FY2022 Annual Report
National Program 215—Grass, Forages, and Rangelands Agroecosystems

The USDA-ARS National Program for Grass, Forages, and Rangelands Agroecosystems (NP215) comprises 97 scientists conducting 27 congressionally appropriated (base program funding of $61M) research projects at 21 locations across the U.S. Those scientists had another productive year in 2022 with scientific output, technology transfer, and collaborations with partners and stakeholders across the U.S. and the world. Scientists in NP215 continue to have significant impact in numerous areas of research that improve management of the Nation's natural resources, including the more than 1 billion acres of range and pasture lands.

NP215 Vision
Healthy, productive rangelands, pastures, forage cropping systems, and green spaces that support rural prosperity, food security, and environmental sustainability.

Mission
The mission of the NP215 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 sustaining environmental and ecosystem services.

Introduction
Across the U.S., range, pasture, and forage-based 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 ecologies, such as 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. Turf covered urban and suburban areas and roadsides also contribute to ecosystem services in regions where they dominate.

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 sustaining the more intensive production of grains or vegetables for human consumption. Knowledge gained through research about the sustainable management of pasture, forage, and rangelands will help producers in the US and across the globe meet the food security demands of a projected 9+ billion people by 2050. In FY2022, the importance of these global applications was demonstrated by collaborations with researchers in Argentina, Australia, Benin, Canada, China, Egypt, France, Germany, Honduras, Italy, Kazakhstan, Kenya, Netherlands, New Zealand, Norway, Pakistan, Portugal, and Switzerland.

The Nation's 30-40 million acres of turf lands are found around our homes, schools, municipal and commercial buildings, parks, greenbelts and recreational areas, 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 alfalfa is the third most valuable crop to U.S. agriculture, behind only corn and soybeans. 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 also critical. 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, on the 246 million acres of Bureau of Land Management rangelands, primarily in the western U.S., total direct spending for hunting, fishing, and wildlife viewing totaled more than $2 billion in 2016. These public lands also supported 26,500 jobs, generated more than $1 billion in salaries and wages, and produced more than $421 million in federal, state, and local tax revenue. Meeting these many demands requires an ever-improving 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 extent of collaboration between NP215 scientists, other federal and state agencies, and private stakeholders. There were 50 new agreements among agency partners such as the U.S. Forest Service, BLM, USGS, NRCS, NIFA, FSA, and NASA, and stakeholders such as the U.S. Golf Association, Bayer Cropscience, Nature Conservancy, and The National Alfalfa and Forage Alliance. ARS continues a 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.

Personnel news in FY2022

New additions to the NP215 team in 2022 were:

• **Dr. Carrie Laboski** was hired as a Research Leader at the Pasture Systems & Watershed Management Unit in University Park, Pennsylvania. Dr. Laboski's research is currently focused on improving sustainability and resilience of agroecosystems through improved soil fertility and nutrient management practices. Before joining ARS, Dr. Laboski was a Professor and Extension Specialist at the University of Wisconsin-Madison.

The following scientists retired or left from the ranks of NP215:

- **Jason Kelley** left ARS Parlier in December 2022 to return to his family farm in Oregon;

The following scientists in NP 215 received prominent awards in 2022:

- **Stuart Hardegree** received a Lifetime Achievement Award from the Society of Range Management.

The quality and impact of NP215 research was further evidenced in 2022 by the following:

- 209 refereed journal articles and six book chapters published;
- 35 new incoming cooperative agreements;
- 2 new patents; and
- 126 students and postdoctoral research associates studying in ARS laboratories.

NP 215 Accomplishments for FY2022

This section summarizes significant and high impact research results that address the specific components of the FY2019-2023 action plan for NP215. Each section summarizes accomplishments of individual research projects in NP215. Of note are the high-impact accomplishments that address key problems facing management of the Nation's grazing lands. Units in NP215 have been 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 FY2022 include significant domestic and international collaborations with both industry and academia. These collaborations provide ARS extraordinary opportunities to leverage funding and scientific expertise, rapidly disseminate technology, and enhances the impact of research.

Component 1: Provide fundamental knowledge and understanding of interacting ecological components of grass, forage, and rangeland agroecosystems.

DNA markers developed for Verticillium wilt resistance in alfalfa. Verticillium wilt (VW) is an alfalfa disease that reduces forage yields by up to 50 percent. Current breeding strategies primarily rely on field or greenhouse screening to identify disease resistant plants, which is a time-consuming process requiring specific conditions to produce reliable results. An ARS scientist in Prosser, Washington, identified VW resistance genes and developed high-throughput DNA markers that accurately identify alfalfa plants that are resistant to VW. Three DNA markers have been transferred to a major alfalfa commercial producer to accelerate breeding efforts to develop new varieties with enhanced resistance to Verticillium wilt.

Discovery of alfalfa pathogens using high throughput DNA sequencing. Stand failures from soil-borne diseases are major problems for alfalfa farmers. Identification of pathogens by isolation in pure culture is difficult, time consuming, and may overlook pathogens that are slow growing or that have specific growth requirements. ARS scientists at Saint Paul, Minnesota and University of Minnesota collaborators identified entire microbial communities in soil and plant samples from eight sites with poor alfalfa seedling establishment by sequencing specific genes used for microbe identification. The relative population densities of specific pathogens from DNA sequencing were confirmed using quantitative PCR assays. Several novel alfalfa pathogens were identified and a widespread soybean pathogen, Phytophthora sansomeana, present in most samples was shown for the first time to cause root rot of alfalfa. Thus, microbial community analysis was found to be a rapid and robust way to identify pathogens that had previously not been known to cause disease in alfalfa seedlings. The identification of widespread seedling pathogens is useful for plant breeders to develop disease resistant cultivars and for seed marketers to use appropriate fungicidal seed treatments so that farmers can achieve vigorous, dense alfalfa stands.

Component 2: Improve the physiology and genetics of plant materials to enhance health, vitality, and utility of pasture, biomass for feed and fuel, rangeland, and turf systems.

New sweet sorghum lines are resistant to sugarcane aphid. Sweet sorghum is used to produce edible syrups, and sugarcane aphid is a major pest for sweet sorghum production. Aphid damage includes leaf discoloration and desiccation, delayed or aborted flowering, and reduced sorghum juice. Few insecticides are available to control sugarcane aphid, and no existing sweet sorghum cultivars have a high level of resistance to this pest. ARS researchers in Tifton, Georgia, developed three new sweet sorghum lines from an initial cross of an aphid-resistant Ethiopian line with a sweet sorghum seed parent and conducted multi-generation breeding selection to increase aphid resistance, good agronomic traits, and high sugar content. Across four environments in 2019 and 2020, these three lines had higher juice sugar content and showed less damage from sugarcane aphids than the popular susceptible cultivar Top 76-6. They also harbored fewer aphids than Top 76-6 in one environment. With the three new lines, growers can produce a sweet sorghum crop without the need to spray insecticide to control sugarcane aphids, which will be particularly beneficial to organic producers. The lines were released in 2022 and seeds have been requested by at least 20 sweet sorghum growers across six states.

New 'Basin' Utah sweetvetch improves seed production. Using flowering forb species in rangeland restoration helps diversify plant communities and sustain pollinators. Utah sweetvetch is a native perennial legume often desired for rangeland seedings, but its use has been severely limited due to low seed production and insufficient seed inventories. ARS researchers in Logan, Utah, developed Utah sweetvetch plants with increased seed production using traditional breeding that selected for and hybridized plants with high seed set. They released this 'Basin' Utah sweetvetch, which has more than double (682 versus 320 kg/ha) the seed production of other available cultivars. Basin Utah sweetvetch also has improved forage production, which is important for wildlife like deer and elk. This new Utah sweetvetch will benefit seed producers, help increase seed inventories, and be a valuable resource for land managers demanding viable flowering forb options for rangeland seedings in the western United States.

New seed treatment strategy boosts Utah trefoil use for restoration. Flowering forb species diversify plant communities and sustain pollinators in the intermountain West. However, there is a problematic lack of native forbs and associated planting "know-how" available for their successful use in rangeland restoration efforts. Utah trefoil is a native flowering legume forb and potential restoration candidate, but little is known about its seed germination requirements. ARS researchers in Logan, Utah, determined that Utah trefoil seed was largely dormant and requires both acid and cold pretreatments for successful germination. While neither pretreatment was effective alone, combined they increased seed germination from less than 1 percent (untreated) to 73 percent. Furthermore, seedling establishment in the field was 50 times greater using the combined pretreatments compared to untreated seed. With this new knowledge available to the seed industry and land managers, Utah trefoil now has the potential to become a valuable native forb for rangeland seedings.

New little bluestem varieties have better establishment. For grassland managers across the Southern Plains, risk of poor vegetation establishment during revegetation projects is a major concern. Germination and establishment are often the critical bottlenecks for warm-season native grass plantings. Producers need warm-season grasses to have better establishment properties while still maintaining productivity and high forage quality, and providing favorable wildlife habitat and ample soil protection. Grasses that can still germinate under low soil water conditions have greater likelihood of emerging and ultimately establishing. Using recurrent selection techniques, ARS researchers in Woodward, Oklahoma, made little bluestem selections with forage production and quality traits similar to currently available varieties, but with superior germination and establishment. These selections have now been released as the new little bluestem varieties 'Ahring' and 'Sims'. Native seed companies are growing these varieties and they will soon be available for producers in the region to use for their native grass planting.

Southern root-knot nematode resistance can be transferred to forage, sweet, and grain sorghum. The southern root-knot nematode causes significant economic damage to many U.S. crops, such as cotton and vegetables. ARS researchers in Tifton, Georgia, previously identified a region on sorghum chromosome 3 that provides root-knot nematode resistance in the sweet sorghum cultivar 'Honey Drip', and tested whether the gene could be transferred to forage, sweet, and grain sorghum to provide resistance in those crops. Repeated greenhouse experiments documented that before incorporating the resistance gene, the sorghum lines were all highly susceptible to the nematode, but after incorporating the gene the lines were all as resistant as the Honey Drip parent. This gene and its associated markers will be useful for breeding programs that want to incorporate southern root-knot nematode resistance into their sorghum lines. The use of resistant sorghum lines will reduce the amount of southern root-knot nematodes in the soil, reduce subsequent nematode damage in susceptible crops, and help reduce the use of fumigants or nematicides.

More rapid genomic approaches help develop Verticillium wilt resistance in alfalfa. Verticillium wilt (VW) is an alfalfa disease that reduces forage yields by up to 50 percent. Current breeding strategies to develop alfalfa varieties that are resistant to wilt primarily use field or greenhouse screening to identify disease resistant plants. This is a time-consuming process requiring specific conditions to produce reliable results. In efforts to increase the efficiency of developing alfalfa resistant to Verticillium wilt, an ARS scientist in Prosser, Washington, used genomic selection tools to identify wilt resistance genes and developed high-throughput DNA markers that accurately identify wilt-resistant alfalfa plants. Three DNA markers have been transferred to a major alfalfa commercial producer to accelerate breeding efforts to develop new varieties with enhanced resistance to Verticillium wilt.

Database development improves homeowner turfgrass selection. Since 1981, the National Turfgrass Evaluation Program (NTEP) has collected data on tens of thousands of experimental and commercially available turfgrasses, encompassing 20 species across multiple locations in the United States and Canada. As part of NTEP, ARS researchers in Beltsville, Maryland, assembled, reviewed for accuracy, statistically analyzed, and reported these data via media and the NTEP web site. Now, a recently developed a database has been created to house and serve

the nearly one million data records collected. Through a USDA Specialty Crop Research Initiative grant to develop low-input grasses, ARS and University of Minnesota collaborators added fanleaf fescue to the publicly available database in July 2022. Development of tablet and smartphone apps are underway and will equip homeowners to locate the best cultivar based on their location, soil type, tree canopy situation and other factors.

Component 3: Develop integrated science-based tools to foster improved management of grass, forage, and rangeland agroecosystems.

Virtual fencing helps grazing cattle reduce vegetation in fuel breaks to fight wildfires. The frequency and severity of large wildfires severity are increasing in western U.S. rangelands, and invasive annual grasses are a significant fuel source for rangeland wildfires. Research is showing that targeted cattle grazing of these grasses in strategic locations can create fuel breaks that help reduce wildfire spread, but keeping cattle within targeted fuel break boundaries without fencing is a challenges. ARS researchers in Burns, Oregon, tested the effectiveness of innovative, virtual fencing technology for keeping grazing cattle within the bounds of a pasture-scale fuel break in southeast Oregon's sagebrush steppe. Virtual fencing was highly effective in containing dry cows and reducing vegetation fuels within fuel break boundaries but was less effective for cows with calves. Cattle consumed about 50 percent of the fine fuel biomass within a 200-meter wide by 3000-meter long, virtually fenced fuel break, compared to about 5 percent of the biomass outside of the fuel break. Virtual fencing, particularly when combined with geospatial technologies for mapping grass fuel accumulations, has strong potential for strategically managing the abundance of grass fuel within fuel breaks and potentially larger rangeland landscapes and could benefit a wide variety of rancher needs.

New technologies advance precision livestock grazing and rangeland management. Tools are needed to help ranchers rapidly respond to changing forage conditions during the grazing season. In extensive rangeland systems, it is often impractical to measure forage availability and quality in-person in the field; and existing remote-sensing technologies do not provide grazing managers with near-real-time, production-relevant metrics, such as available plant biomass, diet quality, or animal weight gain, at spatial scales relevant for management decisions. ARS scientists in Fort Collins, Colorado, linked long-term, field-based datasets with freely available satellite data to accurately predict daily plant biomass, diet quality, and animal weight gains across highly variable conditions. These remote sensing advances yield near-real-time plant biomass and diet quality maps at fine (100 feet) spatial scales to assist managers with ranch- and pasture-scale decision-making. In related research, ARS scientists in Fort Collins, Colorado, and University Park, Pennsylvania, tested innovative sensors on free-ranging beef cattle in seven states, from the western United States to Florida, to quantify their foraging behavior and distribution. Topographical variations consistently affected cattle distribution on grazing lands. Integrating three animal sensor types--GPS tracking collars, accelerometers, and jaw movement devices--revealed how daily metrics of foraging behavior are influenced by grazing management and give managers real-time indicators of how forage conditions affect livestock intake and weight gains. These near-real-time tools, combined with commercially

available technologies such as virtual fencing, open a new frontier for precision livestock management that increases efficiency and lowers environmental impact by accurately matching forage supply with animal demand in extensive rangelands.

Component 4: Generate strategies to manage grass, forage, and rangeland agroecosystems that simultaneously contribute to environmental conservation and are beneficial to human and animal use.

Targeted forages and additives reduce cattle enteric methane emissions. Reducing enteric methane emissions of dairy cows can lower their climate footprint, and diet formulation is targeted as one way to achieve less methane. For grazing cows, one option is to grow high tannin forages in pastures, since tannins have several dietary benefits, including reduced enteric methane. However, tannins can interfere with cow digestion and reduce their productivity. Supplementing grazing diets with oilseed additives can counteract the negative tannin impacts and the oilseeds may themselves further reduce enteric methane due to their high lipid content. ARS scientists in University Park, Pennsylvania, used a lab-based fermenter system to evaluate how adding three oilseeds (soybean, sunflower, canola), either alone or in combination, to a diet containing a high-tannin lespedeza forage affected methane emissions. Canola and sunflower led to 79 percent and 67 percent less methane than soybean, and the combined oilseeds led to 84 percent less methane than soybean. Soybean's lower lipid content was most likely the reason for its lowest effectiveness. Real-world challenges for implementing these diet options include the high cost and limited availability of canola and sunflower, and difficulty growing lespedeza in many environments. However, these results are adding to an expanding knowledge of dietary options for reducing methane from dairy cows and developing ways to overcome challenges for widespread adoption by dairy producers.

New cost-effective approach determines silage quality. Analyzing harvested silages for organic acids (lactic, succinic, acetic, and propionic acids) is critical for assessing silage quality for its value as an animal feed and spoilage risk during storage. Traditional approaches for analyzing industrially and agronomically relevant silage can be expensive and time consuming. ARS researchers in Madison, Wisconsin, demonstrated that the quantity of silage organic acids can be predicted mathematically from the way they interact with visible and near-infrared wavelengths of light. This new approach is a low-cost, high-throughput method for rapidly characterizing silage water extracts and can benefit the silage research community by substantially reducing cost of analysis and increasing throughput. Further development could allow cost-effective, on-farm silage quality diagnostics that save producers money and enable real-time decision-making, including identifying potential forage spoilage and avoiding potential impacts associated with livestock consumption of poor-quality feed.

Restricting grazing after wildfire does not improve vegetation recovery. Intermountain West ranchers depend on grazing public lands. After wildfire, public land management agencies often restrict grazing access for 2 years or longer to improve vegetation recovery. However, benefits of longer vegetation recovery times remain unknown, and grazing restriction can negatively

impact rancher profitability. ARS researchers in Dubois, Idaho; Miles City, Montana; and Woodward, Oklahoma, evaluated the effects of fire season and post-fire grazing deferment on big sage vegetation communities near Dubois. Grazing deferment for 2 years did not increase cover of desirable rangeland plant groups compared with sheep grazing the first fall season after fire. Furthermore, 4 years after fire, areas that had spring and fall burns had about 5 percent more perennial grass cover than unburned areas. These results will help public land agencies and ranchers understand how to graze rangelands after fire to realize ecological sustainability and economic benefits.

Fire, but not grazing, increases invasive annual grasses on rangelands. Invasive annual grasses are a major threat to western North American rangelands by decreasing biodiversity and increasing fuel that promotes more frequent and intense wildfires. Overgrazing and fire have historically both been implicated as contributors to the invasive grass problem. However, experimental comparisons between fire and contemporary grazing, especially off-season fall and winter grazing, are lacking. ARS researchers in Burns, Oregon, compared the effects of moderate grazing during the off season and fire in sagebrush communities. Areas with fire had greater than 250 percent more invasive annual grass abundance than control areas that had no grazing or fire, and grazed areas had about 50 percent fewer less invasive grasses than control areas. These results suggest that fire, but not off-season grazing, is a threat to the sustainability of sagebrush communities at risk of exotic annual grass invasion. Land managers and livestock producers are very interested in this research and have implemented off-season grazing pilot projects.