

The Creation and Role of the USDA Biomass Research Centers

By WILLIAM F ANDERSON¹, JEFFREY STEINER², RANDY RAPER³,
KEN VOGEL⁴, TERRY COFFELT⁵, BRENTON SHARRATT⁶, BOB RUMMER⁷,
ROBERT L DEAL⁸ and ALAN RUDIE⁹

¹USDA-ARS, c/o William Anderson, P O Box 748, Tifton, GA 31793, USA

²USDA-ARS, Office of National Programs, Washington, DC, USA

³USDA-ARS, Booneville, AR, USA

⁴USDA-ARS, Lincoln, NE, USA

⁵USDA-ARS, Maricopa, AZ, USA

⁶USDA-ARS, Pullman, WA, USA

⁷USDA-FS, Auburn, AL, USA

⁸USDA-FS, Portland, OR, USA

⁹USDA-FS, Madison, WI, USA

Summary

The Five USDA Biomass Research Centers were created to facilitate coordinated research to enhance the establishment of a sustainable feedstock production for bio-based renewable energy in the United States. Scientists and staff of the Agricultural Research Service (ARS) and Forest Service (FS) within USDA collaborate with other federal agencies, universities and private partners to design, implement, and disseminate findings from research that has high impact on the bioenergy industry. The centers draw upon expertise in diverse disciplines and a history of long term research conducted at multiple locations within each region. Feedstocks development and production aspects are region specific. However, soil, water, and air quality as well as methods to minimize the adverse affects of bioenergy on existing agricultural markets are central to all production systems and regions.

Key words: Feedstock, breeding, production, logistics, conversion, life-cycle analysis, carbon sequestration, greenhouse gas emissions

Introduction

Since the creation of the Department of Energy (DOE) in 1977, the United States Government has advocated the development of renewable energy systems. Over the past decade the executive and congressional branches of the United States government have placed a greater emphasis on reducing our dependence on foreign oil. The current administration formed the Biofuels Interagency Working Group (IWG) on 5 May 2009 composed of members of Department of Agriculture (USDA), DOE and the Environmental Protection Agency (EPA) and published a report (Biofuels Interagency Working Group, 2010) that describes a new approach to meeting the goals set forth by the Renewable Fuels Standard within the Energy Independence and Security Act of 2007 (EISA)(Pub L.). This act requires that by the year 2022, 36 billion gallons of biofuels be added to transportation fuel and that 21 billion gallons would come from non-cornstarch products such as sugar or cellulosic feedstock. The IWG suggested developing a strategic plan across the USA.

Government that would increase public-private partnerships in research and development. As part of this effort, Secretary of Agriculture Vilsack announced the creation of five USDA Biomass Research Centers on 21 October 2010 (Vilsack, 2010).

Make-up and Purpose of the USDA Research Centers

The five research centers are ‘virtual centers’ comprised of a network of over 100 existing USDA Agricultural Research Service (ARS) and Forest Service (FS) locations (Fig. 1). The main purpose of the centers is to facilitate improved coordination and complementation of existing and future research that enhances the establishment and support of regional biofuel supply chains based on agricultural and forestry feedstocks. Research related to biomass supply chains is currently being conducted at many ARS and FS locations, consisting of 1) dedicated feedstock development through genetics and breeding; 2) feedstock production protocols; 3) logistics of planting, harvesting, and preprocessing; 4) feedstock conversion; and 5) natural resource assessments that lead to life cycle analyses (LCA). Among the current national natural resource networks being leveraged are the Long-term Agro-ecological Research (LTAR) network that utilizes our ARS watersheds, Greenhouse gas Reduction through Agricultural Carbon Enhancement network (GRACEnet), and the Renewable Energy Assessment Project (REAP). The centers also provide a long-term leadership structure that can partner with other USDA agencies, universities, state energy organizations and private industry.

Regional Center is the development and subsequent best management production practices of high performing herbaceous and purpose grown wood biomass feedstock. Both the Western and Northwestern Regional Centers focus on woody biomass and industrial oil crop production with appropriate cropping systems. The Northwestern Center also researches woody biomass supply, wood energy and biofuels, and the use of post-harvest residues of small grains, particularly within wheat based production systems. In all the regions research efforts address the effects of dedicated feedstock production on water (nutrient escape) and air quality (greenhouse gas emissions and carbon sequestration) as well as methods to minimize the adverse affects of bioenergy on existing agricultural markets. Best management practices include means of production with minimal inputs on marginal lands such as increasing system efficiency through introduction of nitrogen-fixing plants and mitigation of any potential invasiveness issues.

Central East-Region - Switchgrass Bioenergy Research and REAP

Much of the current research within USDA-ARS on biomass for bioenergy has evolved from programs designed to develop cultivars and production systems for producing high biomass for livestock, whether as pasture or hay. Scientists from the Central-East hub have linked with multiple ARS locations throughout the country to expand the program into bioenergy research. The program at Lincoln, Nebraska is one of the best examples of how research has evolved at ARS locations to address dual purpose (livestock feed and bioenergy feedstock) from a single perennial grass species. Work began in 1935 with germplasm collection and evaluation of native switchgrass (*Panicum virgatum* L.) which led to early cultivar releases, and then subsequent breeding and selection led to the release of improved upland type switchgrass cultivars ‘Trailblazer’ and ‘Shawnee’. The Department of Energy adopted switchgrass as one of the primary biomass species due to its high productivity and good abiotic stress tolerance (McLaughlin & Kzvos, 2005).

The USDA-ARS Lincoln group began research on switchgrass as a bioenergy feedstock in the 1990’s with genetic assessment, management studies, and large-scale net energy and economic trials. Information from these studies was used to establish a regional, large scale on-farm trial in 2000 with ten cooperating farmers in three states. A research team composed of agronomists, geneticists, plant physiologists, chemists, soil scientists and economists used the five year data from these field scale trials to determine the net energy, fiscal and carbon economics of growing switchgrass for bioenergy in the Midwest USA. Results from the trial demonstrated that switchgrass production for bioenergy was economically viable (Perrin *et al.*, 2008; Schmer *et al.*, 2008) and that soil carbon increased on average at the 10 locations by over 5 Mg ha⁻¹ at 5 cm depths and three times that amount at depths of 120 cm (Schmer *et al.*, 2011). More recently members of the research team have assessed conversion potential of switchgrass through wet chemistry (Dien *et al.*, 2006) and through use of near-infrared spectroscopy (Vogel *et al.*, 2010). The key to producing these types of high-impact publications has been the collaborative nature of the team. Research team members meet regularly to discuss new studies or additional information from current studies and coordinate efforts. Generated information from these studies is vital to producers, biorefineries in the region, and the National Agriculture Statistics Service (NASS).

The ARS Renewable Energy Assessment Project (REAP) team was formed in 2005 to address concerns regarding the harvest of corn stover as a bioenergy feedstock. The foundation for REAP was built on long-term ARS research. The overall challenge was to determine how to harvest corn stover and other crop residues without depleting soil organic carbon or increasing the risk of erosion and subsequent loss of soil productivity. The four objectives of REAP are to: (1) Determine the amount of crop residues (e.g. corn stover, cover crop) that must remain on the land to maintain soil organic carbon and sustain production; (2) Estimate the trade-off between the short-term economic return to growers versus the long-term benefits to soil, water, and air; (3) Develop robust algorithm(s) to guide the amount of crop residue that can be sustainably harvested without degrading

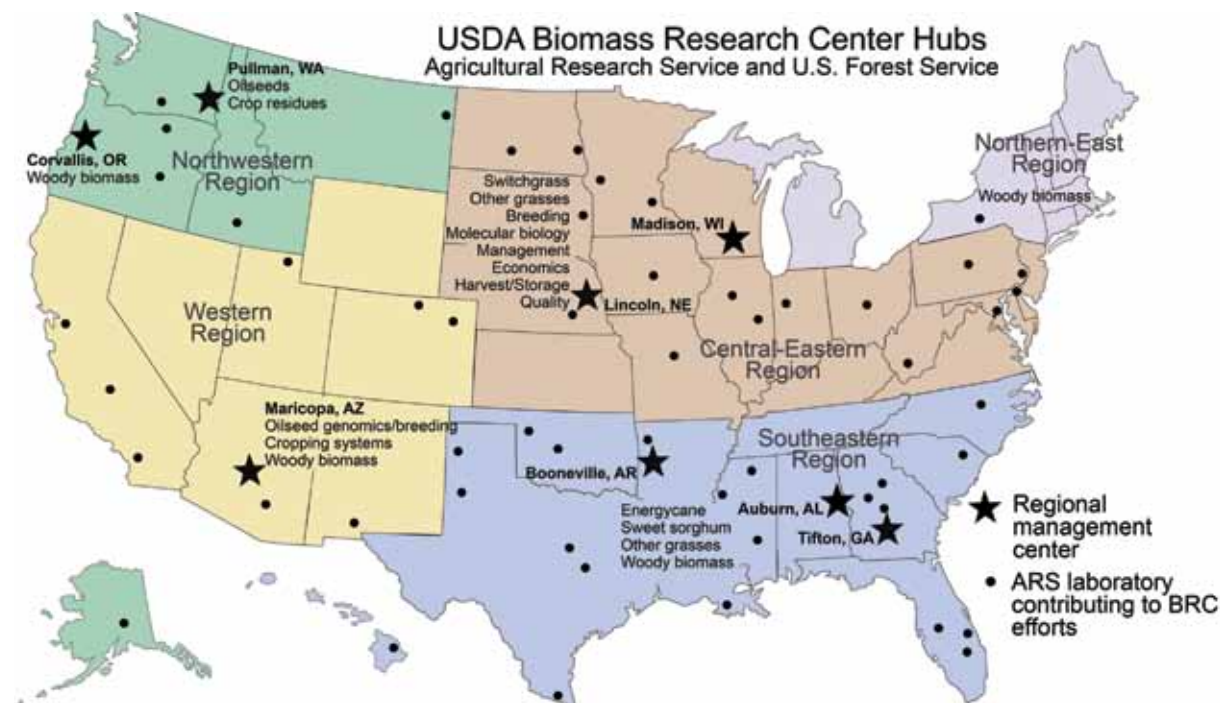


Fig. 1. USDA Biomass Research Centers.

The centers are divided into five areas of the United States and are led by either FS or ARS or both as in the case of the Southeast and Northwest regions. Each region has coordinators at one or more ‘hubs’ that interact with multiple research locations (spokes). Cooperative research can occur across the country depending on required expertise and facilities. The primary effort of biofuel research and development in the Northern-East Center is on woody biomass, including improving short-duration woody-crops, sustainable management systems and life-cycle analyses. The Central-East Regional Center focuses on the development of perennial grasses, biomass sorghum, and corn stover cellulosic biomass. The main emphasis of research for the Southeastern

the soil resource, environmental quality, or productivity; and (4) Develop management strategies supporting sustainable harvest of residue. Among the 12 publications contributed to the literature since its inception are effects of removing corn stover on soil quality (Karlen *et al.*, 2011) and requirements needed to maintain soil organic carbon levels (Wilhelm *et al.*, 2007). A concept paper addressing the need to balance economic drivers against limiting factors (Wilhelm *et al.*, 2010) provides the cornerstone for future studies focused on developing multifunctional landscapes that will simultaneously address multiple critical functions including production of food, feed, fibre, and fuel; protection of soil, water, and air quality; provision of appropriate wildlife habitat; and creation of rural economic development opportunities.

Research within the Central-East Regional Center over the next 5 years will continue to focus on switchgrass and other perennial grasses such as big bluestem (*Andropogon gerardii* Vitman) and indiangrass (*Sorghastrum nutans* (L.) Nash) and some native legumes for use in multi-species biomass production fields. This work will be part of a large regional project in cooperation work with Iowa State University, Purdue University, University of Wisconsin, University of Minnesota, and the University of Nebraska. Additional research on developing biomass sorghums will continue with the ARS sorghum project at Lincoln and cooperating universities as well as using corn stover for bioenergy within the REAP project.

Northern-East Region – Wood Products to Energy

The Northern-East Region centered out of Madison, WI will be instrumental in developing the research plans for work related to wood products for bioenergy. The US Forest Service developed a research and development plan for bioenergy and bio-based products (US Forest Service, 2010). A goal had been set by FS in 2007 to replace 15% of gasoline with ethanol from wood while reducing greenhouse gas emissions. The research and development plan has set three goals; 1) Provide the nation with sustainable and economical forest biomass management and production systems; 2) Provide the nation with competitive biofuels and biopower conversion technologies and bioproducts that reduce greenhouse gas emissions and fossil fuel use; and 3) Provide the nation with information and tools for decision making and policy analysis (US Forest Service, 2010).

Among the expected products from the first goal will be best-management practices for sustainable wood biomass; new varieties of wood that are not only fast growing and high producing but also pest resistant and water and nutrient efficient; synthesis of environmental impacts and management systems to offset these impacts; and improving harvesting, handling and transportation of woody biomass. The second goal is expected to deliver feedstock characterization databases; value added products from lignin; and improvements in conversion efficiencies for the production of fuels and chemicals from both fermenting organisms as well as via thermo-chemical platforms. A recent discovery in this area has facilitated collaboration with major industry partners (Zhu *et al.*, 2009). The third goal will deliver better tools for regional assessment of forest bioenergy resources; life-cycle analyses for carbon and greenhouse gas accounting; models to assist in site selection of bioenergy facilities; and logistics and decision support tools.

Southeast Region – A Diversity of Feedstock

The Southeast Regional ARS labs have collaborated with multiple national ARS labs. The southeast has been identified as a potential major contributor to the production of renewable fuels in the United States due to high net primary productivity (NPP), mainly attributed to long growing seasons, normally high rainfall, and tremendous forest and cropland resources (Lowrance *et al.*, 2011). USDA-ARS research on biofuels has concentrated on assessing perennial and annual grasses for biomass. These include tropical/subtropical energy cane, and napier grass (*Pennisetum*

purpureum Schum.), as well as photoperiod insensitive *Miscanthus* within pasture, agroforestry and forest-based systems. Annuals include biomass or and sweet sorghum in rotation with existing row crops. Bermuda grass (*Cynodon* sp.) has been evaluated for potential dual use as hay for livestock or as a bioenergy feedstock (Anderson *et al.*, 2010) and dedicated tall bunchgrasses have been compared under low inputs (Knoll *et al.*, 2011). Switchgrass and *Miscanthus* sp. have the production and cold tolerance for northern areas of the Southeast while energy cane and napier grass have shown the greatest potential for the sub-tropical plant adaptation zones. ARS sugarcane research locations at Houma, LA and Canal Point, FL have produced energy cane lines for evaluation throughout the Southeast at ARS locations (Viator *et al.*, 2011) and comparison to other grasses in colder climates (Burner *et al.*, 2008). Research is being conducted on rotational annual cropping systems of bioenergy crops such as biomass sorghums with traditional row crops and winter nitrogen-fixing cover crops. ARS scientists in Alabama showed that removal of cover crops for biomass had negative effects on subsequent crops (Raper *et al.*, 2011).

The USDA-ARS Biomass Research hub at Booneville, AR focuses much of their work on aspects of agroforestry and small farm production practices which can be an important component of biomass production in the Southeast. Their research enhances knowledge of the benefits and limitations of annuals, perennials, and trees for bioenergy and livestock production during transition of traditional agricultural production systems to more integrated systems that sequester large amounts of carbon, reduce runoff and protect soil quality, produce optimum crop yields, require minimal energy inputs, and maximize small farm profits. Research conducted at the center includes both laboratory and field components designed to fill the gaps in technology and management practices necessary for small farms to contribute to bioenergy/livestock production systems.

Across the region, numerous studies are being conducted on environmental impacts of growing and harvesting large acreages of biomass from forest products or dedicated crops which are based off of previous studies (Lowrance & Sheridan, 2005). Related to forestry research, a simulation tool to compare alternative methods of moving biomass from the forest to a wood-using facility was developed at Auburn, Alabama, with partners across the United States (<http://www.fs.fed.us/r6/nr/fp/FPWebPage/FP70104A/Programs.htm>). Private contractors, government agencies, and municipalities use this tool to make effective comparisons. Also, Auburn researchers helped develop new equipment to bundle and bale woody biomass that will reduce transportation and handling costs (Meadows *et al.*, 2009). Two equipment manufacturers now have new commercially-available equipment as a result of Forest Service field studies. This equipment will help expand the renewable energy feedstock supply by making forest residues more accessible.

Northwestern and Western Regions – Oil Seed Crops and Woody Biomass

Biofuel in the western United States is anticipated to be produced from a limited number of feedstocks. These feedstocks include crop residue, grasses, oilseeds, and woody biomass with a large fraction of biofuels produced from oilseeds in this region. Therefore, the Northwestern and Western Biomass Research Centers have been designated as the lead Centers for developing oilseed crops for bioenergy.

Seed from oilseed crops have the highest energy content of all agricultural crops. Oilseeds, however, are not widely grown in the western United States. Oilseed crops such as canola have been grown with success in the west, but their absence from cropping systems is largely due to the lack of viable markets. Other oilseed crops (e.g. *Camelina sativa*) have the potential of being grown in the western United States and adoption to the region will require agronomic or rotational practices and development of high yielding cultivars. The goal of the research to be conducted by the ARS under the USDA Northwestern and Western Biomass Research Centers is to develop the knowledge and technologies required to successfully grow and enhance the oil production efficiency of oilseed crops, identify economically viable cropping systems that protect environmental resources, and develop adapted high yielding germplasm.

Research undertaken by these Regional Biomass Research Centers will result in new oilseed cultivars that enhance crop performance in the field and the conversion efficiency to biofuel; new strategies for growing oilseed crops in rotation with conventional crops that aid in diversifying and enhancing farm economies; management strategies to control pests in more diverse crop rotations that include oilseeds; crop management systems developed that more efficiently utilize fertilizers and reduce loss of nutrients to the environment; and tillage and crop management systems that enhance soil quality and reduce emissions of greenhouse gases and particulate matter from farm lands.

Research on ‘Feedstock Development’ addresses improvement by traditional and non-traditional breeding methods of seed characteristics and growth characteristics such as increased seed size; reduced seed dormancy; increased oil content; cold, heat, and drought tolerance; rapid growth; uniform and early maturity; and non-shattering seed. Research on ‘Feedstock Production’ addresses the development of agronomic and land management practices such as defining potential production areas; determining sowing and fertility requirements; developing profitable cropping systems; developing tillage and residue management systems; and developing weed, insect, and disease management strategies. In addition, research on production systems would address the environmental effects of various cropping systems on greenhouse gas and particulate emissions; wind and water erosion; and carbon sequestration and storage to help develop life cycle analyses. Research on ‘By-Product Utilization’ addresses the development and enhancement of additional products from the meal and other plant constituents to increase the profitability of the crop such as utilization of the meal for animal feed, use of glucosinolates as biofumigants, and fatty acid residues as binders and resins.

The woody biomass work in this region will focus on biomass supply and utilization research, wood energy and biofuels research, and economic analysis of fuels treatments. Collaborative work with the Forest Products Laboratory, US Department of Energy and the PNW Research Station on national and regional assessments of biomass supply has provided a quantifiable estimate of future woody biomass. Biomass utilization and capacity studies have also been an important area of research (Lowell *et al.*, 2008). Other important research includes harvesting logistics and landscape assessment, wood energy and wood pellet research (Nicholls *et al.*, 2009). Biofuels and biochar research is also an important focus in the region (Dumroese *et al.*, 2011). Lastly, economic analyses of fuel treatments are critical to assess the feasibility of woody biomass supply and to identify strategic areas for fuel treatments (Barbour *et al.*, 2008).

The Forest Service biobased products and bioenergy research program will provide the science and technology to sustainably provide the quantities of wood for bioenergy and bioproducts, maintain and enhance forest productivity, reduce treatment costs, and increase efficiency. This research will help provide the science and technology to sustainably produce, manage, harvest and convert woody biomass to cellulosic ethanol, biochar and other high-value products. Together, these can reduce investor risk and contribute to US energy security, environmental, and economic goals.

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