FEATURES

Agroforestry, Poultry Litter, and Soil Health

A Long-Term Experiment in the Ozark Highlands

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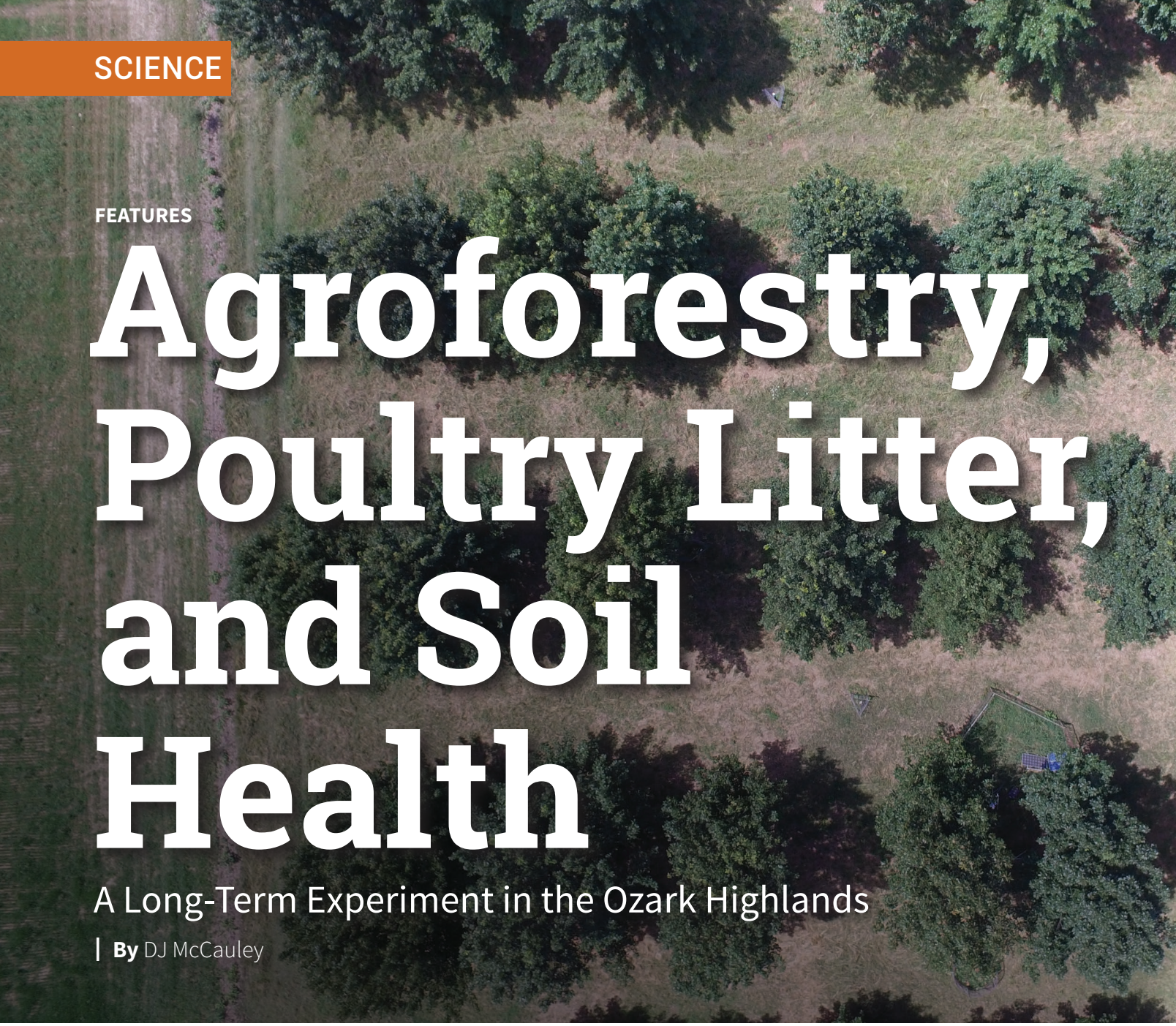

The Ozarks agroforestry site near University of Arkansas, viewed from above. Photo courtesy of Amanda Ashworth.

Agroforestry—the intentional management of trees along with pasture or crops—could be an important avenue for farmers to sequester additional carbon *and* make use of land unsuited for conventional crop production. Between widely spaced trees, producers can plant forages, which means feed for livestock and short-term income while the trees grow. Before long, the innovative farmer could harvest lumber, nuts, or fruit from those trees. It creates multiple revenue streams on one piece of land while increasing biodiversity and sustainability.

But how do you manage those trees? How are they impacting soil health?

These are the questions that researchers in Fayetteville, AR seek to answer. Back in 1999, a combination of industry members, university researchers, and USDA-ARS scientists joined forces to create a long-term agroforestry site near the University of Arkansas.

Now, researchers are reaping the rewards of two decades of hard work as they see how tree species and management regimes impacted soil health. Using the Soil Management and Assessment Framework (SMAF), they detail how agroforestry management could help producers better manage and maximize soil health outcomes.

Coauthors Helen Amorim, Amanda Ashworth, and Tom Sauer weigh in, citing their recent publication in

Agroforestry is the practice of managing trees as part of an agricultural ecosystem.

For two decades, researchers in the Ozark Highlands have cultivated a long-term agroforestry site with multiple tree species under different fertilizer regimes.

Using the Soil Management and Assessment Framework, the team parsed out the interacting impacts of tree species and fertilizer on soil health in an *Agrosystems, Geosciences & Environment* article.

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Agrosystems, Geosciences & Environment (https://doi.org/10.1002/agg2.20194). Their paper is a standout submission to a special issue collated by editor Jerry Hatfield, titled "The Role of Innovative Cropping Systems to Enhance Soil Health and Cropping Resilience."

Let's dive in.

The Site

The little island of trees near the University of Arkansas is bordered by a freeway on one side and a bike path on the other. The tops of the cottonwoods poke above the canopy, outgrowing the orderly rows of pines, pecan, sycamores, and red oak trees surrounding them as forages like orchardgrass and a native warm-season grass mix grow below.

Aesthetically pleasing as it is now, it would be tough to picture what the field looked like in 1999 when it was just an abandoned, unproductive field in the corner of the research farm. But USDA-ARS researchers, including SSSA Fellow Tom Sauer, partnered with the National Agroforestry Center in Lincoln, NE, and the USDA-NRCS to plant out the site. They've been testing out a variety of tree species ever since.

They planted oak trees to satisfy a small market niche for lumber, pecans for nuts to harvest, and some pine. At the behest of Jim Jones of Hammons Black Walnuts, they also planted black walnut trees in the centermost rows. They left alleys between rows, planted with forages for grazing research.

"Around 2010 or so we realized the black walnut wasn't doing so well," Sauer says. He designed the site while he held the USDA-ARS position that SSSA and ASA member Amanda Ashworth now occupies—soil scientist in the Poultry Production and Product Safety Research Unit in Fayetteville. Now Sauer is stationed in Ames, IA.

Left: Amanda Ashworth (left) and Kent Heikens collecting soil samples in 2016. **Right:** Pecans harvested from trees at the Ozark agroforestry site. Photos courtesy of Tom Sauer.

In 2014, the crew chose three new tree species to take the place of the struggling black walnuts.

"Even though it's a small site, there's a lot of variation," Ashworth explains. "The east side has really nice soil, the middle is really wet, and the west is too rocky for a lot of trees to grow."

They tailored their picks to soil conditions. Pitch-loblolly pines were planted in the rocky west. The wet center got fast-growing, water-loving cottonwoods, and the well-suited east received sycamores. By 2021, the cottonwoods were already 70 ft tall.

Though the center rows changed drastically, the pecan trees in the southernmost section and the red oak in the north have remained the same since 1999. Management has been fairly consistent, too—for the first decade or so, the eastern half of the rows were fertilized with poultry litter (including manure and bedding material) while the west received inorganic nitrogen fertilizer. Poultry litter is an (over)abundant resource in Arkansas. In fact, poultry is the largest agricultural product in the state, garnering more than US$34 billion in 2014, according to the Arkansas Farm Bureau. By using poultry litter to fertilize trees, USDA-ARS researchers hoped to find both an inexpensive nutrient source and a means of preventing phosphorus buildup in the surface soil and loss into streams and waterways through runoff.

These constant factors—pecans, oaks, poultry litter, and inorganic nitrogen fertilizer—laid the foundation for a long-term comparative study. The team wanted to take a systems-approach to evaluate the effects of 20 years of management on soil quality and carbon storage. So began the foray into using the Soil Management and Assessment Framework (SMAF) on an agroforestry site.

Using SMAF for Agroforestry Soils

Helen Amorim came on board at the USDA-ARS site in 2019 as a visiting doctoral student from the Federal Rural University of Brazil in Lavras (UFLA), from which she graduated in the spring of 2021. Ashworth, armed with funding from a Foundation for Food and Agriculture Research (FFAR) New Innovator Award, tasked Amorim and a master's student at the University of Arkansas, Shane Ylagan, with finding a means of quantitatively measuring soil health outcomes so the group could compare the impact of tree species and management. They turned to SMAF.

"To start using SMAF, you must select the soil quality indicators," Amorim explains. The tool requires that you input a minimum data set, including at least one of each of three types of indicators: physical, chemical, and biological. "Once you have all these soil properties, you combine them into one integrated index. You get a score, from 0 to 1, which makes it much easier to analyze."

Members of the research team, including Jeff Cook (left), Robert Rhein (back, center), and Dirk Phillip (right), weighing out fertilizer treatments in 2019. Photo courtesy of Tom Sauer.

In fact, the SMAF tool was first published in *Soil Science Society of America Journal* in 2004 by thought leaders Susan Andrews, Douglas Karlen, and Cynthia Cambardella (https://doi.org/10.2136/sssaj2004.1945).

The final soil quality index (SQI) accounts for your soil's "inherent capability" based on location, including climate and soil type. As the SMAF tool generates your SQI, it also accounts for the crop you'll be growing, adjusting the score to match. Users input this information in the form of a crop code.

For example, if your soil tests low for phosphorus relative to your region, and you're planting a crop that requires a great deal of phosphorus, your score would be closer to 0 than if the crop required less P. This 0-to-1 scale helps take the guesswork out of management decisions for producers. Intuitively, if you see a lower score, you know you need to amend or improve that metric. It's much easier to interpret than seeing your soil has, say, a P content of 35 mg kg^{-1}. The SQI provides an algorithm-driven index informed by a huge collection of region-specific soil health and climate data.

But there's one little problem: there are *no* crop codes for trees.

"We used the understory vegetation instead," Amorim says. "It's not ideal, but it did give us somewhere to start since all the vegetation are forages at the site."

Without tree crop codes, the SMAF algorithms cannot interpret soil metrics in terms of the nutrient requirements of different tree species. Instead, the team attributed any differences in the SQI returned at the site to differences in tree species and management.

Unexpectedly, they found that there was an interaction between the tree species and fertilizer type in terms of soil organic carbon scores (the biological indicator in SMAF) and the overall SQI. The team found that red oak fertilized with inorganic N fertilizer had higher levels of soil organic carbon (SOC) than those fertilized with poultry litter. The reverse was true in pecan—SOC scores were higher under poultry litter than inorganic N.

"It was surprising to see that SQI differed by both species and fertility source," Ashworth says. "Overall, SQI was the highest in pecans that received poultry litter, which was slightly higher than in red oaks that received inorganic nitrogen combinations."

This round of soil health tests is just the beginning of the research going on at the Ozark Highlands site. Ashworth, Sauer, and multitudes of other collaborators are planning more studies, investigating the long-term benefits and impacts of management on these tree species.

Jeff Cook measuring groundwater depths at the Ozarks agroforestry site in 2019. Photo courtesy of Tom Sauer.

Practical Implications

"In agroforestry we typically use trees that are well adapted to low nutrient environments, and it's tough to find sufficiency readings for those tree species," Sauer says. "It's not like an orchard—often the best you can find is information from nurseries growing seedlings, and it's tough to translate that information to pine or oak trees in the field."

For producers, understanding best-management practices for agroforestry systems could mean better soil health outcomes. The study from the Fayetteville site shows how management and tree species can interact to change soil health outcomes. Knowing that pecans sequester more carbon under a poultry litter fertilizer regime could save you big bucks over the life of those trees.

And when it comes to innovative cropping systems, these researchers see tons of potential for creative, innovative, sustainable agriculture.

"You could integrate agroforestry with livestock, or with vegetable production, or with crops that need protection from wind," Jerry Hatfield says. "Agroforestry is not for everyone—it takes a different style of management. But we do know that these trees can be beneficial for crops, and they're putting a lot of carbon in the soil and storing it in the biomass of the trees."

Getting involved doesn't have to be complicated, either. Sauer has a great tip for sticking your toes in the waters of agroforestry.

"It could be as simple as thinning out some of the existing trees at the edge of your forest and planting forages for cattle to graze," Sauer says. "You'd have a silvopasture virtually overnight."

All told, the long-term agroforestry site in the Ozarks Highlands is a good example of how some trees can transform marginal land, conferring a multitude of environmental benefits. It's aesthetically pleasing, sequesters carbon, and provides shade and shelter for both livestock and researchers alike. As Amorim says, "It really is the best place to work."

DIG DEEPER

Read the *Agrosystems, Geosciences & Environment* (AGE) study, "Soil Quality Assessment of an Agroforestry System following Long-Term Management in the Ozark Highlands," here: **https://doi.org/10.1002/agg2.20194**.

Interested in other innovative cropping systems? Check out the AGE special issue, "The Role of Innovative Cropping Systems to Enhance Soil Health and Climate Resilience" here: **https://bit.ly/3ydGh5S**.

See the original SMAF study, published in the *Soil Science Society of America Journal,* here: **https://doi.org/10.2136/sssaj2004.1945**.

Finally, check out the latest edition (3rd) of the ASA book, *North American Agroforestry*, available at **https://bit.ly/3eb6XL8**. Get 35% off until 30 Mar. 2022 with discount code NAA35.