STEPHEN AUSMUS (D1235-10)

Soil scientist Doug Karlen instructs technician Tanya Ferguson (accompanied by her hearing guide dog) on how to visually assess soil quality impacts of harvesting crop residue as feedstock for bioenergy production. The foreground shows signs of severe soil erosion where about 90 percent of the stover was harvested.

Cellulosic Ethanol From Corn Stover

Calculating—and Improving—the Bottom Line

In the Midwest, 100 to 150 million tons of corn stover—crop residue—is now left on fields to prevent erosion and return nutrients to soil.

Now corn stover is being eyed as a possible source of cellulose for biofuel production. But the costs and benefits of harvesting stover need to be determined.

"Crop residue is not just trash," says soil scientist Doug Karlen, who works at the ARS National Soil Tilth Laboratory in Ames, Iowa. "We need to find ways to develop site-specific practices for managing corn stover removal—not a 'big-box' approach to soil management. With the right approach, corn stover can have bioenergy benefits for U.S. consumers and producers alike."

Karlen, who is the research leader in the Soil and Water Quality Research Unit, is part of a national team conducting multiyear evaluations of the environmental and economic costs and benefits that might accrue from large-scale corn stover removal to produce ethanol. This project—the Renewable Energy Assessment Project, or REAP—is under way at sites in Alabama, Colorado, Indiana, Iowa, Minnesota, Nebraska, Oregon, Pennsylvania, and South Dakota.

Karlen recently finished a round of research that looked at how harvest practices affect fertilizer costs and the quality of the harvested stover for biofuel feedstock. His research team included Iowa State University engineer Stuart J. Birrell, Idaho National Laboratory (INL) scientist Corey W. Radtke, and ARS plant physiologist Wally Wilhelm. Wilhelm is in the Agroecosystem Management Research Unit in Lincoln, Nebraska.

It's All in the Cut

In 2005, this group—along with INL scientist Reed L. Hoskinson, who has since retired—established experiments in cornfields near Ames and then harvested the cornstalks at four different heights to measure the amount and quality of stover that could be harvested using different removal strategies.

The scientists varied the amount of biomass removed by changing the type and cutting height of the combine head.

Their “high-cut top” harvest was obtained using a row-crop head and cutting the plants just below the cob so that only the cob and plant parts above it entered the combine. This left a 30-inch stubble behind on the field.

The “normal cut”—which used a standard harvester head with snapping rollers—left only 16 inches of stubble. But this cut did not increase the amount of harvested biomass, because more plant material was pulled through the rollers and left on the ground.

“Low-cut” harvests—which reaped almost the entire cornstalk and the cob—were also made with the row-crop head and left only about 4 inches of stubble. A second low-cut harvest, called “high-cut bottom,” took place after the high-cut top harvest. The collected biomass from this cut consisted only of the lower 30 inches of cornstalks and any remaining leaves. In all of the harvest scenarios, the grain was separated from the cob before the researchers started their assessments.

After the harvests were complete, the scientists evaluated factors such as how stover removal could potentially affect future crop production and soil quality, how potential ethanol production might vary with harvest protocol, and how to deal with engineering challenges associated with harvesting.

The researchers found that the base of the high-cut bottom feedstock was around 64 percent water, which decreased its value as a feedstock. Any biomass with high water content is generally more expensive than dry biomass to harvest, store, and transport to an ethanol conversion facility.

The team also found that stover removal resulted in per-acre losses of up to 45 pounds of nitrogen, 2 to 4 pounds of phosphorus, and 23 to 38 pounds of potassium. In some soil types, these losses could result in long-term potassium deficiencies that would reduce crop productivity unless the fields were amended with fertilizers.

Translated into dollars, the low-cut harvest scenario could cost producers $25 to $30 per acre, depending on their fertilizer costs. Compensating for loss of other soil nutrients—including calcium, magnesium, iron, zinc, copper, and manganese—would increase producer costs even more.

Conversion Calculations—Cobs and All

Stover from the four harvest groups was then converted to fuels via thermochemical processing. Karlen’s team measured the resulting energy yield and decided that the most likely factor driving conversion efficiency was the level of moisture in the feedstock.

The team also used a screening method to estimate how the four groups of stover responded to chemical pretreatment. These pretreatments partially break down feedstock, making the plant sugars more easily accessible for fermentation.

STEPHEN AUSMUS (D1236-13)

Soil scientist Doug Karlen (left) discusses commercial combine modifications that Stuart Birrell, associate professor at Iowa State University, designed to collect corn stover as a bioenergy feedstock for the REAP (Renewable Energy Assessment Project) cooperative research project.

They found that using a common pretreatment with the high-cut top stover resulted in production of significantly more ethanol than the high-cut bottom stover. These results indicate that the high-cut top stover would be less expensive to prepare for ethanol conversion.

After pretreatment and fermentation screening, they found that the resulting ethanol yields between the normal-cut and high-cut top harvests were indistinguishable. This suggests that normal-cut stover harvest—characterized by convenience and speed, acceptable stover water content, and potentially lower processing costs—appears to give producers their best stover harvest option for biofuels.

“Our results indicate that the cob and upper portion of the corn stover have the best characteristics for being made into ethanol. And if we harvest just this part of the plant for biofuel, we will probably leave enough crop residue on the field for soil conservation,” Karlen says.

The team plans to continue its research on how harvest height affects stover quality. They will also vary agronomic practices—such as crop spacing, fertilization rates, and use of annual and perennial cover crops—to assess how these factors affect stover quality.

These long-term studies support regional corn producers in their search for optimal combinations of sustainable practices that maximize production, reduce costs, and protect natural resources.—By **Ann Perry,** ARS.

This research is part of Soil Resource Management, an ARS national program (#202) described on the World Wide Web at www.nps.ars.usda.gov.

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