Union of Concerned Scientists

THE ENERGY-WATER COLLISION

Managing the Rising Tide of Biofuels

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BIOFUELS hold out the promise of alleviating two major problems: global warming and our nation's dependence on oil. Unfortunately, today's biofuels have serious secondary impacts that undermine their climate benefits and pose a threat to water resources. How we choose to produce biofuels—which crops are used, how and where they are grown—can mean the difference between a wise resource strategy and a wasteful and destructive one.

Expanding U.S. biofuel production will require tradeoffs between ambitious fuel production targets and other societal goals, including protection of the water we need for drinking, growing food, preserving aquatic habitats, and producing electricity. Current U.S. biofuel policy has supported rapid growth in corn ethanol[1] but taken a toll on our water resources—without reducing heat-trapping emissions.[2] Next-generation "cellulosic" biofuels made from grass, wood waste, or even garbage can reduce biofuels' impact on water resources *and* reduce emissions, but only if we make smart choices.

The First-Generation Biofuel: Corn Ethanol

Corn ethanol currently accounts for more than 90 percent of U.S. biofuel production. Driven by federal and state mandates and incentives,[3] ethanol production has grown dramatically over the past decade: from 1.5 billion gallons in 1999 to 10.5 billion gallons in 2009.[4] During that same period, the fraction of the U.S. corn crop dedicated to ethanol production rose from 5 percent to 30 percent.[5]

The associated increase in crop prices was welcome news to corn producers, but the diversion of corn away from food and animal feed markets has increased agricultural production worldwide to make up the difference. This expansion of agriculture has accelerated the conversion of forests to farmland, which releases the heat-trapping carbon dioxide stored in trees and soils, thereby eroding or eliminating the climate benefits of biofuels made from corn or other food crops.[6] In addition, the rapid expansion of corn ethanol production has come at a high cost to freshwater resources in several regions, and to the health of marine fisheries in the Gulf of Mexico.

Corn is a particularly resource-intensive crop, typically requiring high levels of fertilizer, pesticide, and soil disturbance. Corn production is responsible for 42 percent of nitrogen fertilizer use in the United States[7]—and nitrogen pollution is the leading cause of poor water quality in our nation's streams.[8]

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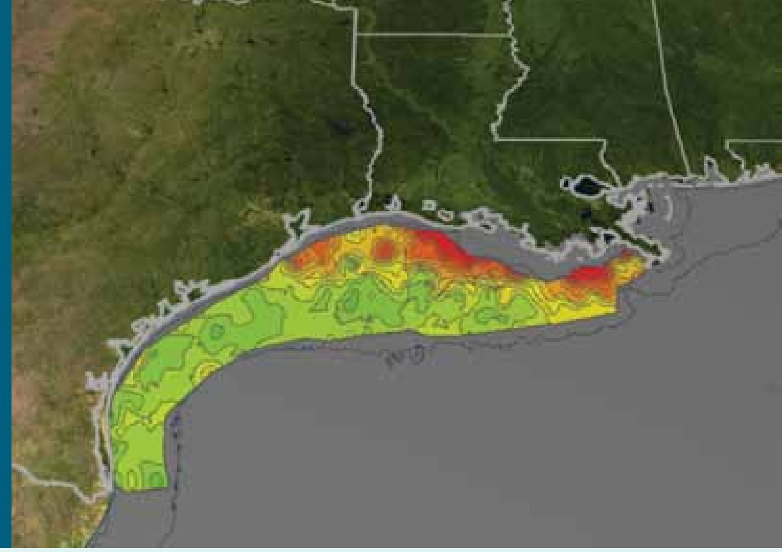
Most of the U.S. corn crop grows in the vast Mississippi River watershed, and runoff of nutrients including nitrogen and phosphorus from corn and soybean cultivation in this region has led to a seasonally large "dead zone" in the Gulf of Mexico where fish cannot survive (see the text box on p. 2).

Corn ethanol and water consumption.

While corn from Illinois, Iowa, and Minnesota is generally rain-fed, farmers are increasingly growing corn in more arid land farther west. There, irrigation consumes large quantities of water. In Nebraska, for example, it takes an estimated 500 gallons of water to irrigate the corn needed to produce a single gallon of corn ethanol; even more is needed in Colorado and Texas.[9] Another way of looking at it is that it would take 30 gallons of irrigation water to produce enough corn ethanol in Nebraska to drive a typical car one mile.[10] Much of this water comes from underground aquifers such as the vast Ogallala, which stretches from Texas to South Dakota; since the advent of substantial groundwater irrigation around 1950, the

Biofuels and the Gulf of Mexico Dead Zone

The Gulf of Mexico "dead zone" peaks in size each summer. In this image, reds and oranges represent low oxygen concentrations.



Map: National Oceanic and Atmospheric Administration

The Mississippi-Atchafalaya River Basin drains 40 percent of the contiguous United States and produces 80 percent of the nation's corn for food, livestock feed, and ethanol.[11] When it rains, excess fertilizer flows from farm fields into creeks, then small rivers, the Mississippi, and ultimately the Gulf of Mexico, where the nitrogen and phosphorus nutrients from this fertilizer cause large and harmful algae blooms. As the algae die and decompose, oxygen in the water is consumed, leading to severe oxygen depletion or hypoxia, which kills fish and other marine life. The resulting "dead zone" peaks in size each summer; over the last five years it has averaged more than 6,000 square miles—larger than Connecticut. A coordinated effort by state and federal agencies to restore the health of affected marine fisheries and ecosystems in the gulf has set a target to reduce the average size of the dead zone by more than two-thirds.[12]

The agricultural landscape in the states contributing to the dead zone is dominated by corn and soybeans, which comprise more than 80 percent of farm acreage in the Corn Belt states of Illinois, Indiana, Iowa, and Minnesota.[13] Most of the growth in demand for corn over the past decade has come from the expansion of corn ethanol, driving increases in corn production at the expense of other crops.[14] Because corn production uses higher levels of fertilizer than the crops it displaces, the problem of nutrient runoff is worsening.

Recently, the National Academy of Sciences found that further conversion of crop or conservation acres to corn would likely increase fertilizer usage, exacerbating nutrient pollution in the Mississippi–Atchafalaya River Basin and the Gulf of Mexico.[15] Other analyses have found that increasing corn acreage to meet federal biofuel mandates would make it nearly impossible to meet federal targets for reducing nitrogen pollution in the gulf.[16]

However, using perennial grasses instead of corn to make biofuels would reduce the contribution of nutrient pollution to the dead zone. Given the magnitude of the challenge, even this shift would not by itself be sufficient to restore affected marine life in the gulf—changes in agricultural practices for both food and fuel crops are needed. But with smart choices, biofuels can lead the way rather than aggravate the problem.

Ogallala has dropped by more than 100 feet in some areas.[17]

The impact of biofuel production on water resources does not stop when the crop is harvested; significant amounts of water are also required to turn the crop into fuel. Biofuel production plants can cause problems for local water resources even in areas where rainfall is sufficient to grow crops without irrigation. In western Minnesota, for example, local officials denied a permit for a proposed corn ethanol plant because the rural water system could not provide enough water.[18]

Water use at corn ethanol facilities has been falling, particularly at newer facilities featuring improved equipment and energy-efficient design, and currently amounts to about three gallons of water per gallon of fuel produced. Yet this is still more than double the water needed to refine an equivalent amount of oil.[19] Production of next-generation biofuels will also consume significant quantities of water, but by adopting efficient technologies and choosing locations with adequate water resources, this problem can be lessened significantly.

Corn production is responsible for 42 percent of nitrogen fertilizer use in the United States—and nitrogen pollution is the leading cause of poor water quality in our nation's streams.

Beyond Corn: Next-Generation Biofuels

Biofuels can be produced from other crops besides corn: biodiesel can be made from soybeans or camelina, for example, and ethanol can be made from sorghum. These crops generally use less fertilizer than corn,[20] and may have other advantages as well, depending on where and how they are grown. All agricultural crops have an impact on water resources; choosing those appropriate to local conditions allows better management of the impacts but does not eliminate them entirely.

To expand biofuel production while reducing heat-trapping emissions and protecting water resources, it will be essential to move beyond our current reliance on food-based biofuels to biofuels made from non-food biomass. New technologies can assist with this transition: some convert cellulose to fuel using biochemistry,[21] some convert biomass into gases that are then converted to fuel,[22] and others use algae or other microorganisms to make fuel directly from sunlight.[23] These next-generation biofuels have much lower global warming emissions than food-based biofuels, and can reduce emissions caused by changes in land use.[24]

Several potential sources of non-food biofuels are summarized here:

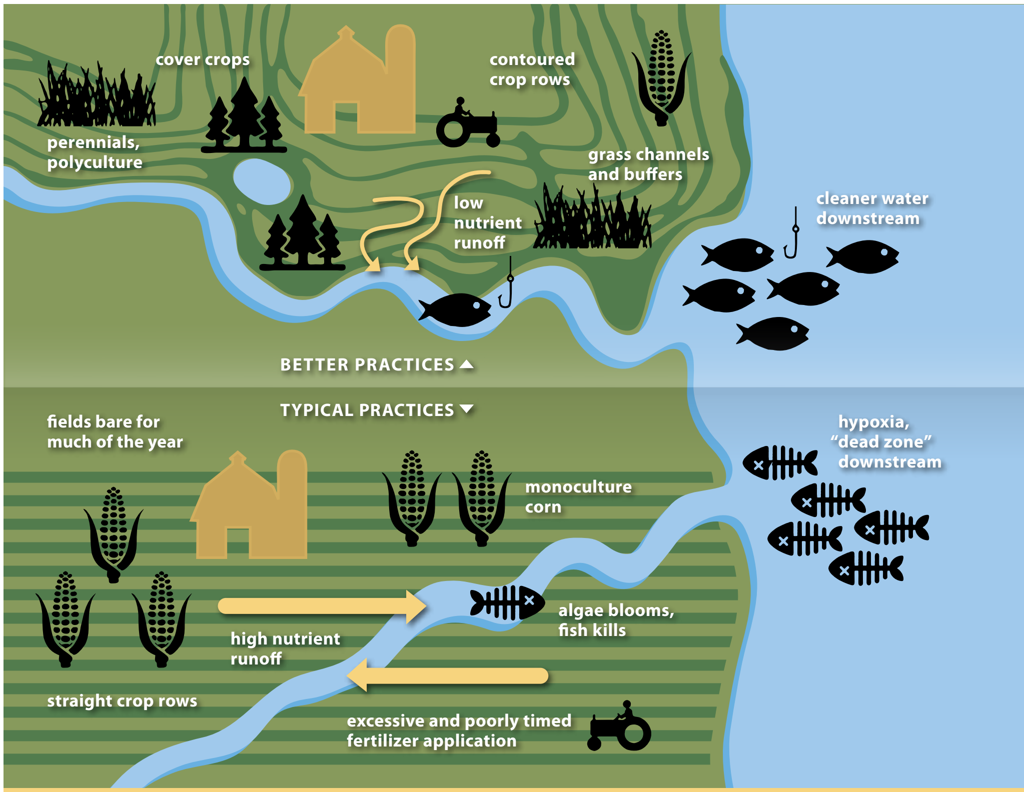
Annuals. Residues of annual crops, such as corn stalks or wheat straw, are a large potential source of cellulose for biofuel.[25] However, this organic matter also plays a critical role in replenishing soil health, slowing erosion, and preserving water quality. Through careful management, some of these residues can be removed while sustaining productive soil and limiting impacts on water quality (see the text box at right).[26]

It takes 30 gallons of irrigation water to produce enough corn ethanol in Nebraska to drive a typical car one mile.

Perennials. Energy crops that can be planted once and then harvested repeatedly for many years could greatly reduce the impact of biofuel production on our nation's water resources.[27] Scientists and farmers are evaluating perennial grasses and fast-growing trees for their potential use as biofuels. These so-called energy crops include perennial grasses such as switchgrass, reed canary grass, fiber cane, and miscanthus, and trees such as willow and poplar, which can be harvested for biomass every three to eight years for many years. Because tillage is not needed for these plants, the roots can penetrate deep into the soil, holding it in place and preventing erosion while increasing the soil's capacity for storing carbon. Perennials' deep roots, year-round ground cover, and limited need for chemicals have the combined effect of limiting runoff and releasing clean water into streams and groundwater.[28]

Perennial polycultures. Producing biofuels from fields planted with mixed species, or polycultures, may provide distinctive benefits. For example, a mixture of grasses, legumes, and other plants can function much like a natural prairie, enhancing soil health and offering greater resistance to erosion, drought, and pests than one plant species by itself. Such polycultures can reduce or even eliminate fertilizer and pesticide use, thereby reducing water pollution.[29]

Perennial polycultures may not offer the highest output in tons of biomass per acre, or the cheapest biomass in dollars per ton. But when



Management Practices Make All the Difference

Whether biofuels are derived from corn, grass, trees, or a polyculture, good management practices can help protect water resources for all users. For example, nutrient management plans based on measurements of soil properties can ensure that fertilizer application is not excessive and is timed to minimize runoff. Replacing dirt gullies with grass-filled channels, changing the orientation of crop rows to follow the contour of the land, and adding terraces and grass buffers can all control water flow and reduce erosion. Crops such as winter rye can be planted between corn growing seasons to provide year-round plant cover that absorbs residual nutrients, reduces erosion, and builds soil quality.[30] Waiting to harvest perennial grasses until the above-ground plant has died off and nutrients have returned to the roots will minimize the need for additional fertilizer.[31] Careful layout of logging roads and protected buffer strips along waterways can help prevent erosion and sedimentation.[32]

Each plot of land is different, with variations in soil, slope, rainfall, and drainage that determine how a given plot should be used. One may be well suited for corn; one near a creek makes more sense for perennial polycultures that minimize fertilizer runoff; one on a ridge is best suited for trees that will provide a wind break. These choices, along with technologies that can convert diverse products into fuels, give farmers multiple options to maintain or increase profits while preserving and protecting their land, water, and environment.

the value of water quality and other environmental benefits are added to the equation, polycultures may offer farmers an attractive alternative to today's cropping systems.[33]

Forests. Logging operations, natural disasters, and disease or infestation can leave behind large amounts of plant debris, some of which can be collected and used for energy. This woody biomass is typically burned to produce electricity or heat, but technologies under development can convert wood waste into liquid fuels as well. As with agricultural biomass, the impact of such operations on water resources depends on the way the operation is managed. Removal of some biomass residue can be a sustainable part of a forest management plan, but overly aggressive residue removal or wholesale clear-cutting depletes both the surface material that shields soil from erosion and the organic matter that protects water quality.[34]

Because collecting widely dispersed wood waste poses logistical challenges, not all of the available resource can be economically utilized. Still, some forest managers see the biomass market as an opportunity to improve forest stands by using the income from biomass sales to offset the cost of removing invasive species, growing valuable understory trees, or reducing the threat of fires.[35]

Other types of waste. Waste from agricultural processing, livestock, construction/demolition, and manufacturing—even ordinary household garbage—contains cellulose that can be converted into liquid fuels. Since it requires no additional cultivation of crops, this approach to biofuel production can dramatically reduce water consumption. Moreover, the use of waste as a biofuel feedstock reduces the environmental impact of landfills and other waste-processing facilities.[36]

Replacing dirt gullies with grass channels (as in this Iowa cornfield) can reduce erosion and loss of nutrients into creeks, streams, and ultimately the Gulf of Mexico.

USDA Natural Resources Conservation Service

Algae. Researchers are experimenting with ways to grow algae and other microorganisms that can produce oil or hydrogen and other chemicals that can be converted into fuel. Like cellulosic biofuels, algae may provide an alternative source of biofuel that avoids some of the impacts associated with food-based biofuels. Algae production requires a significant amount of water, but using nutrient-rich brackish water or polluted water from treatment plants could accelerate algae growth while reducing nutrient levels in the water—turning a problem into a solution. Though algae-based fuels are in an early stage of development, their potential to help reduce oil dependence, heat-trapping emissions, and impacts on water resources merits close attention.[37]

A Low-Carbon, Water-Wise Future

We must make smart choices in the biofuels we pursue. That is, we cannot realize the energy security and climate benefits of biofuels by simply expanding and intensifying current agricultural systems, particularly corn production for ethanol. The cost to our nation's water resources and the impact on global land use outweigh the benefits. However, by improving agricultural practices for all crops, and increasing the share of next-generation cellulosic biofuels, we can add diversity to our agricultural landscape, improve rather than degrade our soils, reduce global warming emissions, and help protect water resources. Pursuing this path will make it possible for biofuels to grow over the long term and help us meet the twin challenges of oil dependence and climate change.

The Union of Concerned Scientists is the leading science-based nonprofit working for a healthy environment and a safer world.

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This fact sheet, which draws from a growing body of research, is part of our "Energy and Water Collision" series that explores the ways in which energy choices affect water resources in the United States, and how this will change in the face of global warming. To download a fully referenced version, visit the UCS website at *www.ucsusa.org/energy-water*.

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Endnotes

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