FY2023 Annual Report
National Program 215—Grass, Forages, and Rangelands Agroecosystems

The USDA-ARS National Program for Grass, Forages, and Rangelands Agroecosystems (NP215) is comprised of 100 scientists conducting 27 congressionally appropriated (base program funding of $63M) research projects at 21 locations across the U.S. Those scientists had another productive year in 2023 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 FY2023, 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 45 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.

The quality and impact of NP215 research was further evidenced in 2023 by the following:

- 159 refereed journal articles and 14 book chapters published;
- 46 new outgoing cooperative agreements;
- one new patent and one new invention disclosure; and
- 181 students and postdoctoral research associates studying in ARS laboratories

NP 215 Accomplishments for FY2023

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 FY2023 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.

New DNA marker technology revolutionizes alfalfa breeding. Using DNA markers to revolutionize plant breeding has lagged for alfalfa due to high costs and because alfalfa's high level of genetic heterogeneity means that many DNA markers do not capture enough information to accurately identify gene locations. In 2018, ARS launched the Breeding Insight initiative (https://breedinginsight.org/), which is now hosted at Cornell University, explicitly to bring these new breeding technologies to underserved crops like alfalfa. ARS scientists in St. Paul, Minnesota; Madison, Wisconsin; Logan, Utah; and Prosser, Washington, collaborated with Breeding Insight to develop 3,000 DNA markers that can be used in any alfalfa population, are equally distributed across the genome, and are inexpensive to use with large numbers of individual plants in a breeding program. Using alfalfa populations segregated for resistance to the disease Aphanomyces root rot, they validated that the markers identify the same chromosomal regions for disease resistance genes as more expensive and time-consuming methods, and found the markers successfully group plants by stem strength, stem color, stem structure, and winter injury. The scientists also used the markers to identify candidate genes for resistance to the two races of the root rot pathogen. The DNA markers are now available to the alfalfa research community as a powerful new tool for crop improvement.

Orchardgrass and wheatgrass varieties improve forage production and rangeland restoration success. Orchardgrass is one of the most important perennial grasses used in temperate grazing pastures because of its high productivity, nutritive value, and palatability. However, in more northern and at higher elevations, orchardgrass often suffers from winter injury and mortality. In the Intermountain U.S. West, native grasses like Discovery and Secar Snake River wheatgrass are widely used to restore rangelands that have been degraded by invasive weeds and frequent wildfire, but these wheatgrasses are often limited by low seed yields and poor establishment. ARS researchers in Logan, Utah, developed an orchardgrass variety called USDA-Yeti that

combines excellent winter hardiness, better stand establishment, and greater forage mass. They also developed 'Destination' Snake River wheatgrass, which has greater biomass, better seed yield, and better stand establishment than Discovery and Secar. These resources will benefit the livestock and dairy industry by expanding options for high-quality orchardgrass at sites at risk of winter injury and will give seed managers and public land managers seed inventories that will improve rangeland restoration success.

Genome and gene discovery improve hairy vetch. Hairy vetch is a hardy annual legume that can be grown as a cover crop to protect soil from erosion, supply nitrogen to soil for crop production, provide forage to feed livestock, and support pollinating bees. Unfortunately, some traits in hairy vetch, such as pod shatter, hard seed, and a high proportion of dormant seed that limits germination, discourage its use as a cover crop. ARS researchers in Madison, Wisconsin, and Clay Center, Nebraska, worked with nongovernmental organizations and private sector partners on generating a new reference genome for hairy vetch that is already facilitating breeding for soft seeded varieties. The genome is expected to greatly facilitate marker-assisted breeding for other useful traits and for gene discovery, transcriptomics, and genome structure. In related research with the Noble Research Institute, the Madison researchers identified more than 24,000 gene products associated with seed dormancy that will help scientists develop hairy vetch varieties with seed that germinate quickly and vigorously and create ground cover while minimizing the risk that dormant hard seed will result in future weed issues. These genomic resources are giving farmers wider options for cover crop adoption and increasing production and ecosystem service goals in their operations.

Origins and potential control for alfalfa bacterial stem blight disease. Bacterial stem blight of alfalfa recently emerged as a serious disease in the western United States, causing yield losses of up to 50 percent in the first annual harvest. Although the disease was recognized in 1904, little is known about the pathogen, mechanism of infection, or alfalfa resistance. ARS scientists in St. Paul, Minnesota, and University of Minnesota collaborators isolated the known pathogen, *Pseudomonas syringae*, and a second pathogen, *P. viridiflava*, from alfalfa samples in California, Utah, Oregon, Minnesota, and Ohio. A genomic study of 94 strains of *P. syringae* and 29 strains of *P. viridiflava* showed that both species are widespread, have been established for a long time, are likely transported by precipitation, and can cause frost damage on alfalfa as a means of infecting plants. A complete genome sequence of 20 pathogen strains identified unique genes for toxins causing disease symptoms. The scientists identified disease-resistant plants in the cultivars Maverick and ZG9830 and several candidate genes involved in the resistance. This research is foundational for understanding that the emergence of bacterial stem blight is not due to recent pathogen introduction or the evolution of aggressive pathogen strains, and that breeding alfalfa for resistance is a viable way the alfalfa industry can reduce damage from the disease.

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.

Red seaweed might reduce enteric methane from dairy cows. One way the agricultural community is exploring ways to reduce its greenhouse gas emissions is by reducing enteric methane emissions from dairy cattle. Adding ingredients to cattle feed that can reduce methane generation in the rumen is one potential management strategy, but more research is needed about how these feed additives affect animal health and productivity goals. Using laboratory in-vitro techniques, ARS scientists in University Park, Pennsylvania, and University of New Hampshire collaborators added three levels of red seaweed to a representative pasture-based dairy cow diet and evaluated the effects on rumen fermentation and methane production. Methane production was almost completely suppressed at all levels of seaweed supplementation, but multiple measures of nutrient digestibility that are indicators of potential animal productivity also declined. This research is critical for the scientific community in their efforts to identify effective methane-controlling feed additives with stable active ingredients, determine optimal doses in cattle diets, and provide information to industry partners as they develop strategies for production costs and scales.

Sorghum significant crop for pollinator activity. Pollinators are experiencing a global decline, which has implications for both human food supply and plant diversity, and producers are encouraged to support pollinator populations by planting nectar-rich plants with different flowering seasons. Promoting wind-pollinated plants, including grasses, is rarely recommended, but many bees and other pollinators have often been documented collecting pollen from grasses. Sorghum, a crop primarily used for grain in the United States, is not recommended to homeowners or farmers as a plant to promote pollinators. ARS researchers in Tifton, Georgia, observed honey bees, bumblebees, and carpenter bees collecting sorghum pollen and hoverflies and earwigs consuming sorghum pollen. They also found that sorghum infested with sugarcane aphids attracted numerous flies, bees, wasps, and ants that feed on the sugary waste product of the aphids. These studies document that sorghum, especially when harboring sugarcane aphids, is a valuable crop for preserving pollinators and other beneficial insects. These finding have important implications for using insecticides in sorghum management, especially for newly released herbicide resistant sorghums.

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

Tall fescue genotype controls fescue toxicosis alkaloid production. Tall fescue is a highly adaptable forage grass in part due to its association with the endophytic fungus *Epichloë coenophiala*, which produces alkaloids that help fescue tolerate environmental stresses. However, some of the alkaloids are toxic to animals grazing the fescue and can result in significant livestock production losses. ARS scientists in Lexington, Kentucky, monitored alkaloid accumulation in fescue plants under different weather conditions for 3 years to determine how plant genotype contributes to alkaloid levels. They found that weather induced different

alkaloid levels but that alkaloid accumulation differences between genotypes tended to be the same, suggesting that plant genetics are responsible for signaling the endophyte to produce different alkaloid levels. This research will provide a foundation for future breeding to identify plant genetic factors responsible for regulating alkaloid levels to simultaneously maintain tall fescue stress tolerance and minimize toxicosis.

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.

Rotational rangeland grazing reduces weight gain. Adaptive rotational grazing has been suggested as a management option to improve production and sustainability. ARS researchers in Fort Collins, Colorado, and Cheyenne, Wyoming, tracked cattle with GPS devices to compare foraging behavior and outcomes between cattle managed in adaptive, multi-paddock rotational grazing and cattle managed in traditional, season-long single paddock grazing. Individual cattle in rotation systems, where the ratio of herd size to pasture size was 10-fold greater, ended up being less selective in the vegetation they foraged, which led to lower diet quality and reduced cattle weight gain by 14 percent every year for 5 years. These unique findings identify the cattle behavior mechanism in rotational grazing that can reduce cattle productivity and can help ranchers identify optimal stocking densities for achieving multiple outcomes on their rangelands. In 2023, the scientists highlighted these findings in more than 25 media outlets (e.g., Beef Magazine, On Pasture, Western Ag Reporter) in the United States and Canada, potentially reaching an audience of more than 4.7 million consumers.

Lawson aerator increases herbaceous cover of rangeland grazing pastures. In western U.S. rangelands, producers graze livestock in a rotational pasture system. Vegetation communities in these pastures that become old and degraded reduce grazing resources needed to meet production goals. This can increase risks for overgrazing more productive pastures, which can reduce the sustainability of those pastures and negatively affect sensitive wildlife species, such as the greater sage-grouse. ARS researchers in Reno, Nevada, used the Lawson Aerator to evaluate the effectiveness of a mechanical treatment to treat rangelands that have become dominated by old, dense, and decadent shrub communities; increase herbaceous perennial vegetation; and promote sustainable grazing resources. Using this treatment on 364 hectares of degraded shrub habitats in northern Nevada increased herbaceous perennial grass densities from 1.2/m^2 to 8.1/m^2 and increased forage from 513 kg/ha to 5,554 kg/ha. These improvements expanded grazing resources on this pasture and increased its use from less than 4 weeks to more than 14 weeks. Federal, state, and private sector land managers have adopted this treatment tool to improve grazing pastures and wildlife habitat; for example, Nevada Gold Mines has already purchased needed equipment and applied the treatment strategy to an initial 75 hectares in their land holdings.

Prescribed fire improves rangeland forage quality and reduces invasive trees. In western rangeland systems, ranchers are constantly seeking effective management options to improve

the forage quality of their grazing lands and control invasive weeds and trees. Prescribed fire can be a powerful tool to help ranchers achieve these goals, and scientific research is critical for identifying its appropriate use. ARS researchers in Miles City, Montana, evaluated the ability of prescribed fire to improve the forage quality of purple threeawn, a native perennial bunchgrass that can dominate degraded rangelands and is mostly avoided by herbivores as forage. Summer and fall fire increased plant mineral contents from deficient levels to levels exceeding requirements for growing cattle. The Miles City scientists also evaluated using prescribed fire to reduce seeds and newly emerged seedlings of Russian olive, which is an aggressive tree species that is difficult to control, invades riparian areas, and reduces native forage availability. Prescribed fire reduced Russian olive seed germination by 80 to 100 percent and killed virtually all Russian olive seedlings less than 10 weeks old. This research is providing much needed information on how prescribed fire can benefit rangeland health and productivity and will give ranchers tools they need to meet their economic and ecological sustainability goals.

Mechanistic models improve mapping rangeland resilience and improve restoration success. Millions of acres of rangeland in the U.S. Intermountain West have been significantly degraded by exotic annual grass invasions, often after wildfire. Restoring these lands depends on understanding, documenting, and using inherent landscape features that enable resisting invasion and becoming resilient against degradation. ARS researchers in Boise, Idaho; Burns, Oregon; Fort Collins, Colorado; and Woodward, Oklahoma, worked with Boise State University and U.S. Geological Survey collaborators on using seedbed microclimate and germination information to develop seedbed favorability models that improve mapping land resilience and resistance. This mapping approach is especially valuable when used with seasonal weather forecasting to identify years when successful restoration is possible in lower-elevation, dryer rangeland ecosystems. This research improves Bureau of Land Management and U.S. Forest Service applications of resistance and resilience metrics used to prioritize rangeland restoration activities across millions of acres of disturbed rangelands in the Intermountain Western United States.