Shoring up the corn belt's soil health with NASA satellite data

29 July 2021, by Lina Tran

A true-color satellite image and topographic map of a field near Clear Lake, Iowa. Scientists took advantage of the contrast between the dark-colored topsoil and lighter-colored poorer layers beneath to estimate the Corn Belt's soil loss. Light-colored areas outlined in black are predicted to have lost topsoil. Topographic map shows widespread erosion on slopes: Red pixels mark convex slopes, or hilltops, while blue pixels mark concave slopes, or the hollows between hills. Hilltops appear lightest, while dark, displaced soil pools in the valleys. Credit: Evan Thaler et al. 2021/©2013, DigitalGlobe; NextView License/Maxar, Inc.

After the corn harvest last fall, Illinois farmer Paul Jeschke planted a fraction of his fields with cereal rye: 60 acres of the 4,500 he farms with his wife, nephew and brother-in-law, tucked behind a pasture, out of neighbors' sight. That way they could experiment with cover crops, Jeschke explained, and no one could view potential failures.

In the coming months, the rye would sprout into a rolling sea of grass. Below ground, it would feed soil microbes and scavenge nitrogen leftover from the corn, preventing it from entering the Illinois River 10 miles away. Above, the thick stand would protect the field from the wind and water that strip soil.

"This is a radically different farming system, and it takes an adventurous mindset to risk growing a crop in such a manner," Jeschke said. Cover crops are grown not to be harvested, but to shield and improve soil when a cash crop isn't growing. "My thought is we're going to have to figure this out sometime or another, and I'd rather do it on the early side than when it may be required."

Soil is the foundation of our food systems, and sustainable farming depends upon healthy soil, which has impacts far beyond the field on air, water and climate. Wind and water, hastened by human activity and climate change, erode the richest soil at the surface. The United States loses around five tons of soil per acre each year, 10 times the rate at which it forms. That's the equivalent of a layer as thick as a dime—which may seem slight, but soil is precious and the layers add up in the long-cultivated Corn Belt.

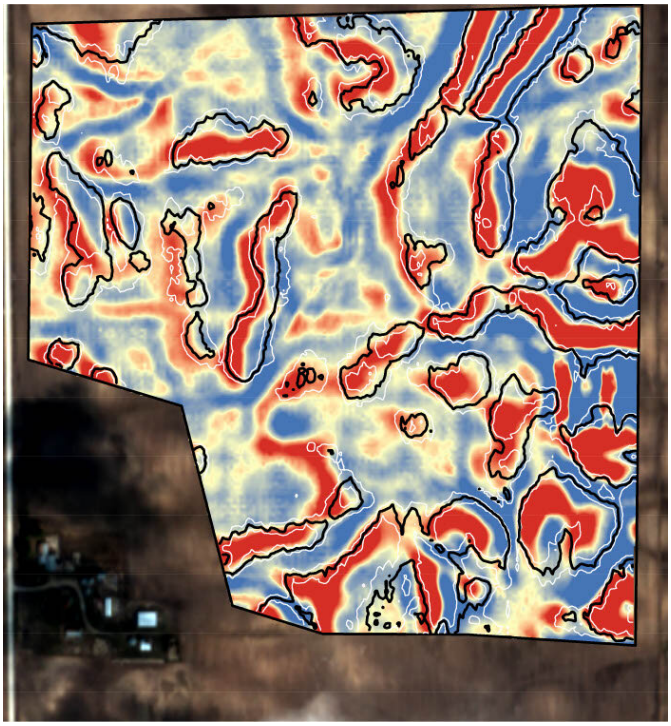
Building soil health is the leading strategy for controlling erosion. Healthy soil is rich with biodiversity and organic matter—the better to glue and anchor clumps of earth. Practices like cover crops and no-till planting are proven to boost soil health. But adopting new ways comes with obstacles, something Jeschke is familiar with in his fourth year of trials.

Hundreds of miles above the Corn Belt, NASA satellites provide critical views of the region. They're helping scientists study soil loss over time and develop tools to support farmers as they adopt and manage conservation techniques.

"The good that conservation practices do is significant," said Laura Gentry, a University of Illinois adjunct assistant professor and director of water quality research at the Illinois Corn Growers Association. She is a partner with NASA Harvest, NASA's food security and agriculture program within the Earth Science division. "Whatever the hurdles are, it's worth it to help farmers address them."

Tracking soil erosion

The Corn Belt is home to the nation's most productive soils. "They should be viewed as a national treasure," Gentry said. "If we aren't doing a good job of protecting them, people all over this country will feel it."



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Bit by bit, wind, water and gravity strip away valuable topsoil. That much is natural, but extreme weather and tillage—overturning soil to prepare it for planting—accelerate erosion. Eroded soils are less productive and leach nutrients. The poorer they are, the more they erode.

Once it's uprooted, soil—and everything in it—is considered pollution. Farmers may compensate for lost nutrients with more costly fertilizers. That sends more pollution into waterways, which impacts local water supplies, and, at worst, leads to disturbances downstream like the Gulf of Mexico's dead zones.

"Erosion affects people on that farm, in that rural community, and in the larger watershed, statewide, regionwide—really the whole country," said Skye Wills, national leader of soil science research at the U.S. Department of Agriculture's National Soil Survey Center in Nebraska. "It just scales up."

Soil also stores carbon: the remnants of once-living things like plants, microbes and insects. When it's disturbed, it releases that carbon to the atmosphere as carbon dioxide, an important greenhouse gas. As one of Earth's biggest carbon sinks, meaning an area that absorbs large amounts of carbon, soil represents an important part of the global carbon cycle.

Views from space help researchers study big-scale problems. NASA's MODIS, or Moderate Resolution Imaging Spectroradiometer, instruments on board the Terra and Aqua satellites, along with the joint NASA-U.S. Geological Survey's Landsat satellites, provide regular observations across the region. Starting with the launch of Landsat 1 in 1972, Landsat's record stretches nearly 50 years back, helping scientists track decades-long changes.

Assessing the extent of erosion has long required time-consuming surveys, but the availability of satellite data and powerful computing tools has led to novel, region-wide approaches.

The Corn Belt is known for its fertile topsoil, the product of millennia of deep-rooted prairie grasses. From space, it looks like dark chocolate, while poor, eroded layers are a lighter milk chocolate. "You can see this driving around or scrolling through Google maps across the Midwest," said Evan Thaler, a University of Massachusetts Amherst geosciences Ph.D. student.

In a recent NASA-supported study, Thaler and his colleagues took advantage of this contrast to estimate the region's total soil loss. Combining topographic data and satellite imagery, they found widespread erosion on slopes. Hilltops appeared lightest, while dark, displaced soil pooled in the valleys.

This pattern suggests tilling is responsible for the most dramatic displacement, Thaler explained. When soil is overturned, it slips down hills, little by little.

Overall, the group estimated roughly one-third of the region's farmland has lost its topsoil entirely. They estimate farmers shoulder up to $3 billion in resulting annual losses.

Much has changed over time. Tilling is far less intense than it was just 50 years ago, said Brian Gelder, a soil scientist at Iowa State University in Ames. Erosion results from many processes occurring at different rates. As climate change leads to more extreme rainfall or drier fields, the picture will continue shifting.

By regularly tracking erosion, researchers can examine how these different processes interact. Gelder co-leads the Daily Erosion Project, which provides farmers and watershed managers estimates of erosion and runoff in Iowa, Nebraska, Minnesota, Kansas and Wisconsin. The team's model is based on topographic and weather data, as well as Landsat and Google Earth Engine to identify tillage practices and the Cropland Data Layer from the USDA's National Agricultural Statistics Service, which draws upon Landsat to identify what grows where each year.

"Satellite views allow us to stay current," Gelder said. "Without them, we wouldn't be able to continuously update our models."

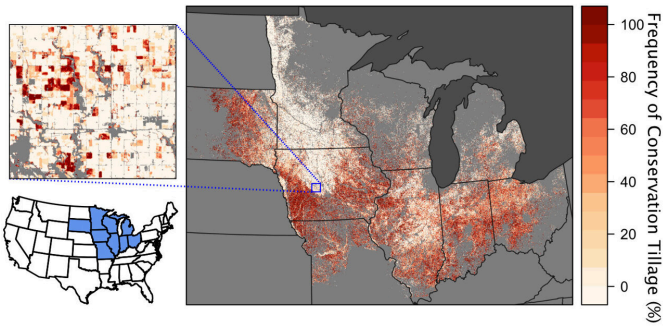
Building soil health

Nationwide, soil conservation was born of the 1930s Dust Bowl, which showed how devastating erosion can be. In response, the U.S. government formed the USDA Soil Conservation Service (now the National Resources Conservation Service), which encouraged methods like cover crops and no-till farming, where new crops are planted directly into the residue leftover from the previous year's harvest. The USDA continues to survey erosion nationwide and help land users design and implement erosion control systems.

"This small handful of in-field practices—reduced tillage, cover crops and nutrient management—are the heroes of multiple natural resource concerns," Gentry said. Together, they reduce erosion, improve water quality, enhance biodiversity and increase soil organic matter. "We're doing all of this with the same practice on the same acre."

Still, no-till acres represent just 21% of U.S. farmland, though combined with reduced-till, they outnumber intensively tilled acres. Cover crops, like Jeschke's cereal rye, are less prevalent, but the landscape is changing rapidly. In 2017, cover crops were grown on 3.4% of cropland—a 50% increase since 2012, according to the U.S. Census of Agriculture.

While the numbers are rising, they reflect the fact that adopting these techniques isn't simple. Besides financial barriers, farmers must learn to control weeds, manage new crops and balance the needs of the cover crop with their primary ones.



Satellite mapping of frequency of conservation tillage in the Corn Belt from 2005-2016, based on data from Azzari et al. 2019. Credit: Jillian Deines et al. 2019

Extreme rainfall associated with climate change in the Midwest presents another hurdle. Intense spring rains delay planting, lowering yields, and higher erosion rates follow delayed planting if summer thunderstorms hit fields before crops establish. Yet conservation methods can boost climate resiliency; healthy soil, for example, effectively filters and stores moisture.

Ultimately, Jeschke said, "the bottom line is the yield." In previous years, he planted the cereal rye by plane, releasing seeds as it flew over the field. But he never achieved much germination that way, and last year opted for the pricier method in which a specialized machine pushes seeds directly into the ground. This is the first season he has enough growth to even begin to assess how the cover crop fields perform against conventional ones.

Satellites provide big-picture insights. Stanford University postdoctoral researcher and NASA Harvest partner Jillian Deines used a combination of machine learning and data from Landsat, MODIS and ESA's Sentinel-1 to examine conservation tillage's impacts on yield across the Corn Belt. Between 2005 to 2017, she found long-term low-till fields experienced an average yield increase of 3.3% and 0.74% for corn and soybeans, respectively.

"Some farmers might see reduced tillage as something they want to try for soil health, but they're worried about hurting their yields," Deines said. "What we see is you can use these practices without hurting your yield in a way that's likely to matter to your bottom line, particularly since reduced-till also reduces fuel and labor costs."

Other researchers are building tools to support farmers with the transition and management. Kaiyu Guan, a University of Illinois professor and computational environmental scientist also working with NASA Harvest, built a model that marries Landsat, MODIS and ESA's Sentinel-2 observations to create a deep data record. Integrated with information on soil and weather, the model leverages a field's history to make informed decisions.

Guan likened the effort to medicine, where patients receive individualized prescriptions. "Satellite data helps us understand the field's conditions and history, and provide a customized 'prescription,'" he said.

Farmers must decide when to plant their fields and when to kill the cover crop, when to apply fertilizers and how much. Left to grow too long, cover crops compete with cash crops when they absorb nutrients or water. Guan's lab is developing complex models alongside field experiments to provide such recommendations to farmers.

Six months after it was planted, the grass' job was complete. Jeschke killed the crop in late May and planted soybeans into the green. Within a month, it faded to a blanket of golden straw. Not long after that, soybean leaves began to peer from beneath.

The plants appeared healthy: They were the same size as those planted in the fields without cover crops. "The results of the yield this fall will be the big determination as to how successful the practice will be for us this year," Jeschke said. "Time will tell."

Provided by NASA's Goddard Space Flight Center

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