Biofuels and Water Quality

Meeting the Challenge & Protecting the Environment

Photo by USDA NRCS

Introduction

A number of initiatives by state and federal government are setting goals for replacement of petroleum-based fuels with bio-based alternatives. The President proposed a national goal of reducing gasoline usage by 20 percent in the next ten years (the Twenty in Ten initiative) in his 2007 State of the Union address. Achieving these results would increase the alternate and renewable fuels goal to 35 billion gallons by 2017 (nearly five times the 2012 current target now in the 2005 Energy Policy Act). The Renewable Fuels Association (RFA), the national trade association of the U. S. ethanol industry, is promoting the 25x25 initiative to achieve 25 percent of U.S. energy from renewable resources like wind, solar, and biofuels by 2025.

From an economic perspective, it makes sense to produce agricultural-based biofuels close to the centers of demand. Thus, the Mid-Atlantic region is seeing a growing interest in production facilities for biofuels. There are about 15 ethanol facilities under construction or planned for the region. Collectively, they will have the capacity to produce about one billion gallons of ethanol per year using corn grain as the primary feedstock. To meet this demand, would require about 370 million bushels of corn per year -- more than 1.5 times the current regional production of corn.

Several biodiesel production plants using waste vegetable oils, soybean oil, animal fats and other opportunity feedstocks are also planned. Biodiesel capacity is growing steadily, but much more slowly than ethanol.

On April 4-5, 2007, the USDA-CSREES Mid-Atlantic Regional Water Program, the Chesapeake Bay Foundation, and the USDA-ARS Beltsville Agricultural Research Center convened a Biofuels and Water Quality Conference. The start of the Conference coincided with the USDA's Prospective Plantings Report; US farmers intend to plant 12 million more acres of corn than in 2006. To put things into perspective, the entire landmass of the State of Maryland is about 6.2 million acres.

The Conference was convened to identify and discuss the impacts, particularly to water quality, from growing and using agricultural-based feedstocks for biofuels production. For ethanol, the current feedstock of choice is corn grain but as cellulosics technologies are developed, feedstock preferences may evolve. Other potential biofuel technologies from gasification to pyrolysis, were also discussed. Feedstocks for these technologies could include agricultural biomass as well as manures and a broad range of urban generated wastes. This document summarizes the findings and recommendations from this two day conference. Research, programmatic and policy agendas for renewable fuels are also outlined.

The Demand for More Corn Production

Corn constitutes about 90% of the feedstock for ethanol production nationwide. The other 10% is composed of other grains such as sorghum, barley and wheat. Corn is used because the operational technologies for using corn grain are proven, fermentation of starches is relatively easy, and feedstock production, storage and handling capabilities are already in place.

For the last several decades, corn prices have been typically \$2.00-\$2.50/bushel. The rate of production has increased so rapidly that estimates of production and impacts on grain use have been revised upward monthly. Corn futures prices in

Photo by USDA NRCS

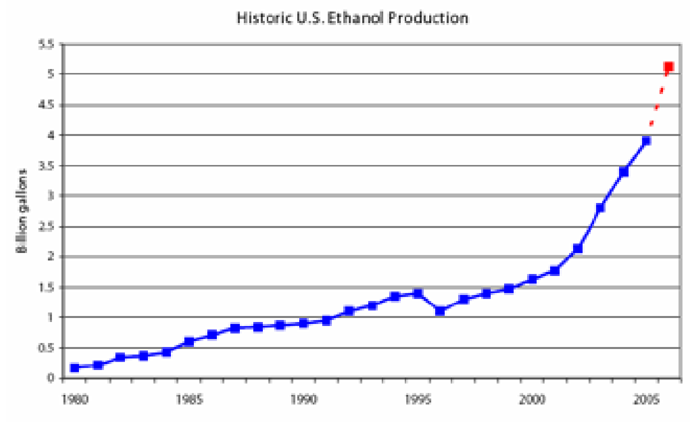
February 2007 were hovering around $4/bushel for Fall 2007 delivery, but are currently in the $3.65-$3.75 range. Corn prices received by farmers have not reached $3/bushel at any time during the past 10 years. The rapid growth in corn demand and prices is a result of increased ethanol production, which is projected to rise to at least 7.3 billion gallons in 2007. In response to the increased demand and price per bushel of corn, more acres are expected to be planted nationwide, as well as in the Chesapeake Bay watershed.

Regional Water Quality

A reasonable estimate of additional corn planted in the Chesapeake Bay watershed is between 500,000 and 1 million acres over the next several years. Increased corn acreage in the Chesapeake watershed will result in increased N fertilizer use and losses to the environment, even under relatively well-managed rotations.

A substantial part of the increased corn acreage will result from continuous corn replacing soybeans in corn-soybean rotations. Corn is an inherently inefficient N user, and N loads from corn-dominated landscapes are typically 20 to 40 lbs/ac (depending upon management and physical factors), the highest loss of any major crop. Nitrogen loss in soybeans is somewhat less (15-30 lbs/ac).

High corn prices provide a disincentive for cropland retirement or conversion to perennial crops. Hence the demand for corn to support ethanol production may reduce acreage in the



Source: Data from Renewable Fuels Association. 2006 figure is U.S. ethanol production capacity as of November 30, 2006.

Conservation Reserve Program and perennial crops and make future conversions to these uses less likely and more expensive.

The following tables estimate the potential impact of these additional corn acreages, assuming that 30% of cotton and soybean acres, 15% of dry hay acres, and 10% of Conservation Reserve Program (CRP) acres within current corn production counties in the watershed would be converted.

Potential net increased N losses, accounting for forgone N losses on the cropland converted to corn, are estimated to be between 8.0 and 16.0 million pounds for the Bay Region, depending on the amount of corn planted. This estimate indicates the importance of nutrient management education so that corn producers practice careful nutrient management and conservation practices to minimize increases in nutrient loadings to water bodies. To put this number in perspective, the Bay states have agreed to a 110 million pound reduction in annual loads of N in order to restore water quality to the Bay and its tidal tributaries.

Additional N loads could be further exacerbated by the practice of adding more fertilizer to increase corn yields. With higher corn prices, both the economic optimum yield and N fertilization rate are increased, and farmers can afford additional inputs that provide small incremental yield increases. As a result, there is a reduced incentive to apply N at rates recommended in nutrient management plans. Increased intensity of grain production will require accelerated and comprehensive implementation of conservation practices just to minimize increases in nutrient losses.

Table 1: Potential N Losses from New Corn Acres in VA, MD, DE, PA, and NY

Cropping Changes	Expected N Loss (lbs/ac)	500,000 Acres		1 Million Acres	
		Acreage ('000)	Increased N Loss (m. lbs)	Acreage ('000)	Increased N Loss (m. lbs)
New Corn Acres	30	500	+ 15.0	1,000	+ 30.0
Soybeans	22.5	236	- 5.3	472	- 10.6
Cotton	14.25	11	- 0.15	22	- 0.3
CRP	3	16	- 0.05	32	- 0.1
Hay	6	250	- 1.5	500	- 3.0
Potential N Loss Increase (m. lbs)			+ 8.0		+ 16.0

Table 2: Potential P Losses from New Corn Acres in VA, MD, DE, PA, and NY

Cropping Changes	Expected P Loss (lbs/ac)	500,000 Acres		1 Million Acres	
		Acreage ('000)	Increased P Loss (m. lbs)	Acreage ('000)	Increased P Loss (m. lbs)
New Corn Acres	4	500	+ 2.0	1,000	+ 4.0
Soybeans	4	236	- 0.944	472	- 1.888
Cotton	4	11	- 0.044	22	- 0.088
CRP	0.75	16	- 0.012	32	- 0.024
Hay	0.75	250	- 0.188	500	- 0.375
Potential P Loss Increase (m. lbs)			+ 0.812		+ 1.625

Increased corn acreage will also impact phosphorus (P) losses. Using the same land conversion assumptions as above and assuming that P losses are similar between corn and soybeans, half the converted land is estimated to have no change in P loss. The conversion of CRP, idle land, pasture or hay will result in major increases in P losses due to increased fertilizer application, runoff, and erosion. Estimates of 3 to 5 lbs/ac are typical for corn or soybeans, whereas losses from CRP, idle land, pasture or hay are typically less than 1 lb/ac.

Increases in corn production of 500,000 or 1,000,000 acres are estimated to result in increased phosphorus losses of 0.8 and 1.6 million pounds per year, respectively, if cultural practices do not change (see Table 2). The conversion of corn-soybean rotations to continuous corn will likely necessitate increased tillage to incorporate residue which would result in greater phosphorus losses per acre.

Livestock Producers and Manure Management

While some crop farmers in the Chesapeake Bay watershed will benefit from high corn prices, many other farmers in the region will face serious economic consequences. Even before the ethanol boom, most of the watershed's livestock farmers depended on corn imported from the Midwest for feed. Current and planned corn-based ethanol refineries will result in many Corn Belt States becoming corn importers, rather than corn exporters in the near future, unless corn acreage is expanded substantially. Short-term, higher corn prices will mean higher profits for corn producers but will simultaneously increase grain costs for animal producers. Due to such a re-shifting of the rural economy, economists are unable to predict long-term effects.

The concentration of grain-based ethanol production will create areas of nutrient surpluses around production facilities and may cause state or regional imbalances. Corn grain ethanol production throughout the U.S. and in the region will increase the availability of the byproduct Dried Distillers Grains and Solubles (DDGS). DDGS are the dry matter that is left over after the fermentation process.

To offset this corn grain deficit, the availability and relatively low price of DDGS may drive many livestock producers to use DDGS as a feed ration alternative. Because much of the feedstock starch has been converted to ethanol, DDGS have approximately three times more N and P than corn by dry weight. DDGS are a relatively high protein substitute in livestock rations.

This animal feedstock is currently most appropriate for ruminant livestock rations. The five states in the Mid-Atlantic are home to nearly 1.5 million dairy cows and 1 million beef cows. At the maximum 20% of ration dry matter content from DDGS, potential consumption of DDGS by

Photo by USDA CSREES

the cattle industries in these states could exceed 5 million tons. At this rate, a combination of replacement of soybean meal, corn and corn silage with DDGS could result in an additional 10 grams of P fed per cow per day. For 2.5 million cattle this equates to about 500,000 lbs of additional P in manure.

Table 3: Impact of DDGS on Phosphorus in Total Ration

Phosphorus contained in one pound of feed dry matter	
	P, grams
DDGS (.74% P)	3.36
Soybean meal (.71% P)	3.22
Corn (.3% P)	1.36
Corn silage (.25% P)	1.12

Producers implementing nutrient management plans (particularly P-based plans) will need to balance feed economics with nutrient management considerations. Nitrogen concentrations in dairy cattle diets high in DDGS may also increase nitrogen content in manure. In addition, as N concentrations increase in manure, subsequent loss via volatilization also increases.

Selling wet distiller's grain results in major cost savings in the natural gas used for drying, but it requires co-location of animal production facilities with ethanol biorefineries to minimize transport cost. There is interest in opening or expanding dairies or feed lots around ethanol facilities. Co-location has significant environmental implications. Large quantities of manure would be generated around a production facility. It is unclear how manures from such co-located facilities would be processed and/or transported to avoid over application on local cropland. Co-location of animal production facilities near ethanol facilities will add to difficulties in addressing the local nutrient imbalances by converting more marketable and transportable manures. Increased DDGS use is likely in the Mid-Atlantic and animal nutritionists are concerned it will offset reductions in manure nutrient content already achieved through feed management. While DDGS are currently used primarily in dairy and beef rations, there is interest in using them in poultry and swine rations to offset high feed grain prices. This would offset phosphorus reductions achieved through poultry feed management through use of the enzyme phytase. DDGS could result in even higher phosphorus content in poultry litter than before phytase since the phosphorus in the DDGS is already highly bio-available.

The Future of Ethanol Production in Cellulosics

Cellulosic ethanol produced from perennial grasses, fast-growing woody species, manures and other wastes could allow the U.S. to meet renewable transportation fuel goals while improving water quality. The rapid expansion

Hulless Barley

Another feedstock of interest for ethanol is barley. Barley can be planted in the fall and grown over the winter and early spring to fit into a popular crop rotation with corn and soybeans. Furthermore, researchers at Virginia Tech recently developed new, winter-grown, hulless varieties of the grain that are easier to mill and appear to be well suited to ethanol production. Preliminary studies suggest the new barley could be grown without fertilization in the fall and winter when most water-polluting nitrogen leaching occurs, and still produce a profitable crop so long as the state maintains its cover crop payments. Because the crop could be sold rather than plowed under, more farmers might plant cover crops, thus reducing the amount of nitrogen reaching the Bay.

Corn "Stover", Photo by USDA NRCS

Switchgrass, Photo by USDA CSREES

of grain-based ethanol products, however, may be a disincentive to development of perennial crops or waste-based ethanol. The technology to produce ethanol from cellulosic materials is rapidly improving but not yet commercially viable in the U.S. The production, storage and handling infrastructure is in place for grain but not for perennial crops or waste. Cellulosic material is harder to handle and assurance of an adequate supply is difficult, with one exception, corn crop residues known as "stover".

Crop residues represent the largest source of potential feedstock for cellulosic ethanol without raising soil losses above "tolerable levels". However, "tolerable" soil loss levels imply substantial increases in erosion and associated N and P losses compared to current conservation or no-till production. The second concern with widespread harvest of corn residue is the impact on soil organic matter and soil quality. Returning corn residue to the soil is critical to slowing the decline of soil organic matter levels associated with tillage and long-term row crop production. Harvesting residue will accelerate reductions in soil organic matter content, which will likely reduce productivity and increase runoff and thereby increase N and P losses in the long term.

Perennial grasses, particularly switchgrass and high biomass producing trees, are currently considered the most promising energy crops. There is considerable interest in switchgrass, which offers clear environmental benefits over a corn grain-stover energy strategy, but it has not realized its potential as a feedstock for ethanol. In part, this is due to the lack of efficient fermentation technologies, but even if cellulosic technology is developed, substantial infrastructure impediments must be overcome.

Creating a future for perennial biomass:

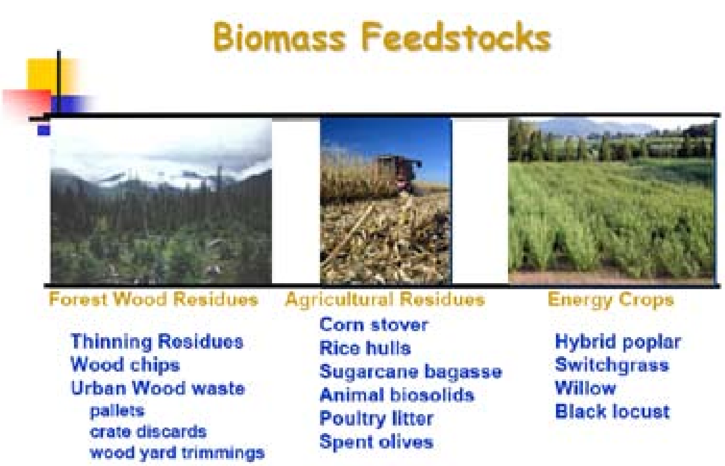
It is currently not in the farmer's economic self interest to grow biomass rather than grain. Technologies, infrastructure and markets must be developed and coordinated for biomass. However, sufficient biomass production must be in place to meet expected market demand. A "chicken or egg" dilemma faces the emerging industry.

Since the biofuels conference, scientists and economists in the Mid-West and Mid-Atlantic have been discussing policy options to create incentives for perennial, warm season grass, such as switchgrass, production and cellulosic technology innovation. A "Biomass Reserve Program" (BRP), comparable to the Conservation Reserve Program, has been suggested. This would pay farmers land rental-like incentives to enter into 10 year contracts to grow perennial, warm season grasses. The grasses would be fertilized under a nutrient management plan and could be harvested for biomass.

Concurrently, a "Biomass Innovation Grant" (BIG) program, comparable to Conservation Innovation Grants would be established to provide funds to advance production, management, harvesting, storage, handling and energy conversion of warm season perennial grasses. The BRP would assure a ready supply of biomass once markets develop and would foster farmer and investor confidence that cellulosic energy conversion would be viable throughout the life of the BRP contract.

Two growing seasons without harvesting are required to establish switchgrass, but replanting is then not necessary for up to 20 years. Either an incentive program or a subsidy is needed to compensate the farmer during the two-year transition. Because of its conservation and water quality benefits, this could be done through federal conservation programs or it could be part of prorated payments to the farmer by the ethanol facilities under a long-term contract for switchgrass produced. A second obstacle is that most grain farmers do not have the equipment to harvest, handle and store switchgrass. Further, there is not currently the transport and storage infrastructure needed to handle the large quantities of materials for an ethanol facility. It would be necessary to grow 50,000 to 100,000 acres of switchgrass within a reasonable transport distance of a production facility using only switchgrass. Switchgrass requires some N and P for optimal production, but the perennial crop requires far less N than corn, and generally requires little P.

Despite the obstacles discussed above, potential economic and environmental benefits are sufficient that perennial grasses are still considered a likely long-term energy crop. Switchgrass is less expensive to produce and provides a greater net energy return than corn. The fermentation co-product is a ligno-cellulosic material that can be dried and burned to provide part of the energy for the facility with net positive energy returns. It is very low in nutrients, is not suited as a feed amendment, and poses little threat to water quality. Switchgrass can be grown on marginal lands or as a buffer. In this situation, it does not compete for acreage for feed grain production. If it is grown instead of corn on productive soils, N and P losses will be reduced by more than 75%. Switchgrass will also sequester carbon, increase soil organic matter and improve soil quality through its extensive, deep root system.



These positive environmental attributes have substantial potential to provide multiple revenue streams. Lower production cost, greater net energy production, multiple revenue streams and environmental benefits of switchgrass all favor its long-term use as a dedicated energy crop. However, the lag in development of fermentation technology and the lack of existing infrastructure prevent it from becoming a major ethanol feedstock for the foreseeable future.

Other Biofuel Technologies

While the greatest effort and production of biofuels has centered on fermentation processes to produce ethanol, there are several other methods by which almost any biological material can be converted to fuel and energy. There are three basic conversion processes: biochemical, chemical, and thermochemical. Each of these processes has the potential to accept diverse feedstocks and produce liquid fuels, combustible gases, direct heat, and commercially valuable industrial chemicals. The ability to accept diverse feedstocks might be a significant economic and environmental advantage over a reliance on the ethanol biofuel production model. Specifically, thermochemical technologies could be used where animal operations are co-located with ethanol refineries to convert manures to biofuels and heat to run the refineries.

Biochemical processing of biomass into energy is the basis of fermentation of starch into ethanol. Additionally, biochemical processes can be utilized to produce energy in the form of biogas (a mixture of mostly methane and carbon dioxide) which can be utilized as a substitute for natural gas. Methane can be used as a source of hydrogen and there are current research efforts directed to utilizing methane directly in fuel cells. The most common applications of this type of biochemical

The primary feedback for biodiesel in the U.S. is soybean oil.
Photo by: Keith Weller, USDA ARS

conversion are the treatment of liquid animal manures and municipal wastewater treatment biosolids in anaerobic digesters. The challenges associated with anaerobic digestion are primarily related to adoption of the technology which can be expensive for small agricultural producers and for cities who wish to retrofit an existing waste water treatment plant.

The conversion of biomaterials into fuel utilizing chemical processes is currently primarily applied to turning fats and oils into biodiesel which can substitute for petroleum-based diesel in virtually any diesel engine. The primary feedstock for this process as currently practiced in the U.S. is soybean oil. However, almost any vegetable oil or animal fat can be converted into biodiesel using relatively simple, clean chemical processes. The challenges to increased biodiesel production include required fuel flow characteristics at low temperatures, production of new engines that can burn 100% biodiesel, utilization of other vegetable oil sources, and the collection and transport of animal fats.

Quite possibly the greatest potential for bioenergy comes through thermochemical conversion. The products of thermochemical conversion include complex combustible liquids, combustible gases, and direct heat. Pyrolysis is the thermal breakdown of organic materials in the absence of oxygen. The primary product is a complex liquid known as bio-oil. This oil can be burned directly or broken down into numerous other combustible products and useful chemicals utilizing well-known processes from the petroleum industry. Another product of pyrolysis is a carbon char that may be a good soil conditioner as well as increasing carbon sequestration in soils. Gasification is a process that thermally decomposes organic materials in the presence of limited oxygen. The products of this process are combustible gases, known as syngas, and heat. Gasification is a well-known technology for converting coal into gaseous fuels. It is now being studied as a fuel-flexible method of converting waste organic materials, or specially grown energy crops, into bioenergy. There are already mature technologies than can convert syngas into numerous liquid fuels. The challenges to greater adoption of thermochemical technologies include transportation of low energy-value organic materials to a centralized conversion facility, scaling the processes to make them more applicable to localized areas, and the handling, processing, storage, and preparation of varying biomaterials prior to feeding into the conversion processes.

There are several processes, other than fermentation for ethanol, by which organic wastes, conventional crops, and new specialty energy

Findings:

- Biofuel (ethanol and biodiesel) production will move to the Mid-Atlantic region.
- Grain-based ethanol will be dominant for the foreseeable future.
- Perennial grass, wood or waste-based cellulosic ethanol production has economic and environmental potential but technical, production and policy constraints impede widespread implementation.
- Corn acreage and fertilization will increase, and unless nutrient management and other conservation practices are intensified, additional nutrient losses will occur.
- Expanded grain and ethanol production supported by government incentives will discourage or slow conversion to cellulosic ethanol renewable energy.
- Thermochemical conversion can lower energy input requirements and at current petroleum prices may be commercially viable without government incentives.
- Thermochemical conversion can produce high-energy fuels and can utilize existing fuel-refining and fuel-distribution infrastructure.

Overarching Recommendations:

- Develop a vision and strategy for a diversified portfolio of biofuels and the feedstocks to support production that is based on a life cycle assessment of the environmental impacts of production.
- Expand financial resources available to farmers to help cover costs associated with protecting the Chesapeake Bay and its rivers and streams.

Policy Recommendations:

- Do not allow early withdrawal from CRP, or state equivalent program, contracts without substantial penalty.
- Retain conservation compliance requirements for commodity support program participation.
- Create equivalent or superior subsidies and incentives for farmers to grow perennial grasses.
- Provide incentives to farmers to assist with start-up and infrastructure costs of perennial grass establishment and production, and assist them in organizing entities to produce sufficient perennial grass for cellulosic ethanol production in an area.
- Provide incentives for implementing nutrient management plans.

Research and Extension Recommendations:

- Support for research, demonstration and education by federal and state governments is needed to better define the impacts of expanded grain production.
- Provide federal funding to support research and development of ecologically sustainable perennial grass or tree-based cellulosic ethanol and thermochemical technologies that protect water quality.
- Provide dairy and beef farmers with the technical assistance needed to reduce manure nutrients through feed management.
- Provide federal funding to support waste to energy biofuels processes such as gasification and pyrolysis – particularly when such processes can help achieve water quality goals.

crops can be converted into useful bioenergy. All of these processes are adaptable to a wider range of feedstocks than ethanol production. These processes can productively utilize "waste" organic materials as well as low-input energy crops. The products of these conversion technologies can include numerous liquid fuels, combustible gases, heat, and a carbon char that could help improve agricultural soils while also sequestering carbon. There are many opportunities and environmental benefits available through these alternative bioenergy production processes. Currently, Virginia Tech and the Beltsville Agricultural Research Center are exploring hybrid gasification and pyrolysis processing systems that could utilize biomass crops and other waste streams to produce energy and biofuels. These technologies are nearer implementation than cellulosics technologies.

For more information and links to other resources, please go to http://www.mawaterquality.org/biofuels

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