USDA National Agroforestry Center

Inside Agroforestry

VOLUME 15 ISSUE THREE

Fuel for the future

Woody biomass is a viable component of the total bioenergy system in the US.

Our growing population is faced with an ever-increasing problem. Today, working lands must meet more than simply the demand for food. In addition to providing an array of ecological services like clean water, soil conservation, and wildlife habitat, working lands – both forestry and agriculture – are being challenged to develop sustainable approaches to produce renewable biomass crops to help meet our nation's energy needs.

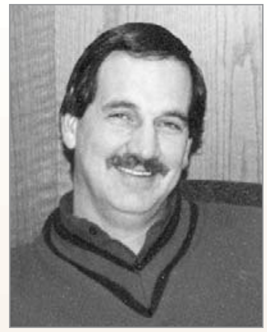
Perennial plants, like trees and shrubs, have the potential to provide large quantities of biofuel feedstock. Given a relatively fixed land base, any agroforestry practice can be designed to produce a harvestable product, and at the same time provide a conservation service which helps to bridge the competition between agriculture and forestry land uses for energy crop production.

To create integrated biomass production systems, it is essential that agriculture and forestry work together. This issue of *Inside Agroforestry* provides an overview of the energy potential of woody biomass.

Inside

NAC Director's Corner

A commentary on the status of agroforestry
by Dr. Greg Ruark, NAC Program Manager



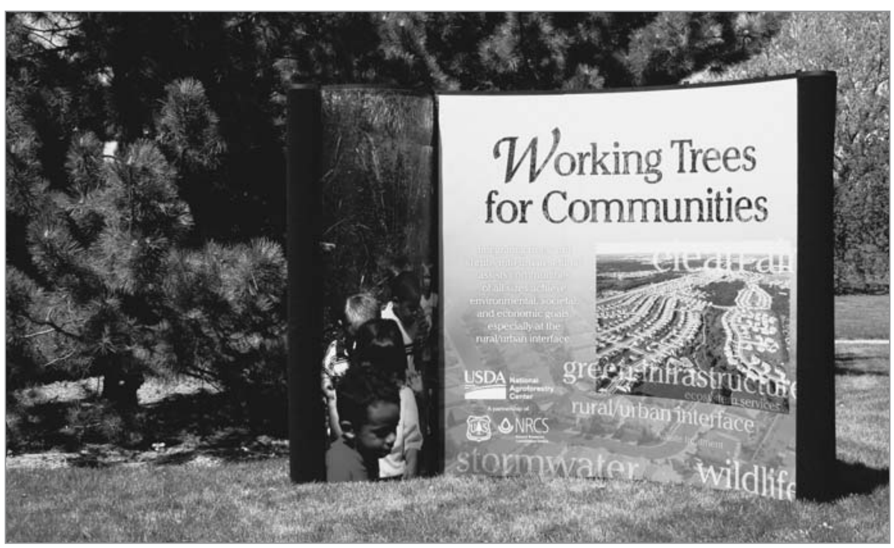
Back to the future

In the search for a more sustainable approach to supplying our nation's future energy needs we have come full circle and are again looking at wood as an essential part of the solution. Rapidly growing tree and shrub types can be grown in ways that maximize the production of woody biomass which can then be harvested and converted to biofuels. Wood, with its high cellulose and hemi-cellulose content, has a high weight to energy conversion ratio that greatly exceeds that of ethanol produced from corn grain. Existing biochemical and/or thermochemical processes can be used to convert wood into bio-oil, ethanol, and syngas products.

The US Department of Energy has recently increased research funding on cellulose conversion technology to improve conversion efficiency, reduce costs, and scale up production levels. Forestry research over the past few decades has led to substantial increases in biomass yield for tree species like aspen, cottonwood, sweetgum, and willow. However, a corresponding effort is still needed to develop woody biomass production systems that are sustainable and that also factor in ways to protect soil fertility and provide wildlife habitat at the landscape level. These production systems also need to minimize unintended negative off-site impacts that are often associated with intensive agriculture, like soil erosion and nutrient runoff. The opportunity to grow trees and shrubs as an energy crop will occur both on lands that are currently forested and on those that are now used for agriculture. As such, it will be important to integrate the production of woody biomass crops with our nation's Farm Bill programs.

Need help marketing *Working Trees*?

Set up an 8′ X 10′ *Working Trees* display at your next workshop, conference, or even at the post office. Using one of NAC's six displays, and the accompanying brochures, is a sure way to start conversations about the benefits of agroforestry. NAC ships displays free of charge; the only cost you incur is return shipping to NAC or to the next user. Visit NAC's website for additional photos, information about how to reserve a display for your event, and to order free supplemental *Working Trees* brochures: *www.unl.edu/nac.*



Working Trees displays for six topic areas are available: agriculture, communities (pictured), water quality, wildlife, livestock, and treating waste. *NAC file photo*

Short rotation woody crops, like hybrid poplar and willow, can grow 15 to 25 feet in only three years. *NAC file photo*

Woodys have biomass potential

Perennial woody crops have the potential to contribute significantly to the production of bio-fuels while at the same time provide a wide range of conservation benefits.

Biomass currently provides about 10 percent of the global energy supply. Developing sustainable approaches to producing renewable biomass crops that help meet our nation's energy needs is an emerging critical challenge. Perennial plants have the potential to provide large quantities of biofuel feedstock, while also providing an array of ecological services and revitalizing declining rural economics.

With a relatively fixed land base, the production of energy crops will compete with traditional agricultural and forestry uses of land. Agriculture and forestry must work together to create integrated biomass production systems.

Agriculture today

Agriculture in the United States is highly mechanized and uses considerable fertilizer and pesticide inputs. The agricultural sector is increasingly vertically integrated and in any given year only a few varieties of corn or soybeans are planted. The downside of our industrial agricultural approach has been the loss of most ecological services across the landscape. The massive spatial scale for cropping and the uniform vegetation provides little opportunity for species diversity and only minimal structural diversity across the landscape. Conservation challenges include managing soil erosion, concentrated livestock waste, runoff of fertilizers and pesticides into surface water and groundwater with substantial downstream impacts.

Conservation benefits of trees on agricultural land

Agroforestry practices that incorporate trees into working agricultural lands have been used in the US since the time when windbreaks were employed to abate soil erosion in the "dust bowl" of the 1930's. In the past 15 years, the interest in and adoption of agroforestry practices have

see **Potential** on page 11

BIG SAVINGS

Whatever the type of farm, there are ways to reduce costs by integrating energy efficient improvements into the operation. Renewable energy adjustments will not only save producers money, but will cut input costs, maintain production, protect soil and water resources, and reduce the negative effects of burning fossil fuels.

There are several ways to incorporate energy-saving strategies:

- Utilize existing on-farm energy by taking advantage of home-based fuels
- Produce and sell energy generated on the farm, and
- Conserve energy

The Natural Resources Conservation Service (NRCS) has developed four tools to help a producer identify where energy costs can be cut. The tools enable the user to calculate potential cost savings for animal housing, irrigation, nitrogen, and tillage. Visit www.nrcs.usda.gov/technical/energy/index.html to access this service.

up to **$1 off** per acre...

...and another $35 in reduced harvest costs by adopting management intensive grazing practices. Cattle maintain or gain an average of 30 pounds when sheltered from harsh winter winds by windbreaks.

up to **$60 off** per acre

Reduce corn fertilizer costs up to $60 per acre by using manure instead of petroleum-based fertilizers. Doubling the use of manure-based nitrogen nationwide could save up to $825 million annually.

All savings expressed in annual amounts

up to

3½

gallons of fuel per acre

Save up to 3½ gallons of fuel per acre by using a no-till system (versus conventional tillage). Doubling no-till acreage (from 62 to 124 million acres nationwide) could save an additional 217 million gallons of diesel fuel and $500 million each year.

Cutworm illustration courtesy FCIT

up to

$2,200 off

on 3,000 acres

Better manage pesticide applications through precision agriculture. Pay for the cost of a basic "auto-steer" guidance system in two years by saving $2,200 in pesticide costs per year on 3,000 acres of cropland. Scouting, spot spraying, and integrated pest management can help realize siginificant savings in pesticide application costs.

up to

20% off

home energy bills

Plant windbreaks to help reduce heating and cooling costs. Individual savings depend on local site and climactic conditions, construction quality of the home, owner living habits, and design and condition of the windbreak.

up to

$66 off

per acre

- Move to a low-pressure irrigation system to save $15 per acre for medium-pressure systems and $66 per acre for high-pressure systems, a potential natiownide savings of over $100 million each year.
- Replace old or inefficient irrigation pumps to achieve a 10 percent improved water use efficiency to reduce diesel consumption by 8 gallons per acre, saving about $18,500 on 1,000 acres. This adds up to a nationwide savings of 27 million gallons of diesel and $55 million annually.
- Windbreaks improve water use efficiency by up to 10 percent by reducing the wind velocity blowing across the crop.

BIOENERG

by Kimbe

Agricultural and forest crops and residues as well as industrial and municipal residues can be used to provide heat, generate electricity, and make fuels, chemicals, and other products. These "biomass" materials are feedstocks that can be converted to energy products through various chemical and physical processes and can help address US energy needs.

In general, there are two approaches to generating energy from organic material:

1. Grow plants specifically for energy use.
2. Use the residue from plants that are harvested and processed for other purposes.

The production of sustainable energy from farm and forestry activities may not change what is grown as much as how crops are marketed and processed. Each biomass material has different characteristics that require different processing methods to convert it to energy. For example, biomass low in ash content and high in lignin is best utilized in co-firing, whereas high sugar composition feedstocks are more efficiently converted to ethanol.

Feedstock

Generating energy begins with "feedstock," or a raw material. The term "biomass" refers to all plant and plant-derived material (organic matter). In the US, biomass feedstocks primarily consist of forest, mill, agricultural residues, urban wood wastes, and dedicated energy crops. Industrial residues such as black liquor from wood pulping and animal manures are also considered biomass resources. Generally, feedstocks can be classified into three categories: **oil crops**, **starch and sugar crops**, and **cellulosic crops**.

Processes

Three primary non-combustion methods convert biomass into energy. These processes convert raw biomass into a variety of gaseous, liquid, or solid fuels.

Products

Oil crops

Oils from some crops, like soybeans and rapeseed, can be used to make fuel for engines. However, these annual crops require intensive management and energy inputs that may not be sustainable in the longer term.

Chemical

Crop oils can be chemically treated to separate out the glycerin component leaving behind methyl esters, what we call biodiesel. Other gasoline additives can also be created.

Biodiesel

Biodiesel can be used pure or mixed with diesel (commonly 20 percent) to help reduce petroleum demand.

Starch and sugar crops

Starches and sugars from crops such as corn or sugar cane can be converted into ethanol. Today, much of the biomass ethanol in the US comes from corn.

Biochemical

Bacteria, yeasts, and enzymes break down the carbohydrates such as starch, cellulose, or hemicellulose. Then the fermentation process converts the resulting sugar into a biomass liquid, grain alcohol, or ethanol, which is a combustible fuel. When bacteria break down biomass, methane and carbon dioxide are also produced. The methane can be captured and burned for heat and power.

Ethanol

Ethanol is combined with gasoline – either 10 percent (E10) or 85 percent (E85) – and is sold as gasohol.

Both biodiesel and gasohol have environmental advantages over purely petroleum-based gasoline and diesel fuel. Blends increase octane levels and promote more complete fuel burning which reduces harmful tailpipe emissions such as carbon monoxide and hydrocarbons.

Availability

The ability to cost-effectively convert woody biomass into energy presents many challenges. Availability, collection (harvest), and storage are all issues that will need to be addressed. Transportation economics may be the overriding factor since raw biomass typically can't be cost-effectively shipped more than about 50 miles for energy conversion.

What's ahead?

In the United States, biomass already provides about 1.2 percent of our nation's total electric sales. We also get about two percent of the liquid fuel used in cars and trucks from biomass.

- **Present and near future:** Easily processed agricultural crops and low-cost industrial residues will likely dominate biomass feedstocks.
- **Mid-term:** Agricultural and forestry residues should enable the biomass industry to expand to make more substantial contributions.
- **Future:** Ongoing research is discovering new ways to replace petroleum-based energy, chemicals, and products with bio-based equivalents.

Cellulosic crops

Herbaceous crops (grasses)

Switchgrass, big bluestem, and other native grasses grow quickly in many parts of the country and can be harvested for up to 10 years before replanting is necessary. In tropical and subtropical climates grasses like elephant grass can also be grown as a source of cellulosic energy.

Agricultural residue

After crops have been harvested, the residue left in the field can be collected and used as a cellulosic energy source. Removing too much agricultural residue, however, can significantly reduce soil quality.

Forestry residue

After trees are harvested from a forest or plantation the portions of the trees that are of poor quality or too small to process are left behind. This material, often referred to as slash, can be utilized as a cellulosic energy source.

Short rotation woody crops (SRWC)

Fast growing trees and shrubs, called short rotation woody crops (SRWC) are grown to harvest at frequent intervals as a source of cellulosic energy. In addition to growing fast, SRWC trees will grow back after being cut, "coppicing." Coppicing allows trees to be harvested every three to eight years for 20 or 30 years before replanting. Willows and poplar species along with other regionally-specific SRWCs are currently being studied as a source of energy.

Thermochemical

When plant matter is heated, but not burned, in the absence of oxygen, it breaks down into various gases, liquids, and solids. These products can then be further processed and refined into useful fuels such as methane and alcohol. Biomass gasifiers capture the methane released from the plants and burn it in a gas turbine to produce electricity.

Pyrolysis

Bio-oil

Gasification

Syngas

For information on these thermochemical processes and the products they yield, see "From Wood To Fuel," page 8)

Combustion / co-firing

The traditional way to convert biomass to energy is simply to burn it (combustion) to produce heat. Worldwide, this is still how most biomass is utilized. An approach that is driving the use of biomass energy is to mix it with coal in power plants – a process known as co-firing. Biomass feedstock can be a substitute for up to 20 percent of the coal used in a boiler system or to generate electricity. Co-firing is also one of the more economically viable ways to increase biomass power generation today.

Heat

FROM WOOD TO FUEL

Thomas Elder
Research Forest Products Technologist
USDA FS Southern Research Station
Pineville, LA

Biomass is an attractive alternative to fossil fuel energy sources because it is carbon neutral and renewable. Presently, biomass supplies about 2.9 quadrillion BTUs or 3 percent of the total energy consumption of the United States. Over half of this supply is derived from woody material through combustion of spent pulping liquors and mill residues. While direct combustion is the most thermodynamically efficient way to recover energy from any material, it is limited because the energy can't be stored and must therefore either be used on site or converted into another form such as steam or electricity. Alternative approaches that may provide more flexible sources of fuels from woody biomass include biochemical and thermochemical processes.

New technology makes it possible to create efficient fuels from wood that can be transported easily.

Biochemical

The most familiar biochemically-produced alternative fuel is ethanol. Ethanol is primarily derived from a process that involves the fermentation of sugars by yeast. Today, domestic ethanol is prepared mainly from the starch in corn kernels, while sugar cane is used in Brazil. Corn leaves and stalks, referred to as corn stover, is also a possibility with their processing to follow the same conversion pathways as other lignocellulosics, like woody biomass, described below.

Woody biomass is primarily composed of cellulose and hemicellulose. It contains some sugars, in the form of long-chain polysaccharides that must first be broken down into simple sugars prior to fermentation. This limitation accounts for the relative efficiency difference of about 60 gallons per ton and 90 gallons per ton for wood and corn, respectively. This discrepancy notwithstanding, when other monetary inputs of growing corn (fertilizer, herbicides, pesticides) are taken into account, the economic competitiveness of wood ethanol grows more attractive. The processes necessary to convert lignocellulosics, such as wood and switchgrass, are still being developed and have not yet been scaled up to produce commercial quantities.

Thermochemical

The primary thermochemical methods for processing wood are pyrolysis and gasification. Both use high temperatures with limited amounts of air to produce varying proportions of solid, liquid, and gaseous products.

- **Pyrolysis** – takes place at about 500°C (932 F). The principal product is a liquid, called pyrolysis oil or bio-oil. This oil is a complex mixture of chemical components that is corrosive and generally needs to be processed further. The process is similar to how petroleum oils are refined. The oil has also been evaluated as a source of chemicals that can be used to produce adhesives.

- **Gasification** – requires high temperatures, 800-900°C (1500-1600 F), and the main product is a low BTU gas, referred to as syngas. Syngas is a mixture of carbon monoxide, carbon dioxide,

see **Potential** on page 10

Environmental benefits of biomass energy

Woody biomass is a more sustainable energy source than that derived from fossil fuels or annual crops.

Fossil fuel is a limited resource whereas woody biomass can be grown again.

Annual crops require higher inputs than perennial woody biomass.

Improve air quality. Woody biomass recycles carbon out of the air and releases it again and is carbon neutral, unlike fossil fuels.

Reduce water pollution. Fewer fertilizers and pesticides are used to grow woody energy crops. Less nutrient-laden runoff from fields keeps our streams cleaner.

Improve soil quality. High-yield food crops tend to pull nutrients from the soil, whereas perennial crops actually improve soil quality. Trees and grasses with deep roots build up topsoil, and put nitrogen and other nutrients into the ground.

Reduce soil erosion. Perennial biomass plants (i.e. trees and grasses) are replanted only every 10 years resulting in less soil disturbance.

Improve wildlife habitat. Woody crops create better wildlife habitat than food crops. Since many species are native plants, they attract a greater variety of birds and small mammals. They improve habitat for fish by increasing water quality in nearby streams and ponds. Flexible harvest schedules make it easier to avoid disturbing wildlife during critical nesting seasons.

NACD digs up "The Hidden Treasure"

Money may not grow on trees, but heat, electricity, liquid fuel, and even plastics do. Children can learn how, with the release of *The Hidden Treasure*, an educational comic book from the National Association of Conservation Districts (NACD). This new teaching tool shows young people and families how woody biomass from our nation's woodlands can provide a wealth of products and energy resources. The book can be previewed at www.discoverycomics.com/review/TheHiddenTreasure.pdf (6.3 MB). Order copies in quantities of 100 (min: 500; max: 2,000) by contacting Nancy Hammond: nhammond@fs.fed.us, fax 402–437–5712, http://www.unl.edu/nac/order.htm.

Timberbelts

Timberbelts are multiple-row field windbreaks that are planted with commercially valuable, fast-growing trees like hybrid poplar or hybrid willow. Timberbelts provide the conservation benefits of a properly designed windbreak but also produce commercially valuable wood products.

The strategy is to harvest half of the timberbelt rows at age 7-12, leaving the other half to provide continued wind protection. Within a few years the stumps will have sprouted and re-established to provide sufficient wind protection at which time the remaining rows can be harvested. This provides continuous wind protection and allows a landowner to reap the associated economic benefits for the adjacent crops.

Hybrid poplar yielded 5 dry tons/acre/year, a reasonable national average, in north central United States and has reached 7 dry tons/acre/year on high-productivity sites. There are approximately 38 million acres of Conservation Reserve Program (CRP) lands; if these acres were planted to hybrid poplar, annual production could reach 16 million BTU's per dry ton/year, that is equivalent to 3,040 trillion BTUs (3 quads)/year.

Short rotation woody crops can contribute significantly to the Nation's energy fuels. An added benefit would be the reinvigoration of rural economies, while producing substantial levels of ecological services.

Short rotation woody crops can be harvested and chipped on site then burned for heating. The cut stumps will resprout for another crop. *NAC file photos*

Conversion

continued from page 8

hydrogen, water, and methane that can be used in internal combustion engines. These compounds can also be readily converted to numerous products, including hydrogen, methanol, ethanol, and liquid fuels. Liquid fuels, such as gasoline and diesel, are made from syngas through an additional process. This product is not the same as bio-diesel, which comes from the chemical reaction of vegetable or animal oils with methanol.

There are several good resources available for more information on converting woody biomass to an energy source:

- Thermal energy, electricity and transportation fuels from wood by John I. Zerbe. Forest Products Journal 56(1):6-14. 2006.
- Biomass as a feedstock for a bioenergy and bioproducts industry: The technical feasibility of a billion-ton annual supply. Perlack, R.D., L.L. Wright, A.F. Turhollow, R.L. Graham, B.J. Stokes and D.C. Erbach. 2005. DOE/GO-102995-2135 ORNL/TM-2005/66.
- Preliminary screening-Technical and economic assessment of synthesis gas to fuels and chemicals with emphasis on the potential for biomass-derived syngas. Spath, P.L. and D.C. Dayton. 2003. National Renewable Energy Laboratory NREL/TP-510-34929.

Integrating both biochemical and thermochemical processes into one biorefinery, a single facility where biomass could be converted to either ethanol or syngas would allow the residuals from the ethanol stage to be further utilized in the thermochemical platform. This is similar to existing petroleum refineries, in that several energy products are made, along with numerous value-added products, maximizing the value of each.

There are various methods that convert energy stored in biomass into forms that can be used for transportation or industrial fuels. The products from these transformations can also be used to replace products currently derived from petrochemicals. The advantages of biomass are well-documented with respect to its renewable nature and environmental benefits. As such, woody biomass has the potential to be scaled up commercially to make a significant contribution to the energy independence of the United States.

Potential

continued from page 3

increased dramatically. The primary reasons for this expanded interest have been for economic diversification and conservation benefits. Trees introduce both vertical and horizontal structural variation in agricultural landscapes. Agroforestry adds plant and animal biodiversity to the landscape that might otherwise contain only monocultures of agricultural crops. Agroforestry can serve to connect forest fragments and other critical habitats in the landscape.

Short rotation woody crops can be incorporated into agroforestry practices like windbreaks and riparian forest buffers or grown as part of a tree plantation. *NAC file photo*

Perennial systems for biofuel production and their conservation benefits

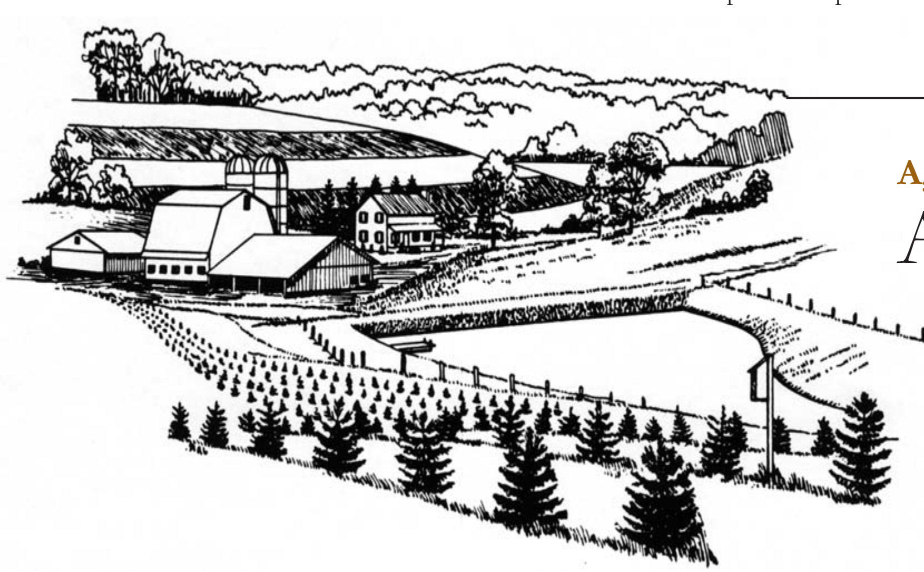
Several woody perennial species can be grown for bio-fuels, while at the same time provide conservation benefits and ecological services that markedly exceed those associated with conventional annual crops like corn. In the United States most research has focused on willow shrubs and hybrid poplar production systems.

- **Willow** – High yields, ease of propagation, broad genetic base, short breeding cycle, and ability to resprout after multiple harvests make willow ideal. Yields of fertilized and irrigated willow grown in three-year rotations have exceeded 10.8 dry tons/acre/year.
- **Hybrid poplar** – Genetically improved cottonwoods and interspecific hybrids have been selected for fast growth. A 5 dry tons/acre/year yield represents a reasonable national average.

Research needs

Although several production systems have already been devised for hybrid poplar and willows, more research is needed to improve the efficiencies and sustainability of these perennial systems. A better understanding is needed of how to manipulate the plant's natural production of specific components already found in the crop such as cellulose, hemicellulose, and lignin to increase energy yields and reduce conversion costs. These efforts will need to be jointly pursued by the forestry and agricultural sectors with an understanding of the barriers and challenges impacting land availability, producer adoption, and key issues surrounding soil sustainability.

Adapted from: Perennial crops for biofuels and conservation*, by Gregory Ruark, Scott Josiah, Don Riemenschneider, and Timothy Volk.*



Agricultural energy

Agricultural lands can provide nearly 1 billion dry tons of sustainably collectable biomass and still continue to meet food, feed, and export demands.

This estimate includes 446 million dry tons of crop residues, 377 million dry tons of perennial crops, 87 million dry tons of grains used for biofuels, and 87 million dry tons of animal manures, process residues, and other residues generated in the consumption of food products.

Upcoming Events

February 4–8, 2007
Sixty-First Annual Meeting Of The National Association Of Conservation Districts (NACD): "Power Of Conservation." Los Angeles, CA. Contact: 202–547-6223, *2007@nacdnet.org*, *http://2007.nacdnet.org*.

February 27, 2007
Ecosystem Service Markets: Everyone's Business. Houston, TX. Contact: Jan Davis, 979–458–6630, *jdavis@tfs.tamu.edu*, or Dr. Neal Wilkins, 979–845–7726, *nwilkins@tamu.edu*, *http://tfsregister.tamu.edu*.

April 9–12, 2007
Emerging Issues Along Rural/Urban Interfaces II. Atlanta, GA. Contact: Dr. David Laband, 334–844–1074, *labandn@auburn.edu*, *www.sfws.auburn.edu/urbanruralinterfaces/*.

June 10–13, 2007
Tenth North American Agroforestry Conference. Québec, Canada. Contact: *info@agrofor2007.ca*, *www.agrofor2007.ca*.

For more upcoming events, visit our website calendar: *www.unl.edu/nac/calendar.htm*.

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www.unl.edu/nac

Mission

The USDA National Agroforestry Center (NAC) is a partnership of the Forest Service (Research and Development and State and Private Forestry) and the Natural Resources Conservation Service. It is administered by the Forest Service, Southern Research Station; and its program manager and headquarters are located in Huntsville, AL, on the campus of Alabama A&M University, while NAC's staff are located at the University of Nebraska, Lincoln NE; University of Idaho, Moscow ID, and in Blacksburg, VA. NAC's purpose is to accelerate the development and application of agroforestry technologies to attain more economically, environmentally, and socially sustainable land use systems. To accomplish its mission, NAC interacts with a national network of partners and cooperators to conduct research, develop technologies and tools, establish demonstrations, and provide useful information to natural resource professionals.

Policy

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