Science Societies

Conservation agriculture, condensed

Synthesizing Its Impact on Greenhouse Gases and Carbon Sequestration

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Barley on a long-term conservation agriculture trial plot at CIMMYT's headquarters in El Batán, Mexico. Here, barley grows in rotation with maize, under zero tillage on the flat, with removal of wheat residues for fodder and retention of maize residues. Photo courtesy of CIMMYT/Flickr.

- Conservation agriculture covers a range of practices, including cover crops, crop rotations, improved irrigation systems, crop residue management, and no-till or minimum tillage.
- A new special section in the *Soil Science Society of America Journal* highlights new research detailing conservation agriculture's impact on reducing greenhouse gas emissions and enhancing carbon sequestration.
- One standout study uses meta-analysis to better understand which conservation agriculture practices positively impact carbon sequestration on a global scale.

Barley on a long-term conservation agriculture trial plot at CIMMYT's headquarters in El Batán, Mexico. Here, barley grows in rotation with maize, under zero tillage on the flat, with removal of wheat residues for fodder and retention of maize residues. Photo courtesy of CIMMYT/Flickr.

Researchers walk a tightrope strung between two competing poles. One pole is the constant, monumental effort to concisely communicate research in the hopes of seeing it put into practice. The other is the simple fact that scientists on the ground are conducting research in specific locations, under specific conditions.

"It is a challenge to come up with soil and crop management recommendations that cover different soils and climatic regions across the world," says ASA and SSSA member Craig Drury.

Meta-analysis can help. Instead of making recommendations based on a single study in a single location under singular conditions, a meta-analysis synthesizes. It pools data from similar studies, increasing their statistical power and giving us a much clearer picture of broader trends. As Madeline Fisher **wrote in this magazine** six years ago, "Scientific debates, even small ones, are never resolved by a few experiments."

These days, a debate smolders about conservation agriculture and the many on-farm practices it encompasses. How can farmers use conservation agriculture to help sequester carbon and decrease greenhouse gas emissions?

This is the question that a new *Soil Science Society of America Journal* (SSSAJ) special section sought to answer. The section, titled "The Role of Conservation Agricultural Practices on Reducing Greenhouse Gas Emissions and Enhancing C Sequestration," brings together studies from across the globe and is edited by Drury (an Agriculture and Agri-Food Canada soil biochemist), ASA Fellow Jane Johnson (a USDA-ARS research soil scientist), and SSSA and ASA Fellow and former SSSA president Charles (Chuck) Rice, (distinguished professor of soil microbiology at Kansas State University).

Here, producers in Brazil harvest soybean while a planter follows behind, planting corn. Photo courtesy of Darren Goebel.

Of the 10 distinct papers, the editors' top pick was a meta-analysis by Rodrigo Nicoloso, a researcher for Embrapa Swine and Poultry in Brazil, co-authored by Rice. The study, "Intensification of No-Till Agricultural Systems: An Opportunity for Carbon Sequestration," synthesizes findings from 121 studies, spanning six continents and 19 countries (**https://doi.org/10.1002/saj2.20260**).

Here, all three guest editors and Nicoloso weigh in on the meta-analysis' findings, the importance of documenting complete data sets, and how the special section can help policymakers and scientists alike better understand how agricultural management impacts carbon sequestration and greenhouse gases.

Getting Meta

Though the guest editors had the idea for a SSSAJ special section in 2019 at the Global Research Alliance's (GRA) meeting of the Croplands Research Group, the meta-analysis was in the making way back in 2008. At the time, Nicoloso was studying for his Ph.D. at Kansas State University with Rice.

"In 2008, people were already talking about carbon sequestration and no-till, saying that if you sample soils deep enough, the difference between tillage and no-till soils disappears," Nicoloso explains. "There were a couple of meta-analysis papers showing this effect, but most of these studies were from temperate regions with very little crop diversity."

The seed of an idea for a broader, more representative meta-analysis of tillage and carbon sequestration was planted then. But it wasn't until 2018, when Nicoloso took a post-doc position at Kansas State University while on sabbatical from Embrapa, that the Rice and Nicoloso finally started the meta-analysis you can read in SSSAJ today.

It compared paired tillage and no-till studies from different climates across the world. Nicoloso initially compiled more than 200 studies but had to pare them down as he realized some were missing essential data. Without those data, some of the studies weren't helpful for comparing the factors contributing to similarities and/or differences between the studies.

“We were looking for paired no-till and tillage plots, but we were also looking for studies showing a pre-treatment baseline for soil carbon stocks," Nicoloso says. “If you don’t have a baseline, you can’t distinguish between carbon sequestration and just avoiding losses.”

Nicoloso also looked for studies with the information necessary to calculate soil masses and soil carbon stocks. He cut out studies that did not have the same crop treatment in both systems, and he organized the studies according to tillage intensity: no-till, then alternative minimum tillage practices (strip, rotary, ridge, stubble-mulch, etc.), disk plow, chisel plow, and finally moldboard plow.

These farmers from Zimbabwe practice conservation agriculture by incorporating green manure crops on their farm. Photo by Sheila Chikulo/CIMMYT.

Three other major variables the duo considered included total nitrogen stocks, climate, and the number of crops in the rotation and their frequency. Nicoloso mentioned that the toughest variables to pin down were important information about clay, silt, or sand content in corresponding soil depths in which researchers measured soil organic carbon and total nitrogen. Because this information was underreported, they could not analyze the impact of soil texture on carbon or nitrogen storage.

Taken together, the data covered 8 of the 12 soil orders according to the USDA soil taxonomy, 953 comparisons of soil organic carbon stocks, and 431 comparisons of total nitrogen stocks.

Data, Synthesized

After corralling 121 different studies, pooling the data, and running statistical analyses, Nicoloso and Rice's findings showed a few key things.

First, they discovered that overall soil organic carbon (SOC) stocks were higher in no-till soils compared with tillage—particularly in the first 15 cm of soil, but even as far down as 100 cm. No-till systems also had higher levels of total nitrogen in the system. They found that carbon sequestration throughout the soil profile was more likely in no-till systems with increased cropping intensity (i.e., double cropping) and diversity, particularly with legumes.

Using legume cover crops helped soils in both tillage and no-till systems alleviate nitrogen losses and sustain carbon sequestration. But in no-till systems, adding legume cover crops promoted increased carbon inputs to the system and supported elevated levels of total nitrogen.

Things get really interesting when you take cropping intensity and climate into account.

"In warmer, tropical regions like Brazil, no-till was very important for soil conservation. You have very strong, concentrated precipitation that can lead to soil erosion," Nicoloso says. Using cover crops and no-till systems can prevent erosion, store water in the soil, and make it possible for farmers in these regions to adopt incredibly intensive systems. In fact, some farmers in Brazil's most productive region—Cerrado—employ a three-crop rotation in a single year, where a corn planter follows right behind a soybean harvester, planting the next season's crop.

A farmer's field in Malawi under conservation agriculture, showing rotation of maize and groundnut and the retention of crop residues. Photo by T. Samson/CIMMYT, Flickr.

The meta-analysis supports sustainably intensifying cropping systems in regions that can support three crops per year, like Cerrado. Doing so could help farmers increase their soil organic stocks, improve their nutrient cycling, and help alleviate the impacts of climate change, Nicoloso explains.

"When we started this study, we kind of knew that no-till systems were better than conventional till," Rice says. "But what no-till systems really allow farmers to do is to look at increasing crop rotation, double-cropping, adding legumes. No-till, with its water savings and planting timeliness, really allows for the system to take advantage of intensification and diversification."

The Big Picture

Our world, with its rapidly changing climate, desperately needs more sustainable agricultural practices. Meta-analyses like the work done by Nicoloso and Rice support farmers in finding systems that work best in their locations, with their particular tools, by taking a bird's-eye view of all the relevant research.

Together, the 10 papers published in the SSSAJ special section highlight the latest research that can help scientists, producers, and policymakers strategize, helping agriculture become part of the climate change solution.

"What's really great about this section—and the meta-analysis—is that this research has been going on for a long, long time," Johnson says. When it comes to tough issues

like climate change, research from Society members and GRA participants is key for helping policymakers craft informed policy. “Really, this is all about the opportunity for us to understand what co-benefits and tradeoffs we have to face to make sure we’re feeding people *and* taking care of our planet.”

Dig Deeper

- The *Soil Science Society of America Journal* (SSSAJ) special section, “The Role of Conservation Agricultural Practices on Reducing Greenhouse Gas Emissions and Enhancing C Sequestration,” can be found here: **https://bit.ly/3mwURjo**.
- The special section’s introduction, “The Role of Conservation Agriculture on Reducing Greenhouse Gas Emissions and Enhancing Carbon Sequestration in Soils,” can be read here: **https://doi.org/10.1002/saj2.20323**.
- Find the meta-analysis, “Intensification of No-Till Agricultural Systems: An Opportunity for Carbon Sequestration,” here: **https://doi.org/10.1002/saj2.20260**.
- Read the *CSA News* magazine article, “Moving Science Forward Through Meta-analysis,” here: **https://doi.org/10.2134/csa2015-60-5-1**.

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