.S. actively engaged in 26 ARS-led and 168 cooperative research projects in NP215. ARS-lead projects underwent review by the ARS Office of Scientific Quality Review in 2018, making FY2018 the start of a new five-year project cycle in NP215.

Personnel news in FY2018

New additions to the NP215 team in 2018 were:

- The Plant Science Research Unit in St. Paul MN welcomed new scientist **Dr. Joshua Gamble** in 2018. Dr. Gamble is a Research Agronomist focusing on agroecology and will be evaluating cropping systems incorporating alfalfa and other perennial forages to improve water and soil quality, protect against erosion, and provide resiliency in response to climate change. His research will also measure economic and environmental impacts of cropping systems that include perennial legumes. Dr. Gamble completed Ph.D. research at the University of Minnesota in Natural Resources Science & Management.
- **Dr. Stella Copeland** joined the Range and Meadow Forage Management Research Laboratory in Burns OR in 2018. Stella is a talented research ecologist with a strong background in restoration ecology with an emphasis on evaluating the efficacy of restoration practices at very large spatial scales. She was previously a post-doc in Flagstaff, AZ with Northern Arizona University and the USGS.
- The Crop Germplasm Research Laboratory, College Station TX, hosted a visiting scientist from Brazil in 2018. **Dr. Allessandra Pereira Favero** is a plant breeder/geneticist employed by EMBRAPA (Empresa Brasileira de Pesquisa Agropecuaria). Her home laboratory is the Southeast Livestock Center, Sao Carlos, Sao Paulo, Brazil. Her work with ARS focused on the breeding and improvement of forages grasses, primarily targeted species of Paspalum.
- **Dr. Sarah Castle** joined the Plant Science Research Unit in St. Paul, MN as a Research Associate working in the area of soil microbiology and soil health. She completed a Ph.D. at the University of Montana in Ecosystem and Conservation Sciences with a dissertation entitled "Ecosystem succession in the earliest stages: Linking microbial community structure to ecological function."
- The Rangeland and Pasture Research Laboratory, Woodward OK, had two postdoctoral research associates in 2018: **Dr. Kundan Dhakal,** ORISE associate with Oklahoma State University, Stillwater. Dr. Dhakal's work focused on evaluation of sorghum germplasm lines for nitrate accumulation while under drought; **Dr. Sonisa Sharma**, of Kansas State University, Hays. Dr. Sharma studied remote sensing of woody vegetation with cross-timbers rangelands.
- **Dr. Edward (EJ) Raynor**, joined the Rangeland Resources and Systems Research Unit, Cheyenne WY, as a postdoctoral research associate. Dr. Raynor will be working on grazing behaviors and animal intake on rangelands as influenced by genetics x environment x management, as well as

analyzing long-term (since 1939) livestock production data as influenced by grazing management strategies, climate extremes, and sea surface temperature anomalies.

- **Dr. Peng Jiang** joined the Molecular Plant Pathology Laboratory, Beltsville MD, as a postdoctoral research associate in 2018. Dr. Peng is studying diagnostic methods for detection of new and emerging viruses infecting alfalfa.

The following scientists retired from the ranks of NP215:

- **Dr. Robert Blank** retired from the Great Basin Rangelands Research Laboratory, Reno NV, in 2018. He continues to work with ARS as a collaborator on cheatgrass and associated changes in soil health pre and post-fire and pre and post herbicide treatments.
- **Dr. Ron Hatfield** retired after 32 years at the Dairy Forage Research Center, Madison WI. Ron, a plant physiologist, was known internationally for his work on plant cell walls, their digestibility, and other research on forage utilization, particularly protein utilization. He also served as RL for the Cell Wall Biology and Utilization Research Unit for many years. Ron provided much leadership and service to the Center during his career, and will be very much missed.
- **Dr. Geoff Brink** retired after 34 years of federal service, the last 16 of them at the Dairy Forage Research Center in Madison WI. Geoff joined ARS as a scientist in MS working on forage livestock systems. He was well known for his work on grazing and pasture management. Geoff served as research leader of the Dairy Forage Research Unit from 2015 until his retirement. He also served as acting Center Director of the DFRC during his last year.
- **Dr. Bob Graybosch** retired from the Wheat, Sorghum and Forage Research Unit, Lincoln NE in 2018. Bob's research was on wheat genetics, and he coordinated the hard winter wheat nursery program.

The following scientists in NP 215 received prominent awards in 2018:

- **Dr. Lauren Porensky** of the Rangeland Resources and Systems Research Unit, Cheyenne WY, was named Outstanding Young Range Professional by the Society for Range Management in 2018.
- **Dr. Prasanna Gowda** received the 2018 Laj Ahuja Ag Systems Modeling Award and 2018 SSSA Fellow award during the Soil Science Society of America annual meeting.

The quality and impact of NP 215 research was further evidenced in 2018 by the following:

- 181 refereed journal articles published;
- one new patents application filed and two new invention disclosures;
- two new cooperative research and development agreement, and 12 new material transfer agreement with stakeholders.

NP 215 Accomplishments for FY2018

This section summarizes significant and high impact research results that address one of the specific components of the FY2018-2022 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 developing ecologically based techniques for quantitatively assessing and monitoring land. Many of the programs summarized for FY 2018 include significant domestic and international collaborations with both industry and academia. These collaborations provide extraordinary opportunities to leverage funding and scientific expertise for 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

Elevated carbon dioxide effects on forage quality in mixed grass prairie. Two of the most important aspects of the global climate are increases in carbon dioxide (CO_2) in the atmosphere and global temperature. ARS scientists in Fort Collins, Colorado, and Cheyenne, Wyoming, in collaboration with ARS scientists in Woodward, Oklahoma, conducted a field experiment from 2007 to 2013 to examine how increasing atmospheric CO_2 (from the current 400 ppm to a simulated future level of 600 ppm) and increasing temperature (by 1.5°C during the day and 3°C at night), both alone and in combination, affected the productivity and quality of forage for livestock in the northern mixed-grass prairie. Total forage production increased by an average of 38 percent over the 7-year study period, but forage quality decreased with increased atmospheric CO_2 combined with warming. Dry matter digestibility of the primary cool-season forage grass (western wheatgrass) dropped from 63.3 percent to 61.1 percent, and crude protein content also decreased from 7.8 percent to 6.5 percent with combined elevated CO_2 and warming. These changes could significantly influence management decisions by ranchers because rates at which individual cattle gain weight during the growing season are expected to decrease. Adaptation strategies to reverse this loss in weight gain could include increasing stocking rates, patch burning, fertilization at low rates, and legume interseeding.

An online decision support tool for ranchers provides a county-level forecast of rangeland vegetation in the Northern Great Plains. Ranchers must decide yearly whether the forage available on their land is sufficient to support their livestock without impairing the future productivity of the land. Forage productivity within a given location varies depending on the weather, and ranchers have traditionally predicted current productivity based on previous experience, which was often not objective. To provide data to help ranchers make their decisions, ARS scientists from Fort Collins, Colorado, collaborated with scientists from Colorado State University, the USDA Northern Plains Climate Hub, the National Drought Mitigation Center, and the University of Wyoming to develop the Grassland Productivity Forecast (Grass-Cast), an online tool that predicts forage productivity based on recent weather patterns in a given area. Grass-Cast uses more than 30 years of historical forage productivity data and combines it with weather patterns to generate a prediction of future productivity. Ranchers will be able to combine these data-driven predictions with their own knowledge of their land and its ability to support livestock to decide how to manage their ranch animals, leading to greater ranch profitability and improved long-term sustainability of forage and animal production in the Northern Great Plains.

Massive seed banks limit Russian olive control. Land managers throughout the West are having difficulty controlling Russian olive trees and reinvading seedlings. In Montana, ARS researchers from Sidney and Miles City, with staff from the USDA Natural Resources Conservation Service in Miles City and Bridger, determined successful practices for controlling invasive Russian olive populations and for returning native species to degraded areas. They found that tree shearing followed by immediate herbicide application to the cut stump resulted in 96 percent Russian olive mortality. Because Russian olive is a nitrogen fixer, a high weed abundance was expected to limit the success of native species planted in their place. However, revegetation was successful in that almost all planted species became established. Although revegetation increased native species diversity and cover, there was no evidence in this 5-year study that the plantings competitively excluded weeds. Newly emerged Russian olive seedling counts were highly variable (approximately 50 to 5,000 seedlings per acre) in the removal area every year of the study. This information provides critical information for understanding the seed banks of Russian olive and mitigation strategies that can be used for its control.

Seeding and herbicides establish native plants in downy brome-invaded landscapes. Managers are struggling to restore native plants to degraded rangelands invaded by downy brome and other invasive weeds, with the end goal of increasing livestock forage production and improving wildlife habitat. ARS scientists in Miles City, Montana, collaborating with Montana Department of Environmental Quality and coal mining industry representatives, seeded native grasses, forbs, and shrubs after herbicides were applied to control downy brome in former coal mining fields that became dominated by downy brome after initial seeding efforts failed. The herbicide glyphosate, when applied in fall, just after downy brome emerged, substantially reduced downy brome cover and promoted native grass and forb establishment. Additionally, this treatment allowed establishment of big sage, among the most difficult and important species to restore to western U.S. rangelands. The strategic application of herbicides timed to the emergence of downy brome will improve efforts to remediate brome infestation of rangelands.

Gene discovery for late flowering in grasses. Perennial forage grasses are the basis of the meat and dairy industry, providing essential nutrition to ruminant animals. Because these grasses require expensive nitrogen inputs, there is a trend toward growing grass-legume mixes that require less nitrogen while increasing forage mass and nutritive value. However, most grasses mature before alfalfa and other legumes, thereby greatly diminishing the anticipated improved nutritive value. Maturation is associated with switching from a vegetative to a flowering state, so later flowering is desirable for grasses used in these mixtures. Previous selection for later flowering generally resulted in decreased seed production, so the selected plants could not be easily propagated. ARS researchers in Logan, Utah, identified late-flowering genes in orchardgrass and developed molecular markers for rapid late-flowering selection. They used the markers to identify late-flowering orchardgrass germplasm and gave grass breeders in China and the United States a valuable tool for distinguishing these genes from genes that control seed production. The markers will also enhance the development of grasses specifically for grass-legume mixtures that better match the timing of maturity among the component plants and improve their overall nutritional quality.

Successful rangeland restoration following disturbance depends on the presence of helpful soil biology. Invasive alien plants are believed to depend less on mycorrhizal (beneficial root fungi) associations than native plants, and weak mycorrhizal responsiveness might thus be a general mechanism of plant invasion. ARS scientists in Miles City, Montana, determined from experiments on 68 Northern Plains grassland species and 95 Central Plains species that symbiotic mycorrhizal associations increased the biomass of 19 percent and 61 percent of species, respectively. However, plants from the Northern Plains tended to have varied responses to these associations. Findings indicate that many plant species may have difficulty becoming established in areas with degraded soil biology. Some plants in the Northern Plains appeared depend less on mycorrhizal association, suggesting that they become more easily established in areas with degraded soil biology. Invasive grassland plants had a wide range of interactions with mycorrhizas and some invasive plants are thought to degrade the quality of a site's soil mycorrhizal biology. There was no evidence that invasive species respond differently to mycorrhizas than native species. Knowing how various plants depend on beneficial soil organisms, combined with assessments of soil microorganisms, will facilitate restoration efforts by matching soil management actions with the species mix that is desired for that location.

Component 2: Develop Improved Pasture Technologies and Management Systems

Molasses can replace corn in grazing dairy cow diets. Farmers who operate grazing dairy farms are interested in replacing corn with molasses as a food supplement for their animals to reduce feed costs and meet the demands of specialty milk markets such as those for organic or grass-fed milk. ARS scientists in University Park, Pennsylvania, gave either corn meal or liquid molasses to grazing, lactating dairy cows and examined the effect on milk yield and milk composition, milk fatty acid profile, and nitrogen use efficiency. Results suggest that molasses can replace corn meal on an equivalent basis without negatively affecting milk yield and composition, while slightly improving nitrogen use efficiency and beneficial fatty acids found in milk. This information offers farmers who operate grass-fed dairy farms a more economical and healthful supplement for their cows.

Improving restoration practices to reduce wildfire threats. The accidental introduction and subsequent invasion of cheatgrass to Great Basin rangelands has increased the frequency of wildfires, and millions of dollars are spent annually fighting them. ARS scientists in Reno, Nevada, have been testing pre-emergent herbicides to control cheatgrass, diminish the levels of cheatgrass-associated fuels for fires, and improve rangeland restoration efforts. This research has resulted in more than a nine-fold increase in the growth of perennial grasses, shrubs, and forbs that successfully suppress cheatgrass. A reduction in cheatgrass-associated fuels significantly reduces the chance, rate, spread, and season of wildfires. Converting cheatgrass-dominated habitats back to perennial grasses, forbs, and shrubs has also substantially improved sustainable grazing resources and improved plant and wildlife diversity in the Great Basin. Using pre-emergent herbicides to control cheatgrass improves the overall health of the habitat and decreases the threat of wildfire, preserves wildlife, increases rangeland livestock production, and reduces the costs of fire control.

Increasing big sagebrush densities for sagebrush obligate species. Recurring wildfires have significantly reduced the density of big sagebrush resulting in loss of critical habitats for sagebrush obligate species such as sage grouse and mule deer. ARS scientists in Reno, Nevada, tested how big sagebrush could be transplanted to increase its density in crested wheatgrass stands. Their efforts resulted in a six-fold increase in big sagebrush density. Fall transplanting versus spring transplanting resulted in larger density increases of big sagebrush. The increase in shrub density improves wildlife habitat and ecosystem function while reducing livestock-wildlife conflicts.

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

More competitive nitrogen-fixing bacteria identified for use in alfalfa production. Most alfalfa seeds are treated with symbiotic bacteria before planting to ensure the formation of nitrogen-fixing nodules on roots. Improving nitrogen fixation reduces the need for synthetic fertilizers, but establishment of the necessary bacterial strains is hampered by competition from indigenous, less effective bacteria. ARS scientists in Saint Paul, Minnesota, and University of Minnesota colleagues developed methods for identifying the origin of bacteria in root nodules in two field sites that had not been in alfalfa cultivation for more than 30 years. All bacteria in nodules originated from soil rather than from seed inoculation and were genetically diverse. However, approximately one-third of the bacterial strains in nodules had a gene involved in transfer of bacterial proteins to plant cells, which appears to accelerate nodulation, potentially making these strains more competitive in forming root nodules. This gene gives researchers a marker to rapidly identify additional strains that would be more effective as seed inoculants. Increasing nitrogen fixation and the amount of nitrogen available to alfalfa plants will increase crop yields without raising costs for crop production.

Near-infrared reflectance spectrometry (NIRS) calibrations predict switchgrass ethanol yields. Conventional wet chemistry analysis of biomass for composition and conversion to ethanol is time-consuming and expensive. A team of ARS scientists from Lincoln, Nebraska; Peoria, Illinois; St. Paul, Minnesota; and Madison, Wisconsin, developed NIRS calibrations that, along with biomass yield data, enable concentrations of switchgrass hexose and pentose sugars to be rapidly and accurately determined, thus allowing calculation of ethanol yields from each sugar in switchgrass samples. These calibrations will have multiple uses in breeding, genetics, and management research and could be used by biorefineries to predict ethanol yield of switchgrass biomass. The calibrations have been transferred to the NIRS Consortium, which is making them available to other switchgrass research groups and laboratories.