Capturing Carbon to Help Slow Global Warming

AGRICULTURE'S ROLE in CARBON SEQUESTRATION MAY HELP the ENVIRONMENT and OFFER NEW MARKETS for FARMERS.

In the past decade, global warming went from being considered a far-fetched scare tactic to a scientific reality. Greenhouses gases — carbon dioxide, methane and nitrous oxide are the main ones — have been steadily increasing in the atmosphere since the beginning of the Industrial Revolution. Released from various natural and industrial sources, greenhouse gases absorb heat and help maintain the atmosphere's climate. Without these gases, the planet would be a large ice cube. But if their concentrations become too high, research has shown that these gases may cause a dramatic increase in temperature. Toward the end of 2004, the Bush administration said that greenhouse gases played a role in climate change, an idea that it had resisted earlier.

In 1997, more than 160 nations met in Kyoto, Japan, as part of a United Nations conference on climate change. The representatives discussed limiting the emission of greenhouse gases, especially carbon dioxide, a gas that had not been regulated before. The report that was issued at the end of the conference became known as the Kyoto Protocol. It created target greenhouse gas emission levels for each of the participating developed countries, relative to 1990 emissions levels. The target for the United States was 7 percent below 1990 levels. The United States and Australia were the two biggest industrialized countries that did not consider ratifying the protocol, for a variety of economic reasons. The protocol was scheduled to take effect 90 days after no fewer than 55 countries, which had to account for 55 percent of total carbon dioxide emissions in 1990, ratified it. On Nov. 18, 2004, Russia ratified the protocol, tipping the emissions percentage to 61.6 percent. This means the Kyoto Protocol became binding on Feb. 16, 2005.

"The Kyoto Protocol brought attention to global warming and greenhouse gases," said Kurt Thelen, MAES crop and soil sciences scientist, whose research focuses on keeping carbon in the soil through agricultural practices. "As more policy-makers focus on global warming, it's allowed us to develop some innovative management practices that we think will benefit both farmers and the environment."

"Agriculture can be a sink for carbon because crops and trees use a lot of carbon dioxide in the process of photosynthesis and store carbon in the soil over time," said Doo-Hong Min, MAES crop and soil scientist, who conducts research at the Upper Peninsula Experiment Station in Chatham. "One of the key components of keeping carbon in the soil is tillage management. In particular, no-till makes more stable soil aggregates that increase water- and nutrient-holding capacity, resulting in potentially better crop production."

"Russia's ratification of the Kyoto Protocol is focusing more attention on carbon," said Phil Robertson, MAES crop and soil sciences researcher, who oversees the Long-Term Ecological Research (LTER) site at the Kellogg Biological Station (KBS). Established by the National Science Foundation, the LTER site is part of a national network studying ecology and environmental biology through long-term research projects. The KBS LTER site is the only agricultural site in the network. With Thelen, Robertson is studying how agricultural management practices can keep more carbon in the soil and out of the atmosphere.

"Two dominant greenhouse gases, carbon dioxide and methane, are carbon-based," said Merritt Turetsky, MAES plant biology and fisheries and wildlife scientist. Her research focuses on permafrost and high latitude wetlands, such as those in Alaska, northern Canada and Siberia, and these areas' ability to store carbon. "For many thousands of years, these cold wetland areas have been a sponge for carbon," she explained. "But as the climate is warming, these areas are melting. We're studying what happens to the carbon when permafrost melts."

Thelen, Min, Robertson and Turetsky are all looking at greenhouse gases from slightly different angles, but all have the goal of reducing their emission by keeping (or sequestering, as the practice is technically known) more carbon in the soil.

"MSU is considered a national leader in carbon sequestration research," Thelen said. "We have expertise in agriculture and ecology, so we can look at all sides of the issue."

Kurt Thelen, MAES crop and soil sciences researcher, studies how to keep carbon in the soil through agricultural practices. Using cover crops is one way to increase plant residue in the soil.

Wetlands and Warming

According to plant biologist Turetsky, wetlands cover just 3 percent of the Earth's surface but are considered one of the most valuable terrestrial ecosystems because of the variety of goods and services they provide. She believes that carbon sequestration should be counted as one of these services. Peatlands are a specific type of wetland that accumulates layers of dead biomass (parts of plants and other living things) in soils. These layers of dead biomass are called peat, and peat is about 50 percent carbon. In Canada, Alaska and other parts of northern North America, peat layers can be up to 5 meters thick. Researchers estimate that peatlands around the globe hold 30 percent of the world's soil carbon pool.

"Carbon storage in peatlands may become a complex climate change issue," she said. "These high latitude frozen wetlands have been a persistent sink for carbon. The ground is saturated with water, so decomposition is slow. Also, the species that grow in peatlands, mostly sphagnum mosses, are resistant to decomposition. But what happens to the carbon when the temperature goes up?"

Turetsky's initial thinking was that the warming would increase decomposition. The resulting increase in carbon dioxide, would, in turn, warm the atmosphere more and cause more of the frozen land to melt.

"We were worried that we were getting into a loop that we couldn't get out of," she explained.

But after she analyzed her data, she found that as the permafrost melted, the vegetation loved the water.

"In Canada, there were different species of sphagnum mosses that grew in a disturbed and wetter environment," she said. "These plants took up more carbon, so our fears about the loop were unfounded. But I'm not sure how fast the species across the entire landscape can adapt to the warmer climate. We're studying that now. Plus, there are a lot of places with infrastructures that depend on permafrost. In Siberia, Alaska and Canada, buildings are sinking as it melts."

As the climate warms, plants get drier and burn more easily. Studying the amount of carbon released by wildfires in northern locations is another facet of Turetsky's research.

"Dry peatlands will burn," she explained. "Especially in large fires like those that Alaska experienced in 2004. A colleague of mine flew over some burned areas in Alaska last fall and saw smoke coming out from under 6 inches of snow. Fires can smolder in peatlands over the winter and then flare up the following year. As the climate warms, we almost certainly will have more fires in the future."

Peatlands have more carbon than trees, but no one had studied how much of this carbon is burnable. So Turetsky is researching that question.

"This raises questions about management," Turetsky explained. "Should peatlands be protected from burning in remote areas to keep carbon out of the atmosphere? Is that even a viable management option? Right now, in Alaska, many fires are allowed to burn unless they directly threaten buildings or other structures. It is clear to me, however, that we shouldn't be doing anything to make peatlands drier, such as lowering water tables to promote carbon sequestration in trees for potential forestry operations. In North America, a lot of that carbon simply will go up in smoke."

Phil Robertson, MAES crop and soil sciences researcher, oversees the Long-Term Ecological Research site at the Kellogg Biological Station. He would like to see carbon markets develop enough to pay farmers to keep more carbon in the soil.

Agriculture's Role in Carbon Sequestration

Crops and other plants use carbon dioxide from the air during photosynthesis. When leaves, stems and other plant residues fall to the ground, the carbon in that material is either converted by microbes to carbon dioxide during decomposition or becomes part of soil organic matter. Certain agricultural practices, such as no-till (which means the ground is not plowed or turned over every year), increase the amount of carbon in the soil by slowing decomposition.

"It's easy for agriculture to get carbon dioxide out of the air," Thelen said. "Ag is kind of the low-hanging fruit as far as carbon sequestration is concerned. We can use agricultural production practices as a short-term solution while alternatives to fossil fuels are studied. I think agriculture could account for about 20 to 40 percent of the emissions targeted in the Kyoto Protocol, which would be about 8 to 10 percent of total emissions."

"Soils have the ability to hold a lot of carbon," Robertson added. "Farmed soils originally had 40 to 50 percent more carbon than they do today."

Using practices such as cover crops, which are planted and then cut down, allowing more residue to work its way into the soil, and no-till and other conservation tillage practices in which the soil is disturbed as little as possible means more carbon is added to the soil instead of being converted to carbon dioxide in the atmosphere.

"No-till is the biggest way to sequester carbon," Thelen explained. "You also use less fuel because the tractor isn't driving across the field as often, and this also reduces emissions."

According to Robertson, keeping carbon in the soil also makes that soil better for agricultural production.

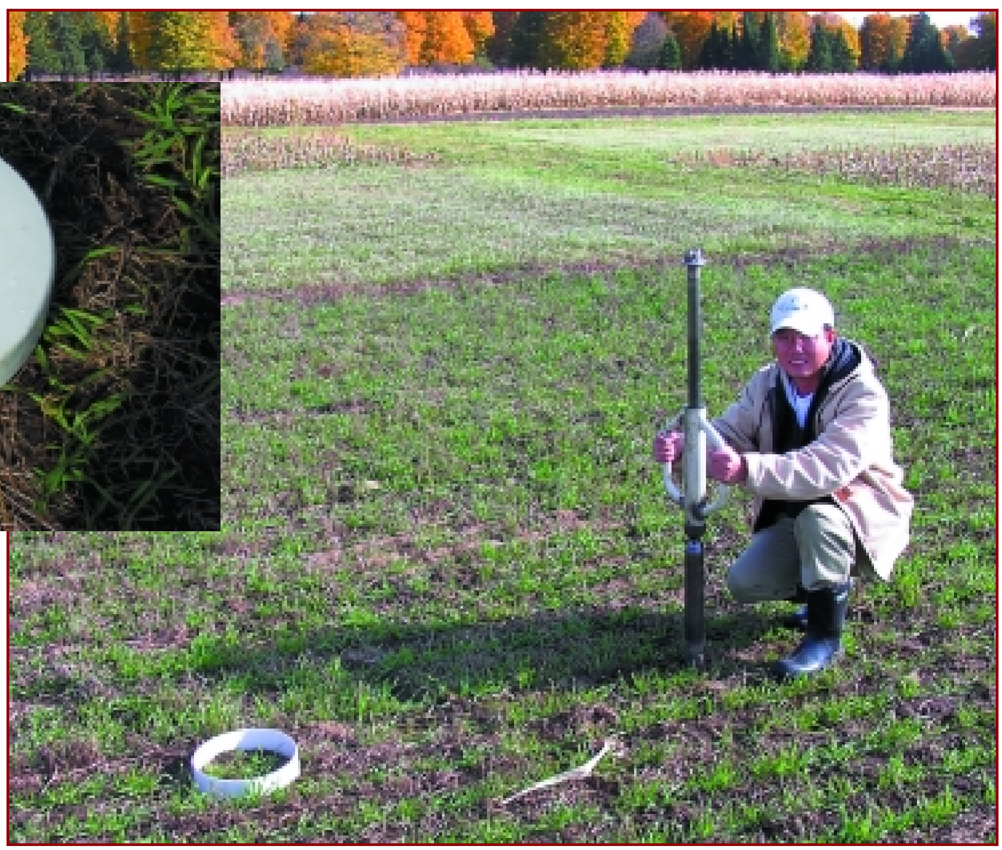
"There are lots of benefits to storing carbon for farmers," he said. "More organic matter in the soil makes the soil more porous, so it holds more water and drains excess water better, which is good for farming. It also allows the soil to hold on to more nutrients that plants need and makes the soil a better habitat for microbes and beneficial invertebrates such as earthworms, all of which are good for agricultural production."

"Farmers understand the benefits of having more carbon in the soil," Thelen said. "And they're interested in carbon sequestration. For a long time, farmers were pointed to as causing problems for the environment. Now they're excited to be part of the solution."

Michigan State is part of the Consortium for Agricultural Soils Mitigation of Greenhouse Gases (CASMGS), a group of 10 states working together to develop tools and provide information to agricultural producers to lower greenhouse gas levels. Fifteen MSU researchers are conducting research through the consortium, a collection of the nation's top researchers in the areas of soil carbon, greenhouse gas emissions, conservation practices, computer modeling and economic analysis. Robertson is the lead investigator for CASMGS at MSU.

Robertson's research at KBS is examining how the rate of carbon gain in managed land, such as agricultural fields, compares to carbon gain in unmanaged lands — lands that are abandoned from agriculture or have never been plowed.

"We've found that fallowed lands gain carbon twice as fast as managed no-till lands," Robertson explained. "But one of the big



Doo-Hong Min conducts research on carbon sequestration at the Upper Peninsula Experiment Station in Chatham. He is studying whether higher latitudes and cooler soils affect soil's carbon sequestration ability.

unanswered questions is the soil's ability to hang on to that carbon. Right now, most Conservation Reserve Program (CRP) lands have a 10-year contract on them. What happens if those lands are plowed after 10 years? How fast will the carbon leave the soil?"

A national program administered by the Farm Service Agency, the CRP is a voluntary program that pays farmers an annual amount to plant a resource-conserving cover crop.

Some preliminary research by Stuart Grandy, a graduate student working with Robertson, is providing some interesting results that may help answer these questions.

Two years ago, Grandy plowed an area at KBS that had never been plowed before. The scientists believed the soil carbon levels were similar to those that would have been found 150 years ago.

"The results showed that this single year of plowing caused a loss of carbon that negated the equivalent of seven to 10 years of no-till storage," Robertson said. "Policy-makers may have to rethink the way some of these conservation programs are structured to ensure that we're accomplishing our goals."

The scientists are also planning to study the effect that no-till has on the carbon in the soil after CRP land returns to production.

"Do you set it back a little or not at all? That research hasn't been done yet," Robertson said.

Much of Robertson's research has been aimed at documenting the actual greenhouse gas cost of agriculture. The studies have looked at every nuance of production — from the fuel use by a tractor to the carbon dioxide required to produce nitrogen fertilizer. When all the numbers are crunched and analyzed, conventional agriculture contributes about 110 greenhouse gas units per year to the environment. Organic farming systems contribute 40, and no-till systems contribute about 10.

"The ideal is to get a negative number," Robertson said. "No-till gets us close to zero, which is much better than business-as-usual but is still only a neutral effect. CRP land is negative 200, which is great, but we can't eat CRP production. The more negative the number, the more positive the impact on the atmosphere. Ideally we want to design cropping systems that are as negative as CRP lands."

In the Upper Peninsula, MAES crop and soil scientist Min's work is studying whether higher latitudes and cooler soils have an effect on the soil's ability to sequester more carbon, as well as how dairy-based forage cropping systems can sequester more carbon, an idea that involves what it is known as full-cost accounting for greenhouse gases.

Other greenhouse gases such as methane and nitrous oxide trap more heat than carbon dioxide does, so small amounts of those gases can affect the environment the same way that large amounts of carbon dioxide do. Methane and nitrous oxide have 21 and 310 times, respectively, higher global warming potential than carbon dioxide does over a 100-year period.

But because carbon dioxide is much more abundant in the environment, most policy-makers are seeking to control levels of that gas first. Limiting emissions of methane and nitrous oxide is talked about in terms of carbon dioxide equivalents — in other

PHOTO: MERRITT TURETSKY

Merritt Turetsky, MAES plant biology and fisheries and wildlife scientist, studies how wetlands can hold carbon. Her research found that certain sphagnum mosses took up more carbon as the climate warmed, but she is unsure how fast other species across the landscape will be able to adapt.

words, 1 pound of nitrous oxide is equivalent to 300 pounds of carbon dioxide. The gases are usually talked about in terms of global warming potential (GWP), which is measured in carbon dioxide equivalents. The GWP of carbon dioxide is one, nitrous oxide is 300 and methane is 30.

Like Robertson's research documenting the greenhouse gas cost of farming, Min's research on full-cost accounting for dairy-based forage systems looks at the amounts of all three gases released by a dairy operation and then compares those to the amount of carbon sequestered in the soil through various forge crop production practices.

"Practices that promote efficient nitrogen use to reduce nitrous oxide emissions include applying fertilizer or animal manure in the spring as close as possible to the active crop growth period," Min said. "You can also do a split application of fertilizer or animal manure for hay and pasture fields, use cover crops, and place nitrogen fertilizer strategically in bands on corn, rather than broadcasting it."

Other strategies that farmers can use to reduce nitrous oxide emissions are using nitrification and urease inhibitors, storing animal waste anaerobically (without air) in liquid form or in a covered lagoon, not applying manure to fallow fields in fall or winter, maintaining optimum stocking density on pasture, and planting filter strips to reduce surface runoff, erosion and nitrate nitrogen leaching.

PHOTO: MERRITT TURETSKY

Wildfires in northern locations are another facet of Turetsky's research. Her work may have implications for fire management in these areas.

Practices believed to reduce methane gas emissions, Min said, include balancing feed rations, improving the quantity and quality of pasture and hay, using feed additives, and using manure management practices such as covered lagoons and methane digesters, and limiting the amount of bedding in the manure.

"Carbon sequestration and greenhouse gas emissions can't be separated in dairy-forage systems," he said, "and these two challenges should be considered as a full-cost accounting at the whole-farm or regional landscape scale."

The Market for Carbon

The worldwide impetus for agricultural carbon sequestration will be carbon markets. As the Kyoto Protocol took effect in February, and Thelen, Min and Robertson all are expecting global carbon markets to heat up and provide additional monetary incentives for farmers to store carbon.

Countries or industries with high carbon emissions could buy emission credits from someone — say, a Michigan farmer — who is able to store more carbon than he or she emits. Using Robertson's results, a farmer who implemented no-till would have 100 carbon credits that a high-emitting industry such as a power company could buy.

"Policy-makers need to make sure that the carbon markets are viable enough to compensate farmers fairly for their carbon storage," Robertson explained. "Otherwise, it won't work. Right now, the issue everywhere is compensation. Until the markets develop over the next few years, we won't know how much per acre income farming for carbon will bring in."

Robertson would like to see carbon markets develop enough to pay farmers to use no-till, cover crops and other practices that keep more carbon in the soil. He also thinks allowing farmers to earn carbon dioxide equivalent credits for reducing the amount of nitrous oxide in the atmosphere would be an incentive for Michigan farmers to participate in the carbon markets. Plant biologist Turetsky is interested in whether landowners can receive money for carbon gained in wetland restoration projects.

"MSU research has shown that agriculture can affect the amount of nitrous oxide in the atmosphere," Robertson explained. "Changing fertilizer application rates and timing can have a big effect on the nitrous oxide levels released. It suggests that farmers should be paid for reducing nitrous oxide emissions to the atmosphere in addition to being paid for carbon storage."

All three scientists emphasized, however, that carbon sequestration is a short-term solution. As the world, and especially the United States, continues its love affair with big cars, big houses and other energy-consuming, greenhouse-gas-emitting products, the soil eventually will not be able to absorb any more carbon.

"Carbon sequestration is not a panacea," Robertson said. "It's good in the short run, but after a few decades, the carbon levels will reach equilibrium and the soil won't be able to hold any more. Sequestration is a bandage that may give us a little more time to develop a low-carbon economy. Storing carbon in places other than the soil is possible, but it is either very risky or very expensive — more than $100 per ton — which makes soil carbon storage very appealing in terms of cost."

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