Science Societies

Study sheds light on sustainability practices that make for more resilient soybean

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Sustainability Practices That Make Resilient Soybean Systems

What makes a soybean system more resilient in the face of drought, floods, and other weather extremes? Decades of research in Tennessee suggest that diversified management practices, including crop rotations and poultry litter applications, can strengthen both yields and soil health for the long haul.

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(coming soon).

Over the last 25 years, Tennessee growers have experienced pretty much every kind of extreme weather: droughts, floods and heavy rainfall, extreme heat, sudden cold snaps and freezes, tornadoes, hail—you name it, says Virginia Sykes, a plant scientist at the University of Tennessee, Knoxville. The university's test plot soybean fields lived through it all. The fields recorded how the crop responds to those extremes as well as to more normal weather, how soil health changes over time and how the crop responds to that, and how both the crop and soil health respond to various treatments and management practices scientists have thrown at the test plots.

Scientists have been working on sustainability options with these plots since 2001—introducing different cover crops, biocovers, and crop rotations. Several things have become clear, Sykes says. One, "these long-term studies are really critical" for seeing how management practices change the soils over time. Two, poultry litter helps increase soybean yield and should be strongly considered by farmers. And three, "these sustainability practices make for a more resilient system that is more stable in the long term."

Now, results from the two-decade experiment show just how important those management choices can be. Sykes and her colleague Isaac Mirahki, then a post-doc in Sykes' lab, found that combining crop rotations with biocovers such as legume cover crops and poultry litter consistently improved soybean yields compared with

simpler no-till systems alone. The findings suggest that diversified management systems can strengthen both soil health and crop resilience over time, reinforcing that no-till alone may not deliver the full benefits often associated with conservation agriculture.

The power of diversification

No-till farming is a cornerstone of sustainable agriculture. As of 2022, 93% of Tennessee farm acreage was managed under no-till conditions, far exceeding the national average. In keeping with the state trend, the two Knoxville research plots have both been managed under continuous no-tillage practices since the start of the long-running experiment, which was started by Fred Allen in 2001 and taken over by Sykes in 2016. For this study, published in *Agronomy Journal* in March, Sykes and Mirahki wanted to see how additional sustainable agriculture practices would affect soybean yield and soil health.

The pair assessed 10 crop rotation sequences of corn, cotton, and soybean at one site and seven rotation sequences of corn and soybean in a different rotation at the other site. Soils at both sites were silt loam. Over time, they found that crop rotations alone resulted in yield gains between 1 and 32%. The greatest increase in soybean yield occurred with a corn–soybean rotation as the two crops work together to enhance soil nutrient cycling and promote microbial diversity.

A recent study published in Agronomy Journal assessed 10 crop rotation sequences of corn, cotton, and soybean at one site and seven rotation sequences of corn and soybean in a different rotation at the other site. Over time, they found that crop rotations alone resulted in yield gains between 1 and 32%.

Overall, diversified crop rotations proved better than soybean monocultures at both sites, Sykes says. "To have a soybean year after year after year, you're going to start getting some pretty significant yield declines." By rotating them, farmers will have better harvests and a more sustainable approach, Sykes and Mirahki wrote in *Agronomy Journal.*

Crop rotations suppress pests, diseases, and weeds; enhance soil fertility; boost crop yields; mitigate nutrient depletion; reduce erosion risk; and improve soil physical properties like structure and permeability. “By systematically alternating crops in temporal and spatial sequences, this method mitigates nutrient depletion, as different species vary in their demands for soil resources, thereby preventing the exhaustion associated with monocultures,” Sykes and Mirahki wrote.

Sykes and Mirahki also compared several biocovers—two legumes (Austrian winter pea and hairy vetch), wheat, and poultry litter—against a winter fallow control. Generally, cover crops did not offer a yield advantage compared with the winter fallow. Wheat showed variable performance year over year, with small yield deficits within a few rotations, Sykes says. This could be due to nitrogen immobilization, she says, which can occur with cover crops that have a higher carbon-to-nitrogen ratio. Legumes also showed variable performance but generally did not increase soybean yield. However, Sykes says, “while we aren’t increasing yield, we also aren’t reducing it, which is an important factor.” And there are other benefits to cover crops, she says.

Austrian winter pea, fallow, and wheat are shown in the vertical plots with crop residue from the previous year's corn, soybean, and cotton crops shown horizontally.

Poultry litter, however, was a standout: Using it as a natural fertilizer, poultry litter yielded up to 31% more soybean than the fallow site with gains year after year. Poultry litter likely provided bioavailable nitrogen, phosphorus, and potassium, which boost soil fertility. It also likely improved soil structure and water retention. Additionally, Sykes says, courtesy of the long-running study, the researchers could tell there is a cumulative effect on system productivity from decades of organic amendment application.

Using it as a natural fertilizer, poultry litter yielded up to 31% more soybean than the fallow site with gains year after year. USDA photo by Bob Nichols.

Why it's not an either-or choice

The results of this study thus appear to favor poultry litter amendments over cover crops. But it's not exactly a fair comparison, Sykes says. For one thing, in this study, the cover crops are planted as late as possible and terminated as early as possible. So "what we saw is probably the minimum benefit you could get from cover crops," she says. If planted earlier and terminated later, farmers could maximize cover crop benefits, she notes. "In those systems, you would get more biomass and with cover crops, more biomass generally means more benefits and faster accumulation of those benefits." Such benefits include pollinator habitat, slowly building soil organic matter, improving soil structure, preventing erosion and runoff, suppressing weeds, and retaining nutrients in the system without reducing yield, she says.

This photo shows hairy vetch on the left and wheat on the right close to termination. In this study, the cover crops were planted as late as possible and terminated as early as possible.

Also unfair is pitting cover crops against soil amendments, Sykes says, when in reality, farmers would do well to use both. Future research should focus on how these strategies work together, she says. Poultry litter currently isn't widely used as a soil amendment in Tennessee, but these results indicate more farmers should consider adding it. It's becoming more readily available as well. Pairing cover crops with poultry litter could be even better, providing a one–two punch: Poultry litter can supply nutrients quickly, while

cover crops gradually improve soil structure, support beneficial microbes, and help fields better withstand stress over time. Adding crop rotation could strengthen those benefits even further. And as we see more weather extremes, Sykes says, growers will need every resilience advantage they can get.

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Yields will vary year to year, depending on conditions, and the benefits farmers will see from amendments, cover crops, and crop rotations will also vary, Sykes says. "Some years, one of these sustainability practices will be better than another, but in general, they're all going to be better than the conventional approach."

Putting decades of data to work

Choosing the right sustainability practices can be challenging. Farmers should work with their CCA or local extension specialists to determine which crop rotations, cover crops, and soil amendments make the most sense for their soils and climates since practices that work well in Tennessee may not perform the same way in Iowa or California. Farmers can also turn to resources like the North American Project to

Evaluate Soil Health Measurements, which runs a database of long-term soil health studies from across the country, including this one.

Sykes also hopes that one day, scientists can turn these decades' worth of research data into practical decision-making tools for farmers. Precision agriculture researchers have already developed tools to help growers choose cover crops, optimize planting dates, and determine ideal termination timing, she says. She would like to see similar tools for crop rotations—programs that could pull from long-term datasets and help farmers compare how different rotation sequences might affect yields over time. "We've got the data," Sykes says. "We need to take those data and make tools that are usable for people."

Along those lines, Sykes also hopes researchers can eventually identify the most effective crop rotation sequences for different regions and conditions. She is currently working on a paper examining corn and cotton yields from the rotations used in this study and would ultimately love to give farmers clearer guidance on combinations such as a 1-2-1-2 corn–soybean–corn–soybean rotation or a 1-2-3 corn–soybean–cotton repeat, or whatever combination proves most effective. We're not there yet, she says, but that's definitely a direction for future research. She is also working on a follow-up paper examining how these treatments affect soil health over time, particularly the buildup of soil organic carbon, nitrogen, and other key nutrients.

For now, the two-decade-long study in Tennessee is providing evidence that building healthier, more resilient soils is less about any single practice and more about how multiple strategies work together over time.

Dig deeper

Mirahki, I., & Sykes, V. R. (2026). Insights from a two-decade research on crop rotation and biocover impact on the sustainability of no-till soybean systems. *Agronomy Journal*, *118*, e70356. https://doi.org/10.1002/agj2.70356

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1. According to the study, what effect did crop rotations generally have on soybean yields?

a. They consistently reduced yields.

b. They had no measurable effect.

c. They increased yields in many systems

d. They eliminated the need for fertilizer.

2. How did legume cover crops generally affect soybean yield in this study?

a. They consistently reduced yields.

b. They had no measurable effect.

c. They increased yields in many systems.

d. They eliminated the need for fertilizer.

3. Which biocover treatment produced the largest soybean yield gains?

a. Poultry litter.

b. Hairy vetch.

c. Wheat.

d. Austrian winter pea.

4. Cover crops with a higher carbon-to-nitrogen ratio can sometimes lead to

a. nitrogen immobilization.

b. phosphorus fixation.

c. increased soybean yields.

d. Both b and c.

5. The results of this study thus appear to favor poultry litter amendments over cover crops. This is not a fair comparison, according to Virginia Sykes, because in this study, the cover crops were

a. planted as late as possible.

b. terminated as early as possible.

c. not suited to the region’s conditions.

d. Both a and b.

This quiz was drafted with AI assistance and reviewed by the editorial team for accuracy and appropriateness.

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