Yale Environment 360

Trey Hill on his farm in Rock Hall, Maryland. MICHELLE FRANKFURTER/FERN

Can ‘Carbon Smart’ Farming Play a Key Role in the Climate Fight?

Markets are emerging to pay farmers to store more carbon in the soil by using improved agricultural practices. But flows of greenhouse gases into and out of soil are complex, and some scientists are questioning whether these efforts will actually help slow global warming.

BY GABRIEL POPKIN • MARCH 31, 2020

Trey Hill led a small group of fellow farmers to a field outside his office in Rock Hall on Maryland’s Eastern Shore. It was a cloudy February day, but the ground was alive with color – purple and red turnip tops mixing exuberantly with green rye, vetch and clover, and beneath it all, rich brown soil. Hill reached down, yanked a long, thick, white daikon radish from the earth and showed his visitors sumptuous coffee-colored clods clinging to hairy rootlets. Those clumps, he explained, hoard carbon – carbon that’s not heating the planet.

Hill didn’t adopt “carbon smart” practices like cover-cropping to fight climate change. He did it to build soil, retain water, and make money. But when the third-generation corn, wheat, and soybean farmer learned about Nori, a Seattle-based startup looking to sell credits for carbon stored in the soils of farms like his, he was all in. Hill didn’t necessarily expect a windfall, but he wanted to show fellow farmers they could make money while helping fight climate change. “If it works out and we make some money on it, that’s great,” Hill says. “If it doesn’t, well, somebody’s got to be first, and we’re willing to take that risk.”

Earlier this year, Nori paid Hill $115,000 for just over 8,000 tons of carbon stored in Hill’s soil. In the future, if each of the 10,000 acres he farms can sock away an

additional ton of carbon per year – around the best he could hope for, he says – he could earn up to $150,000 annually.

As efforts to wean society off fossil fuels have stalled, "natural climate solutions" such as soil carbon sequestration have rapidly gained steam. In 2018, the National Academies of Sciences, Engineering, and Medicine reported that "negative emissions technologies" – techniques for removing carbon from the atmosphere, rather than simply reducing new emissions of carbon – are needed to stabilize global warming below 2 degrees Celsius (3.6 degrees Fahrenheit), the level scientists believe could be catastrophic.

The Academies' report identified soil sequestration as a cost-effective and readily available climate solution, with the potential to remove 250 million metric tons or more of carbon dioxide per year in the United States alone. That's about 5 percent of the U.S.'s annual CO2 emissions, which totaled 5.4 billion tons in 2018. This month, a team led by researchers at The Nature Conservancy (TNC) estimated that if implemented globally, soil conservation and soil-building activities could provide nearly 10 percent of the carbon reduction needed to avoid breaching the 2-degree barrier.

Corporations, philanthropists, and governments are pouring millions of dollars into soil-climate initiatives.

Millions of dollars are now pouring into soil-climate initiatives from corporations like Microsoft and General Mills, philanthropists like Leonardo DiCaprio, and governments large and small. A Boston-based agricultural technology firm, Indigo Ag, says that thousands of farmers working more than 18 million acres of farmland, nearly all in the U.S., have expressed interest in enrolling in its carbon-sequestration program. A consortium of food giants and non-profits like TNC has raised more than $20 million to build a marketplace to sell soil carbon credits. Cities such as Boulder, Colorado and San Francisco are including soil carbon storage in their climate action plans. California already pays some farmers for reducing their greenhouse gas emissions, and Maryland legislators are considering new funding for "carbon-smart" farmers like Hill.

At the national level, U.S. Senator Cory Booker (D-NJ), Representative Deb Haaland (D-NM), and Representative Chellie Pingree (D-ME) have introduced bills that would pay farmers to adopt climate-friendly practices. Even Secretary of Agriculture Sonny Perdue has endorsed the concept.

But a growing number of scientists worry that mounting societal pressure to *do something* to counter climate change is pushing money into so-called carbon farming before the science needed to underpin it is mature. New studies reveal that even long-accepted carbon sequestration practices may not yield hoped-for climate benefits. Measurements of soil at depths down to 2 meters have cast serious doubt on the climate impact of reducing soil tillage, and similar studies are now questioning how much carbon cover crops can sequester in some circumstances. A

massive ramp-up of soil carbon data from working farms is urgently needed, experts say.

Even some supporters want to rein in the hype.

“We’re in a period of carbon exuberance,” says Philip Taylor, an ecologist and co-founder of the Boulder-based regenerative agriculture organization Mad Agriculture. “Society’s hope and wish that agriculture will solve climate change is overstated.”

Trey Hill shows off the carbon-rich soil under his crops. GABRIEL POPKIN/FERN AND E360

From when the first plow broke ground, agriculture has emitted carbon dioxide. Turning topsoil mixes underground carbon-containing molecules with atmospheric oxygen, creating the greenhouse gas that, more than any other, is imperiling civilization. Recent estimates suggest that some 133 billion tons of carbon, roughly a fourth of all carbon emitted by humans since the Industrial Revolution, has been lost from soils globally.

Technological advances have dramatically upped farming’s emissions in the last century. Fossil fuel use by the food system, including fuel for tractors and transport and energy for fertilizer production, now accounts for more than 10 percent of all greenhouse gas emissions. Fertilizer added to soils can cause microbes to emit nitrous oxide, or N2O, a greenhouse gas 300 times more potent than carbon dioxide per molecule. N2O is now responsible for around 6 percent of global warming, according to the U.S. Environmental Protection Agency.

But there is hope that such trends could be reversed. In 2004, Rattan Lal, a soil scientist at Ohio State University, estimated that changes in farming and soil management practices could, in theory, coax up to two-thirds of all carbon lost from soils back underground, potentially drawing down atmospheric carbon dioxide considerably. Lal and others recommended practices shown to increase the fraction

of carbon-containing compounds in upper soil layers, including reducing or eliminating tillage that exposes soil carbon to air, mulching fields with crop residues, and planting cover crops – cereals, legumes, or other vegetables grown not for harvest but to reduce erosion and enrich soil with nutrients and carbon-rich organic matter.

Some farmers, it turns out, were already adopting such practices. The U.S.’s no-till movement began in the 1940s, when soil conservation became a priority after plowing of arid Western land sparked the ruinous Dust Bowl, and newly available herbicides allowed farmers to kill weeds without turning soil. More than a third of U.S. cropland is now farmed without tillage, and another third is under so-called low-till management, according to U.S. Department of Agriculture (USDA) statistics.

Cover crops have also gained steam, though more slowly. In 1992, to reduce pollution into the Chesapeake Bay, the state of Maryland began paying farmers to plant cover crops on bare fields. Hill, despite being skeptical that he would benefit, was an early adopter. “It had nothing to do with climate or soil health,” Hill says. “All of us thought it was a bunch of environmental BS… Then we found that it works and saw that the soil started to change.” Where Hill grew cover crops, his soils eroded less and held more water.

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Planting cover crops is starting to catch on widely, with a 50-percent increase nationwide from 2012 to 2017.

Maryland now boasts the nation’s highest cover-cropping rate. Cutting-edge farmers like Hill have graduated from single-species plantings to diverse mixtures like the one he showed off in February, which provide not just erosion and runoff reduction but also nitrogen fixation and food for pollinating insects. The practice is starting to catch on widely, with a 50-percent increase in nationwide cover-cropping rates from 2012 to 2017.

The idea of paying farmers for actually drawing down carbon, however, has not taken off. No one knew how to accurately, yet affordably, measure the small, slow changes in soil carbon that might accrue over one or even multiple growing seasons. The gold standard for soil carbon measurement involves extracting multiple cylindrical cores from a field, drying them, combusting them in an oven, and measuring the carbon dioxide released – a time-consuming and expensive process.

Technology has finally started to catch up with ambition. Hill, like many farmers, now uses software that logs rivers of data about his farming practices – every time he drives a field, sprays a chemical, or plants a crop – into a software program called Granular, which helps him fine-tune his inputs and decision making. The same data, scientists realized, can be used to estimate a farm’s carbon sequestration and greenhouse gas emission rates.

Granular staff connected Hill with Nori, a startup company launched in 2017 by idealistic young environmentalists looking to use tech to bring down the costs of compensating farmers for carbon sequestration. Nori staff thought Hill's Granular data could help crack the carbon measurement problem. What followed was an educational process for both sides. Nori's founders weren't familiar with the subtleties of conservation tillage. Hill didn't know much about blockchain, the theoretically secure, bank-free technology that Nori wanted to use to funnel payments to farmers from carbon-dioxide emitters seeking offsets.

The startup company Nori divided Trey Hill's farm into parcels based on carbon storage capacity, which could then be purchased by companies and individuals looking to offset their emissions. CREDIT: NORI

After two years of conversation, Nori decided to sell credits based on five years' worth of Hill's carbon-sequestering practices, from 2014 to 2018. Nori would calculate Hill's climate impact using COMET-Farm, a digital tool produced by the USDA. COMET-Farm takes in farming practice information from platforms like Granular, mixes it with weather data from satellites and sensors and soil information from USDA databases, and uses sophisticated computer models to estimate how quickly carbon builds up in soils and greenhouse gases escape.

By not requiring a site visit or soil samples, which can run thousands of dollars, Nori kept verification costs low. The verification process cost Hill around $3,500, though he will need to pay for an audit in 10 years to confirm that carbon was actually stored.

On October 7, Nori offered Hill's credits for $16.50 per ton, with $1.50 going to Nori and $15 to Hill. A total of 342 buyers purchased 8,010 tons' worth of credits out of 14,011 offered, according to Nori. Available on the company's website are satellite images of Hill's fields along with the number of credits sold against each and even the names of some buyers, which included individuals looking to buy just a credit or two; companies such as the travel company BootsnAll, whose leaders wanted to reduce their firm's carbon footprint; and institutions like Arizona State University and the University of Southern California's Schwarzenegger Institute.

That radical transparency is what sets apart Nori's program for Hill. He now has blockchain-certified evidence that his crops are grown using climate-friendly

methods, which he hopes will help him sell wheat and soybeans for a premium, perhaps to affluent, climate-conscious consumers in the nearby Washington, D.C area. And he’s investing the money into making his operation even more sustainable. He just ordered a piece of equipment called a roller-crimper that kills cover crops without chemicals and plants a cash crop in the same field pass. Hill says the new machine will enable him to spray less herbicide and drive his fields fewer times in a season, racking up additional gains that will support further sales through Nori.

Despite the strong launch, Nori’s success is not assured. When I spoke with Christophe Jospe, Nori’s chief development officer, in December, he hoped to sell 100,000 tons’ worth of credits by the end of the first quarter of 2020, but to date the company has not held another sale; Jospe now says more than 150 farmers representing more than 500,000 acres are working through the verification process, with the plan to sell their credits later this year.

Growing numbers of scientists question the science underpinning the soil carbon sequestration gold rush.

Competitors are close on Nori’s heels. Last June, Indigo Ag announced that it would open a carbon market. The company will publish its monitoring and verification methods this spring and hopes to sell credits by the end of the year. A third organization, the Ecosystem Services Market Consortium, will target corporate, municipal, and other large buyers, offering credits for carbon sequestration as well as water quality and avoided runoff. The marketplace is piloting its program on 50,000 acres of farmland and has announced a nationwide target launch date of 2022.

With legislation that would provide incentives to adopt regenerative agriculture techniques under consideration in both chambers of Congress, farmers may soon have even more ways to get paid for fighting climate change. Things are happening internationally as well. Australia and the Canadian provinces of Alberta and Saskatchewan have paid farmers for soil carbon sequestration, and the French government in 2015 launched the “4 per 1000” initiative to increase soil carbon stocks by 0.4 percent per year.

“There’s very strong momentum,” says Lal. “I’m very impressed with what is happening.”

A growing number of scientists, however, are not as impressed as they’d like to be with the science underpinning the soil carbon sequestration gold rush.

In 2006, USDA soil scientist John Baker analyzed studies that had measured the effects of no-till on carbon through 1-meter-deep soil samples. Historically, most

studies have measured only the top 20 or 30 centimeters (8 to 12 inches) – the so-called plow layer – and found carbon building up there. The few studies that went deeper, however, often found that a roughly equal amount of carbon disappeared in the layers below 30 centimeters. No-till appeared to change the vertical distribution of carbon rather than the total amount sequestered, Baker and colleagues reported. More recent papers have confirmed Baker's findings.

Soil that is mechanically tilled falls apart in water [right], compared to non-tilled soil that contains more organic matter. LANCE CHEUNG / USDA

Cover crops have maintained a stronger reputation as a climate solution. The TNC study published this month estimated that if farmers around the globe adopted the practice, they could take up nearly half-a-billion tons of carbon dioxide annually.

But the study, like most others to date, relied on measurements made mainly in the plow layer. Recent deep-soil studies have questioned cover crops' climate benefits. In a 10-year experiment that sampled down to 1 meter, soil scientists at Iowa State University found that deep-rooted perennials and cover crops revved up soil microbes that released much of the crops' deposited carbon back into the atmosphere. "Simply adding more carbon in doesn't necessarily mean that carbon is going to stay there," says study coauthor Steven Hall.

University of California, Davis researchers, in a 19-year study that measured down to 2 meters' depth, found that cover-cropping alone didn't add carbon, unless supplemented by compost, which can be expensive. "It was really surprising to us," Nicole Tautges, the study lead, says. "The way we see it, at least in our semi-arid Mediterranean production context, cover crops don't seem to be doing what people say they do."

Still other studies have found that increasing soil carbon can, in some cases, supercharge soil microbes that consume nitrogen and emit the powerful greenhouse gas nitrous oxide, potentially offsetting carbon sequestration's climate benefits unless nitrogen fertilizers are carefully managed.

Studies questioning soil carbon sequestration's benefits, however, are often conducted at long-term university or government research plots, which do not necessarily replicate the many and various management decisions made on real-world farms, experts say. "The papers that go against the initiative I think have as many holes as the papers that argue that you can do it," says Mark Bradford, a soil scientist at the Yale School of Forestry & Environmental Studies.

Existing methods cannot accurately measure how quickly carbon accumulates on a particular farm.

COMET-Farm, the tool Nori relies on, reflects both the promise and the limitations of today's soil science. It is based largely on computer models that the U.S. uses to annually report agriculture-related greenhouse gas emissions to the United Nations. Numerous people, including Bradford, say these models – validated by data gathered from more than 100 research sites – are among the best attempts to simulate soil's complex chemistry and biology.

But even 100 sites capture only a tiny sample of the 300,000 known soil types and the thousands of decisions a farmer could make over a career's worth of growing seasons. COMET-Farm also essentially punts on the deep soil question, considering only changes in carbon in the upper 30 centimeters of the soil.

For William Schlesinger, president emeritus of the Cary Institute of Ecosystem Studies in Millbrook, New York, who has strongly questioned whether soil carbon sequestration can fight climate change, ignoring the subsoil is a potentially fatal flaw for emerging carbon markets. "Before payments were achieved, I'd want to see somebody having sampled down to 1 meter depth, and only pay for the net total accumulation, if any," Schlesinger says.

Keith Paustian, a soil ecologist at Colorado State University who leads the development of COMET-Farm, says his team will soon publish statistical uncertainty estimates for the model's predictions, which will aid Nori and other users. But he thinks the science is already robust enough to support carbon markets. "We've got a pretty solid empirical base from decades of soil science and field measurements," Paustian says. "I definitely think that we know enough to move forward."

Last year, Bradford assembled a group of researchers from academia and conservation to assess whether available science supported soil-based climate solutions. In a paper in *Nature Sustainability*, the authors agreed that regenerative agriculture practices can sequester carbon. But they acknowledged that existing methods cannot accurately measure how quickly that carbon accumulates on a particular farm. One of Bradford's doctoral students is developing a handheld field scanner to provide such measurements by correlating properties of light reflected off of soils with soil carbon content.

Corn grows on a North Carolina farm that uses no-till agriculture, which helps maintain carbon-rich soil structure.
SAM RAY / SHUTTERSTOCK

Bradford also calls for dedicated experiments to sample a far wider range of farms, growing practices, and soil types. He is advising Indigo Ag on such a project, the Terraton Experiment, that’s slated to run through at least 2029 and will support the company’s carbon market. The study has already sampled soils on tens of thousands of acres, some to a depth of 1 meter, and will ultimately compile the biggest dataset ever collected to assess the climate impact of farming practices, says Dan Harburg, Indigo’s senior director of systems innovation.

One participating farmer, Tom Cannon of Oklahoma, told me Indigo researchers visit his farm weekly to take soil samples and interview him about his practices. “It’s the most comprehensive amount of data anybody has asked me for,” he says.

Beyond scientific and measurement uncertainties, scientists also worry that simple biophysical limitations of soil carbon sequestration are being overlooked. USDA’s Baker notes how easy it is for carbon stored in topsoil to be released back to the atmosphere if, say, a farmer decides to till after years of no-till, or soil microbe respiration rates increase as the globe warms – something predicted by multiple studies. “You’re not locking carbon in a vault,” he says.

Additionally, notes Hanna Poffenbarger, a soil scientist at the University of Kentucky, no soil is a bottomless carbon sink. Even topsoil, where potential carbon gains are best documented, re-equilibrates to a stable carbon concentration after a few decades of no-till farming or cover cropping. A 2018 review from researchers in the United Kingdom noted that that is already happening in some places.

Everybody I spoke with agrees that regenerative agriculture is good for soil health and has important environmental benefits that may be worth paying for. Most believe that soils may have a role to play in drawing down carbon. But nearly all scientists also want more certainty before wholeheartedly endorsing fighting climate change using farming practices.

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Says Baker: “To rely on those for real mitigation of climate change is, I think, a risky business.”

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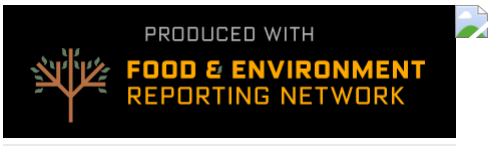

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