FY 2011 ANNUAL REPORT
NATIONAL PROGRAM 213 – BIOENERGY

USDA's Agricultural Research Service (ARS) leads USDA intramural scientific research to enable new practices and technologies for increasing the energy efficiency of agricultural operations. ARS bioenergy research is organized into three components, and integrated through five USDA Regional Biomass Research Centers. The centers are networks of ARS and Forest Service Research and Development facilities and scientists are designed to complement and coordinate USDA Agricultural Research Service (ARS) and Forest Service Research & Development (FS) intramural research from across the country to help accelerate the establishment of commercial region-based biofuel supply chains based on agricultural and forestry-based feedstocks.

SELECTED ACCOMPLISHMENTS

USDA REGIONAL BIOMASS RESEARCH CENTER ACTIVITIES

USDA Regional Biomass Research Centers launched. Secretary Vilsack announced the five regional *USDA Biomass Research Centers* as a part of a major policy speech at the National Press Club on October 21, 2010. The Regional Biomass Research Centers serve to coordinate USDA Agricultural Research Service and Forest Service Research and Development intramural research across the country to help accelerate the establishment of commercial region-based biofuel supply chains based on agriculture and forest-based feedstocks.

The Western and Northwestern Biomass Research Centers have developed a coordinated strategy focused on oil seed cops to meet the immediate feedstock needs for jet and marine fuels used by the aviation industry and military. Oil seed crops can be used to also diversify income in existing wheat-based systems in the western half of the U.S., but expanded production will need to be done in ways that don't seriously disrupt existing grain markets. Also, large areas of western rangelands are degraded by invasive pinion pine, western juniper, and eastern red cedar tress. Sustainable harvest and range restoration plans are being developed to utilize this biomass as a feedstock for aviation fuel production.

The Central-East Biomass Research Center is focused on the genetic development and sustainable production of switchgrass, other perennial grasses, and crop residues like corn stover for cellulosic biomass feedstocks. This region is highly productive and produces a significant amount of the corn used for ethanol production. The challenge to dedicated feedstock production in the region is integrating biomass production into existing agricultural landscapes in ways that enhance soil and water quality throughout the region. Opportunities also exist for developing winter oil seed crops that can be planted between summer-grown corn and soybean crops, and thus not impact existing commodity crop markets.

Southeastern Biomass Research Center research is focused on semitropical perennial grasses such as sugar cane, Napiergrass, and biomass sorghum that can be harvested for sugars and cellulose, as well as woody biomass from residues and purpose-grown wood. Nearly half of the biofuel needed to meet RFS2 mandates will likely come from feedstocks produced in this region. More efficient uses of mixed landscapes must be developed to take advantage of the highly productive growing conditions in this region, and to develop strategies and technologies that help ensure dependable supplies of feedstocks are produced for biorefineries.

First USDA Biomass Research Centers Customer/Stakeholder Workshop. The national workshop was held March 15-17 in Denver, Colorado. A special focus was placed on the gaining information about the perspectives and research needs of downstream industry sectors that require feedstocks to produce biofuels competitively priced with petroleum-based fuels. Workshop guests included 24 industry customers, 15 U.S. Government agency representatives, and 11 stakeholder partners from DOE laboratories, universities, and non-government organizations. Twenty-seven senior ARS scientists, the five regional center coordinators, and four Office of National Program Bioenergy Team members hosted the workshop and facilitated the customers and stakeholders listening sessions. The ARS scientist team began to develop the USDA Biomass Research Center *Action Plan*, prepare responses to the customer input, and create a formal communication plan. Follow-up regional workshops are planned. Customer workshops are critical to ensuring our research is relevant and meets the needs of commercial companies.

Exploring collaborations with USDA NRCS. ARS Office of National Programs leadership from Beltsville, Maryland met with Natural Resources Conservation Service (NRCS) Deputy Chief of Science and Technology to discuss ways the USDA Biomass Research Centers can provide ready-to-use conservation and energy conservation technology for development of technical guidelines in support USDA conservation programs. Meetings were also held with NRCS Western National Technical Center in Portland, Oregon on February 3 and with senior NRCS Energy Team leadership in Washington, D.C. on September 27. The agencies discussed establishing a formal agreement between the NRCS National Technical Center and the USDA Biomass Research Centers, and NRCS requested ARS assistance in developing a farmer workshop for on-farm biodiesel production from oil seed crops to replace purchased farm fuels.

Cooperative agreement signed with DOE Idaho National Laboratory. A non-funded cooperative research agreement was signed between the ARS National Laboratory for Agriculture and the Environment (NLAE) in Ames, Iowa and Battelle Energy Alliance to formalize cooperation for the development of sustainable bioenergy feedstock production strategies and decision technologies for the sustainable harvest of biomass. Planned collaborations include implementing a landscape vision for sustainable feedstock supplies, and sharing field, laboratory, and computer simulation data for testing a crop residue management tool that will help commercial interests determine amounts of cellulosic residue feedstocks that can be sustainably harvested for biofuels. The *Residue Removal Tool* is being delivered to USDA NRCS for implementation in the conservation planning toolbox.

Support for Title III Defense Production Act Initiative. There is a lack of manufacturing capability for producing aviation and marine biofuels in the United States. On August 16, the President announced that the Navy, DOE, and USDA are jointly investing up to $510 million with the private sector to construct several commercial aviation biofuels refineries. USDA is providing technical advice based on ARS research and analyses in support of the initiative, and is participating on the multi-agency team developing the funding selection criteria and assessing the feedstock components of submissions to the request for information. ARS is also participating in a USDA sponsored workshop that will bring diverse biofuel supply chain participants to encourage the development of new partnerships.

Second Annual U.S.-China Advanced Biofuels Forum. USDA and DOE hosted a delegation of 30 Chinese officials and technical experts met with DOE at the Idaho National Laboratory September 14-16, and September 19-21 with USDA ARS and Forest Service scientists at Tifton

and Griffin, Georgia. Information was exchanged about the genetic improvement of dedicated non-food biomass crops and their sustainable production in the southeastern United States and China. The second *Sino-U.S. Biofuels Forum* was held September 23 in Washington, D.C. Meetings were held between ARS and ZTE Company to discuss the development of a research partnership to advance sustainable production of sweet sorghum for biofuels. These scientific exchanges support the MOU between China National Energy Administration, USDA, and DOE.

Support for commercial aviation biofuel production. ARS scientists from El Reno, Oklahoma, Albany, California, Parlier, California, Riverside, California, and Maricopa, Arizona and the Office of Technology Transfer have helped facilitate meetings hosted by economic development groups in Kansas and California to address feedstock choice for commercial aviation biofuel development projects under study. ARS also continues to provide technical information on sustainable oil crop production, and the availability of pinion pine, western juniper and eastern red cedar biomass that can be harvested from degraded rangelands in 17 western States. This effort supports USDA NRCS conservation efforts and the Department's *Farm to Fly* initiative.

Developing biomass research partnerships in South America. Several South America countries are expanding production of biomass sweet sorghum for renewable energy production. Future U.S. demand will increase, so establishing research partnerships can provide an opportunity to accelerate improvement of new materials adapted to U.S. conditions. ARS researchers from Mandan, North Dakota and Wyndmoor, Pennsylvania provided technical assistance to the USDA Foreign Agricultural Service at the *Energy Climate Partnership of the Americas* (ECPA) project in Montevideo, Uruguay. ARS experts and the *Instituto Nacional de Investigacion Agropecuraria* (INIA) exchanged ideas for designing a successful national biofuels research program. The ARS scientists from Lincoln, Nebraska and Beltsville, Maryland were hosted by the U.S. Embassy in Buenos Aire,s made presentations, and met with researchers from INIA in Colonia, Uruguay, and with *Estacion Experimental Agropecuaria Obispo Colombres* (EEAOC) at Tucuman City, and *Instituto Nacional de Tecnología Agropecuaria* (INTA), the *Ministerio de Agricultura*, and *Maizar* at Pergamino in Argentina. As a result of these efforts, public-private research partnerships are emerging that will result in sorghum biomass improvement and commercialization efforts in the southeastern United States.

USDA and FAA deliver the Feedstock Readiness Level Tool. Air industry experts recognized disconnects between the technical readiness of a fuel conversion processes and the availability of needed feedstocks for producing aviation biofuels. The commercial air transportation industry requested that USDA develop a *Feedstock Readiness Level* (FSRL) *Tool* to complement the internationally recognized *Fuel Readiness Tool* that was developed by the Commercial Air Alternative Fuel Initiative (CAAFI). A USDA/FAA team created the FSRL to track progress on the development of agricultural and forest-based feedstocks needed to produce jet fuels for the aviation industry. USDA and FAA delivered the FSRL tool at the CAAFI Annual Meeting in Washington, D.C. on November 30. ARS National Program Staff from Beltsville, Maryland led this multiple agency effort.

Southeast Regional Biomass Research Center Customer-Stakeholder Workshop. The Southeast Regional USDA Biomass Research Center held a half-day meeting in Tifton, Georgia to share information about the Center with collaborators and agency partners. Fifty-five people attended the session with an additional eighteen participating through a remote conferencing. A series of presentations highlighted the national objectives of the USDA Biomass Research

Centers, regional perspectives on agricultural and woody biomass production, and industry perspectives on biomass conversion opportunities. Outcomes from the meeting included e-versions of the organizing presentations, an initial catalog of regional bioenergy research work, and near-term research planning action items. Forest Service Research and Development (FS) and ARS Regional Biomass Research Center coordinators from Tifton, Georgia, Auburn, AL, and Booneville, Arkansas identified a need to develop a regular webcast to share research progress and identified research areas where ARS and FS researchers have common research topics. This meeting provided more details for development of a regional strategic plan that was initiated at the national customer stakeholder meeting held in Denver, Colorado, and allowed broad participation from across the southeast states.

FEEDSTOCK DEVELOPMENT

Feedstock development research is designed to help accelerate the availability of bioenergy crops with increased yields and improved feedstock characteristics for the production of renewable energy. Fundamental research on the molecular, biochemical, and genetic control of key plant traits impacting energy and co-product value is being applied that will lead to more efficient biomass conversion of into bioenergy and value-added co-products.

New energy cane variety developed. ARS scientists at Houma, Louisiana and their collaborators have developed a new sugarcane variety with fiber-rich stalks that could help set the stage for producing biofuels from cellulose. Millions of acres of dedicated feedstocks will need to be produced to help meet legislated biofuel targets, and energy cane is one of the crops that will be needed for the southeastern region of the United States. The new cane variety *Ho 02-113* was bred with biofuel use in mind, and is one of four high-fiber varieties that have been released in anticipation of biorefinery needs for Gulf-Coast-specific crops. *Ho 02-113* produces dense stands of high-fiber stalks, making it more adaptable to a wider range of environments than typical cane intended for sugar production. In addition to being able to produce new growth from un-harvested stalk material, it also survived natural outbreaks of brown rust, smut, leaf scald and mosaic disease. ARS researchers publically released *Ho 02-113* in cooperation with Louisiana State University and the American Sugar Cane League. This effort is a product of the Southeastern Regional USDA Biomass Research Center.

Corn gene enhances switchgrass biofuel production. ARS scientists at Albany, California have increased starch production in switchgrass by up to 250 percent using a novel form of the corn gene *cg1* (*corngrass1*). Starch produced by *cg1* switchgrass was converted into simple sugars such as glucose and without energy-intensive and expensive pretreatment of biomass. Moreover, *Cg1* switchgrass does not produce seeds or pollen, thus preventing the inadvertent movement of this gene by pollen to native switchgrass populations, thus protecting natural sources of genetic variation. The *cg1* switchgrass represents a new model way to genetically improve feedstocks for the biofuel production industry. The research collaboration is between ARS scientists, and ones at the Department of Energy, Energy Biosciences and Joint BioEnergy Institutes. This effort is a product of the Central-East Regional USDA Biomass Research Center.

New genetic diversity cooperative for *Saccharum* and perennial grasses. ARS scientists from Canal Point, Florida, Houma, Louisiana, Tifton, Georgia, and Lincoln, Nebraska have begun a public-private cooperative for improving sugarcane and energy cane that will provide important new sources of genetic diversity to help meet the feedstock demands of both the sugarcane and

the emerging biomass industry in the southeastern United States. Based on the successful *Germplasm Enhancement of Maize* (GEM) *Project*, this cooperative will develop a pipeline of superior and genetically diverse sugarcane varieties and related energy grass feedstocks. Despite the high quality of current ARS sugarcane varieties, new genetic diversity is needed to overcome constraints to dependable feedstock production. A pilot program has been initiated involving ARS, university, and industry partners for sugarcane and energy cane germplasm enhancement. Resulting hybrid clones from crosses will be released as public germplasm and shared among public institutions and private industry members. Additional commercialization agreement opportunities are likely to exist beyond this initial cooperative effort. This effort is a product of the Southeastern Regional USDA Biomass Research Center.

Genetic diversity in switchgrass is key to future high-performance. Switchgrass is a native perennial grass that will be used to produce biofuels and other forms of renewable energy across the eastern part of the country. As a dedicated biomass industry expands and matures, it will be critical to have a range of switchgrass varieties adapted to different production conditions across the region. ARS scientists from Madison, Wisconsin have identified five distinct lineages of switchgrass that date back to the times of the last Ice Age: *Gulf Coast lowland, Southern Plains lowland, Southern Plains upland, Central Plains upland,* and *Eastern upland*. Today's North American populations are the result of refuge environments that have preserved the ancient genetic diversity for tens-of-thousands of years. A dryland refuge in the U.S. southwest and Mexico is the only source of upland plants adapted to northern climates and dry soils. A western Gulf Coast coastal plains population and a lowland plains refuge along the northern and eastern Gulf Coast serve as sources of plants adapted to lowland warm climates and wet soils, and are also a source of remnant hybrids between upland and lowland ecotypes that originated hundreds of generations ago before upland and lowland ecotypes genetically by flowering time separated. The Gulf Coast region continues to serve as a rich resource of genetic variability for switchgrass genetic improvement. This research was done in collaboration with the University of Georgia, the Great Lakes Bioenergy Research Center, the Bioenergy Sciences Center, and China Agricultural University, and is a contribution of the Central-East Regional USDA Biomass Research Center.

SUSTAINABLE FEEDSTOCK PRODUCTION

Sustainable production systems research will provide strategies that help ensure cost-effective, high-yielding, and dependable supplies of feedstocks are produced in ways that enhance the quality of the natural resources base, and minimize negative impacts on existing land uses and markets. ARS investment in long-term networks of natural resources and farming systems research is being leveraged to support the production of feedstocks along with other food, feed, and fiber crops.

Chicago Council on Global Affairs (CCGA) utilizes Renewable Energy Assessment Project. Results from the ARS Renewable Energy Assessment Program (REAP) led by ARS scientists at Ames, IA were used as the basis for a facilitated discussion on *Landscape Approaches for Sustainable Biomass Feedstock Supplies* at a CCGA Advisory Committee Meeting in support of their project *Managing Great Lakes Agriculture and Forestry Residuals*. The one-year effort funded by the USDA agency Rural Development allows the CCGA to make technical assessments of untapped biomass sources from agriculture and forestlands and match these with potential energy conversion projects in Indiana, Illinois, Ohio, Michigan, Minnesota, and

Wisconsin. This effort demonstrates effective interagency collaboration with a private partner that will help ensure sustainable supplies of cellulosic feedstock are available for the production of biofuels and biopower. This effort is a product of the Central-East Regional USDA Biomass Research Center.

Clear invasive trees on western rangelands to produce jet fuel. Eastern Red Cedar, Pinion Pine, and Western Juniper trees are native, but have become an invasive nuisance and fire hazard on formerly productive Western U.S. rangelands. Clearing the red cedar will also restore the rangeland productivity for native wildlife habitat and cattle grazing. ARS efforts at Burns, Oregon, Reno, Nevada, and El Reno, Oklahoma are underway to assess biomass amounts, develop restoration management plans, and estimate the economic and natural resources benefits of tree removal. Using a remote sensing technique developed by ARS scientists from El Reno, Okalahoma who worked with USDA NRCS, the team estimated that the 12 million tons of red cedar growing in the 17 greatest impacted counties is enough to produce 800 million gallons of biofuel or nine million megawatt hours of electricity. ARS, NRCS, and Forest Service in Reno have produced an inventory of pinion pine and juniper infestations on public and private lands in Nevada, Arizona, New Mexico, Utah, and California. In addition to making an inventory of western juniper in Oregon, ARS at Burns has completed assessing the impact of biomass removal and developed restoration management methods that will improve habitat for endangered sage grouse while improving grazing for cattle. Commercial business developers are using this information to develop business plans for building first-of-its-kind aviation biofuel production facilities. This effort is a product of the Southeastern, Western, and Northwestern Regional USDA Biomass Research Centers.

Helping the Colville Tribes produce biofuels. ARS has developed a strategy for moving up planting time so rapeseed plants can become established in autumn and survive the winter. Using information about present and near-term weather conditions to determine when to plant, successful establishment of rapeseed rotations crops has the benefit of helping fend off weeds in wheat fields, reducing soil erosion, and utilizing excess nitrogen that could be lost to ground and surface waters. The Colville Confederated Tribes are working with ARS scientists at Pullman, Washington and Washington State University to use this approach to produce winter oil seed crops on tribal lands. Their plan is to extract the seed oil and make biodiesel for their fleet of school buses, and then sell the crushed seeds to local farmers as a livestock feed supplement. USDA's Risk Management Agency has already used the research findings as the basis for providing crop insurance for rapeseed grown in northern Washington. This research is also timely since EPA has determined that canola-based biodiesel meets requirements for greenhouse gas reductions under Renewable Fuel Standard 2 guidelines. This effort is a product of the Northwest Regional USDA Biomass Research Center.

Switchgrass production environment affects ethanol yields. Theoretical ethanol yields were determined from biomass harvested from switchgrass production fields on 10 farms for a five-year period in Nebraska and South and North Dakota. Near Infrared Reflectance Spectroscopy (NIRS) calibrations developed by an ARS team from Lincoln, Nebraska and Madison, Wisconsin were used to determine predict ethanol yields. Theoretical ethanol yield varied by year and between fields, with five-year means ranging from 91 to 103 gallons per ton of biomass. Total theoretical ethanol production ranged from 187 to 394 gallons per acre across fields planted to forage type switchgrass cultivars. Because of the liquid fuel differences, biorefineries will need to test switchgrass for biomass quality and consider the yearly variation that can occur

in biomass production across a region when developing their business plans. This effort is a product of the Central-East Regional USDA Biomass Research Center.

Rapid estimation of cellulosic ethanol yield. ARS and the *Near Infrared Spectrophotometry Consortium* (NIRSC) established a cooperative agreement for transferring switchgrass composition NIRS calibrations to public and private laboratories and industries developing switchgrass as a biofuel biomass crop. The NIRSC is an association of commercial analysis laboratories, universities, government agencies, plant research companies, and instrument companies that collaborate to develop standardized NIRS methods, and disseminate information about the accuracy and application of NIRS technologies. ARS scientists at Lincoln, Nebraska led this new effort that has provided a rapid method to mass screen the quality of switchgrass genetic lines for improved performance, and for biorefiners to accurately assess the expected ethanol yields from biomass produced across a wide range of production field conditions. This effort is a product of the Central-East Regional USDA Biomass Research Center.

BIOREFINING

Biorefining research develops new value-added coproducts and improves the performance of existing commercially preferred technologies. For over 50 years, ARS has been a world leader in the development of technologies to utilize agricultural products. This research is not only critical to economical biofuel production, but also an expanding economy based on biobased products produced from agricultural feedstocks.

Biodiesel provides five-to-one return on fossil fuel energy inputs. The value of different biofuels is based on their total life-cycle net energy return. For instance, the net energy return for corn ethanol is estimated to be 0.5 BTU/BTU and the net energy return of petroleum-based fuels is about 0.9. ARS researchers at Wyndmoor, Pennsylvania, along with other USDA and university collaborators, completed a life-cycle analysis of soybean biodiesel production and showed that for every BTU of fossil energy used to produce biodiesel, 5.5 BTUs of biodiesel are produced. A previous assessment based largely on pre-1990 data estimated a net return of 3.2. The new study also determined that the higher biodiesel energy return were due to improvements in soybean crushing facility and biodiesel refinery facilities, soybean farmers adopting energy-saving farm practices such as reduced tillage; and improved soybean yields. These findings point out the need access to up-to-date data and on-going techno-economic analysis of entire supply chain contributions to biofuel production energy efficiency.

Protein-rich biomass produces stable pyrolysis oils. A major problem with pyrolysis oil is its high oxygen content that leads to high acidity, chemical instability, and corrosion to handling equipment. ARS researchers at Wyndmoor, Pennsylvania showed that when protein-rich biomass such as oilseed press cake is used as a feedstock, overall pyrolysis oil yield remains unchanged but more oxygen is released as water and fewer acids are produced than with typical low-protein feedstocks. Consequently, the resulting pyrolysis oil is less acidic and has greater energy content, so offers significant advantages over pyrolysis oil derived from purely lignocellulosic biomass. A patent application has been filed and proposal submitted to the USDA/DOE 9008 Grant Program for further commercial development.

Designing high-performance yeast for cellulosic ethanol. Yeasts used for ethanol production from corn grain starch are unsuitable for the production of cellulosic ethanol because the yeasts are poisoned by the byproducts created when fermentable sugars are produced from cellulosic

biomass, and the yeasts don't utilize xylose that constitutes about one-third of cellulosic biomass sugars. Using adaptation and genetic engineering techniques, ARS scientists at Peoria, Illinois developed a new industrial yeast strain that both tolerates the toxic byproducts and efficiently ferments xylose to ethanol.

Fate of antibiotics used in ethanol production. Antibiotics are used to control bacterial contamination at commercial fuel ethanol facilities, but the fate of these drugs had not been documented. A significant concern has been whether there are antibiotic residues in dried distillers grains (DDG) that are used for livestock feed. ARS scientists at Peoria, Illinois and the National Corn-to-Ethanol Research Center measured the activity of a common antibiotic used by ethanol producers, in ethanol process streams and found that biologically active virginiamycin did appear in the DDG. However, this research showed that the antibiotic is not biologically active in DDG used as livestock feed.