FY2020 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 95 scientists conducting 26 congressionally appropriated research projects at 22 locations across the U.S. Those scientists had another productive year in 2020 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 FY2020, the importance of these global applications was demonstrated by collaborations with researchers in Argentina, Australia, Brazil, Canada, China, Denmark, Estonia, Ethiopia, France, Germany, India, Israel, Kazakhstan, Kenya, Netherlands, New Zealand, Norway, Pakistan, Portugal, Russia, South Africa, and Uruguay.

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 FY2020

New additions to the NP215 team in 2020 were:

- **Dr. Sultan Begna** joined the Water Management Research Unit at Parlier CA as a research agronomist. Before joining ARS, Sultan was working as an agricultural scientist for New Mexico State University. His research focuses on improving the yield and quality of alfalfa and other forage crops.
- **Dr. Michael Sullivan** was selected as Research Leader of the Cell Wall Biology and Utilization Research Unit, Madison WI. Mike has been a Molecular Geneticist with ARS since 2000. His research program is focused on utilization of forage protein and cell wall components in dairy production systems. The CWBUR unit also welcomed **Dr. Laurie Reinhardt** as a Support Chemist. Although Laurie is not new to the Unit, she is now applying her expertise in qualitative and quantitative small molecule analysis to support numerous Unit research endeavors in plant specialized metabolism and animal nutrition..
- **Dr. David Jaramillo** joined the Pasture Systems and Watershed Management Research Unit in University Park PA as a postdoctoral research associate. He recently completed a Ph.D. at the University of Florida, and his research will focus on evaluating alternative forages to extend the grazing season to compensate for periods of low perennial cool-season pasture production.
- The Plant Science Research Laboratory in St. Paul, MN welcomed two new scientists in 2020: **Dr. Shaun Curtin** joined ARS after postdoctoral work at the University of Minnesota and as a Senior Research Scientist with Calyxt, Inc. His expertise is in genome editing, legume and cereal transformation, small RNAs, and legume genomics. He is currently working on identifying genes controlling desirable traits in legume crops, determining relationships of root architecture with root functions in soybean and alfalfa, and improving legume transformation and gene editing technologies. **Dr. Zhanyou Xu** joined ARS after postdoctoral work with Texas A&M in collaboration with ARS scientists in College Station, TX. He worked as a soybean breeder and Genetic Project Lead for Syngenta and most recently as a Lab Analytics Lead for Bayer AG. His expertise is in plant genetics, marker assisted breeding, bioinformatics, and machine learning. He is developing genomic selection methods for alfalfa to accelerate breeding for stress tolerance, forage quality, disease resistance, and root architecture.
- **Dr. Sean Kearney** joined the Rangeland Resources and Systems Research Unit, Ft. Collins CO, as a postdoctoral research associate. Sean received his Ph.D. from the University of British Columbia, and is working with Dr. Lauren Porensky on using near-real-time satellite time series data to produce fine-scale (30m) maps of forage quality and forage biomass, and the translation of this data to predict livestock weight gains.

The following scientists retired from the ranks of NP215:

- **Dr. Byron Burson** of the Crop Germplasm Research Unit, College Station, TX retired in 2020. Dr. Burson worked for ARS for more than 40 years and had a successful career as a research scientist with the genetics of warm-season grasses.

The following scientists in NP 215 received prominent awards in 2020:

- The Collaborative Adaptive Rangeland Management Stakeholders Group (CARMSG) project of the **Rangeland Resources and Systems Research Unit, Ft. Collins CO,** received the Outstanding Achievement Award for Land Stewardship award from the Society for Rangeland Management.
- **Dr. Michael Ralphs** of the Poisonous Plant Research Laboratory, Logan UT, received the Sustained Lifetime Achievement Award from the Society for Rangeland Management "for long-term contributions to the art and science of range management and to the Society for Range Management."
- **Dr. Kevin Panke-Buisse** received a 2020 Excellence in Technology Transfer Award from the Midwest Region of the Federal Laboratory Consortium for Technology Transfer (FLC) for his work with other ARS researchers on "Tools for Identifying Host Microbes for Viruses and Antimicrobial Resistance."

The quality and impact of NP215 research was further evidenced in 2020 by the following:

- 181 refereed journal articles and 3 book chapters published
- 1 new patent received and 4 new invention disclosures

NP 215 Accomplishments for FY2020

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 FY2020 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.

Managing Midwest dairy forage production systems to maintain soil carbon. The U.S. dairy industry is committed to environmental stewardship goals, including neutral or reduced carbon emission from dairy farms. Research is needed to determine the opportunities on farms to reduce carbon emissions and sequester carbon, the latter of which includes soil carbon storage. ARS researchers at Saint Paul, Minnesota, monitored carbon balances for 9 years on three fields on a large dairy that uses both solid-liquid separation and anaerobic digestion for manure management. Under the current alfalfa-corn silage production with conventional tillage and inputs of liquid dairy manure, the field soils were losing carbon, with losses more than three times greater under corn silage than alfalfa. To maintain a neutral carbon balance in corn silage, the equivalent of 70 percent of the carbon removed in harvested corn would have to be returned to fields. That value is 30 percent for alfalfa. However, returned carbon should be even greater to have net soil carbon storage. This rate of carbon returns to fields may require changes in tillage, crop rotation, and manure management, all of which may be a challenge given how such changes affect other enterprises on the farm. These results are being used by scientists developing decision-aid tools that can evaluate whole-farm carbon uses and balances, by dairy producers to understand the tradeoffs in their carbon management, and by dairy industry stakeholders supporting carbon sustainability goals

Determining plant properties and management practices that improve rangeland restoration after wildfire. Grasses are critical plants used in seeding rangeland in the western U.S. for restoration after wildfire and where invasive species threaten ecosystem function. These rangelands vary widely through the year in soil temperature and moisture conditions that affect grass seedling establishment, and grasses vary inherently in how well they establish. ARS researchers in Boise, Idaho; Burns, Oregon; Fort Collins, Colorado; and Woodward, Oklahoma, along with collaborators at the University of California, found that seeds planted later in the fall have a much higher chance of surviving winter mortality, and that diversifying the seed mix is key to ensuring that at least some seedlings successfully establish. ARS researchers in Logan, Utah, examined the effect of soil water on root and shoot growth of seven grass species. Three species increased both root and shoot biomass in response to water,

while four other grasses increased shoot growth but not root growth. They also found that higher seed mass produced seedlings with more shoot and root biomass that favors short-term growth, while less seed mass produced seedlings with greater surface area of leaves and roots that is better for long-term growth. These findings can improve successful seedling establishment by public land management agencies, help develop more recalcitrant native grass species, and match grass populations to specific site conditions—all to improve re-seeding efforts and make western rangelands more fire and weed resistant.

Survey of pollinating insects in centipedegrass lawns. In the United States, turfgrasses are a major component of the landscape and cover more than 40 million acres. Centipedegrass is a warm-season turfgrass that is often grown in the southeastern United States. Recently, honeybees were documented collecting pollen from the flower structures of centipedegrass. To understand the role of turf species such as centipedegrass in supporting pollinators, ARS researchers in Tifton, Georgia, and scientists from the University of Georgia surveyed bees in centipedegrass lawns in central and southern Georgia. Numerous bees were observed, of which 79 percent were Lasioglossum species (sweat bees). Minor species observed included long-horned bees; other species of sweat bees, including metallic green sweat bees; bumble bees; leafcutter bees; and small carpenter bees. These data indicate that diverse bees are residing in or near lawns and forage in and around the lawns seeking centipedegrass flowers. The knowledge that many bees are present in centipedegrass lawns indicates that homeowners and landscape managers should apply insecticides conservatively, since certain insecticides are toxic to foraging bees in lawns.

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.

AlkarXL, a new tall wheatgrass cultivar for use on saline, semiarid lands. With urban spread in the western United States, farmers and ranchers rely increasingly on marginally productive soils that are frequently high in salt to produce forage. Tall wheatgrass is one of the most salt tolerant grasses used for fall and winter livestock grazing on dryland salty soils, but the yield and quality of this forage for livestock production needed improvement. ARS scientists at Logan, Utah, in collaboration with seed companies, developed and released 'AlkarXL', a new tall wheatgrass cultivar with better forage quality for use on saline soils. Across multiple locations, years, and harvests, AlkarXL produced 3.02 tons per acre of forage, which was on average 14 percent greater than five other common tall wheatgrass cultivars. AlkarXL's protein content of 6.2 percent after harvest in the summer was 11 percent greater than these other cultivars. AlkarXL also had higher protein in the fall after regrowth (12.8 percent) than these cultivars and was well above the 7 percent protein level needed by grazing ruminant livestock. Seed of AlkarXL is now commercially available, providing an improved forage grass for marginal salty rangelands.

Genes associated with Verticillium wilt resistance in alfalfa are identified. Verticillium wilt is an alfalfa disease that reduces forage yields by up to 50 percent. An ARS scientist in Prosser, Washington, identified DNA sequence changes in two different alfalfa genes that were reliably associated with resistance to Verticillium wilt and accounted for one-third of the variation in resistance to the disease.

Based on these results, a rapid polymerase chain reaction (PCR) test was developed that may help identify alfalfa plants with increased resistance based on genetic differences. The PCR assay is being further validated in commercial populations. If successful, this new test will accelerate the development of improved alfalfa varieties by making it easier for breeders to select for substantial changes in resistance to Verticillium wilt.

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

Grass-Cast: A new decision-support tool helps livestock producers improve productivity from rangelands. Western U.S. livestock producers on rangelands can best manage their operations when they use flexible stocking strategies to match the forage needs of their animals with the forage availability on their land. Because forage growth varies greatly depending on precipitation, producers need ways to predict how much forage will be available to take advantage of flexible stocking strategies. ARS scientists from Cheyenne, Wyoming, and Fort Collins, Colorado, in collaboration with Colorado State University, the University of Arizona, and the National Drought Mitigation Center, developed Grass-Cast, a grassland productivity forecasting tool. Grass-Cast uses year-to-date climate data and seasonal precipitation outlooks to forecast forage production for rangelands at the 6 x 6-mile spatial resolution. Grass-Cast was publicly released in 2018 for the Northern Plains, in 2019 for the entire Great Plains, and in 2020 for New Mexico and Arizona. The public release included the co-development of a new website, which was recently expanded in 2020 and is co-managed by the USDA Northern Plains Climate Hub and the National Drought Mitigation Center at the University of Nebraska. Grass-Cast has garnered widespread media coverage at regional and national levels, including a USDA official press release, blog posts, radio news stories, and stories in agricultural newspapers and websites. Livestock producers are interested in having Grass-Cast expanded to the Great Basin, California, and even Canadian prairies.

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.

Alfalfa leaf protein concentrate is a sustainable alternative to fish meal for aquaculture diets. Aquaculture is the production of fish and shellfish in controlled conditions and is the fastest growing food sector worldwide. However, fishmeal used in diets of most aquaculture species is a limited, unsustainable resource with volatile pricing. To determine if alfalfa could be a source of protein for use in aquaculture, ARS scientists at Saint Paul, Minnesota, and collaborators from the University of Minnesota pressed fresh alfalfa foliage to produce a juice and then concentrated the proteins by various methods. A heat treatment resulted in a protein concentrate with the most favorable amino acid profile that did not contain antinutritional factors commonly found in proteins from other plant sources like seed meals. Feeding studies with yellow perch and rainbow trout found that both species accepted alfalfa protein concentrate in feeds. Approximately 800 pounds of protein concentrate can be produced from an acre of alfalfa, and the remaining plant residue can be used as a feed ingredient for cattle, or as a bioenergy feed stock. This research on alfalfa protein concentrate provides the

aquaculture industry with the promising development of a sustainable alternative to fishmeal in diets and alfalfa production industry with a new, high-value use for their crops.

Early alfalfa establishment in silage corn can increase dairy farm profitability. Corn and alfalfa are major crops grown in rotation on dairy farms in the United States. The same alfalfa crop lasts several years, but the conventional practice of planting alfalfa in the spring after a corn crop results in lower yields and farm profitability the first year because the alfalfa is not fully established. ARS and University of Wisconsin scientists at Madison, Wisconsin, developed an alternative system where alfalfa is established a year earlier by interseeding into corn. This results in full alfalfa production the following year. The scientists recently used crop yield data, estimated feed values, and farm production costs to show the benefits of the new interseeding alfalfa production system could increase net returns by about 15 percent compared to the conventional spring-seeded alfalfa system. The early alfalfa establishment also improves forage yields and provides cover crop benefits for protecting soil and water resources. Dairy farmers will be able to use this new crop production approach to increase their economic and environmental sustainability.

Development of genomic tools to identify gastrointestinal parasite resistant sheep. Perhaps the most important means of parasite control is an animal's natural resistance. Genetic resistance to parasitic nematodes varies among individual animals within a breed and is moderately heritable. The ability to identify genetic markers of animal resistance to parasites will have wide benefit in the sheep industry as parasites become increasingly resistant to dewormer treatments. A team led by ARS researchers in Booneville, Arkansas, identified gene DNA sequence variation that was associated with resistance to gastrointestinal parasites in sheep. The team is funded by NIFA's Organic Agriculture Research and Extension Initiative and included colleagues from Louisiana State University, Virginia Tech, Katahdin Hair Sheep International, University of Nebraska-Lincoln, and University of Idaho. This information is important to producers, scientists, veterinarians, and extension specialists to increase natural parasite resistance in sheep and to reduce the use of dewormers, which can in turn reduce parasite resistance to dewormers and extend their effectiveness.

Mixing alfalfa and birdsfoot trefoil into tall fescue pastures can improve growth performance and economic return of beef cattle. High nitrogen fertilizer costs and increased emphasis on environmental stewardship have renewed interest among beef producers in the western United States in integrating legumes into their high-productivity, irrigated pastures. However, these producers need to know how forage and livestock growth on grass-legume mixtures compare to that on conventional grass-only pastures fertilized with nitrogen. ARS researchers at Logan, Utah, measured herbage mass, nutritive value, steer growth performance and economics of tall fescue pastures mixed with alfalfa or birdsfoot trefoil compared to fescue-only pastures with nitrogen fertilizer. The grass-legume mixed pastures had slightly less herbage, but nutrition and steer growth performance were better than that with fertilized grass pastures. Without the added cost of fertilizer, economic returns for the grass-legume pastures were 2.4 (trefoil) and 1.7 (alfalfa) times greater than the fertilized grass pastures and were competitive with many other crops grown in the region. These novel grass-legume mixtures can help U.S. beef farmers increase the forage and livestock productivity of their pastures and rangelands while reducing dependence on petroleum-based commercial fertilizer.

Napier grass (Elephantgrass) as a bioenergy feedstock. Napier grass has the highest biomass productivity of any grass for cropping in the southeastern United States, but management practices to optimize its use in the production of bioethanol are needed. Over a 5-year period, ARS researchers in Tifton, Georgia, and Peoria, Illinois, compared how harvest management affected how much bioethanol could be produced. If the crop was fertilized in May and harvested once per year in December, production was consistent over 5 years. In contrast, two harvests per year (June and December) led to dramatic declines in production beginning in Year 3. The ethanol yield per acre was 962 gallons in the second growing season and 1,368 gallons in the fourth season, which out-yields a 180 bu/acre, corn-for-ethanol field by a considerable margin. This work will help bioethanol producers and farmers in the Southeast maximize Napier as a competitive bioethanol feedstock.

Use of noninvasive specimens can help diagnose livestock exposure to poisonous plants. Larkspurs, lupines, and death camas can be acutely toxic to livestock and are serious poisonous plant problems in western North America. Poisoning of livestock by plants often goes undiagnosed because there is a lack of appropriate or available specimens for analysis. ARS researchers at Logan, Utah, developed procedures to detect toxic compounds in easily obtainable animal samples (rumen contents, ocular fluid, earwax, hair, oral fluid, and nasal mucus) to help easily diagnosis cattle that consumed toxic plants. The advantage of using theses samples is that collecting them is noninvasive and relatively easy. No special equipment is required, and untrained personnel can easily collect the samples. These methods will be valuable for livestock producers, extension agents, veterinarians, and especially laboratories to help diagnose animals that are poisoned by common toxic plants found in rangeland environments.