agro forestry

A growing science seeks to boost its practice

by Madeline Fisher

Shelterbelts, or windbreaks, protect adjacent field crops, reduce wind erosion, and store carbon. A typical, two-row, mixed species field windbreak will store between 15 and 30 metric tons of carbon per mile. *Photo by Erwin Cole (USDA-NRCS).*

Silvopasture is the practice of planting trees as shelter for grazing livestock. This photo shows beef cattle grazing on *Brachiaria brizantha* (grass) grown under *Eucalyptus* hybrid trees on a commercial farm in Brazil. *Photo by P. K. Nair, University of Florida.*

In the 1930s, millions of trees sprang up in America's Great Plains. As the Dust Bowl

raged, the federal government embarked on an ambitious plan to plant windbreaks, or shelterbelts, which could quell the region's eroding winds and stem the loss of topsoil. The goal was to plant belts that were 5 to 15 rows wide from the Canadian border to the Texas Panhandle. World War II ended the program early, but not before some 18,000 miles of trees were planted along section lines and around farmsteads throughout the Plains.

It was the United States' first large-scale attempt at agroforestry—the planting of trees to serve agriculture—and it wouldn't last. When center-pivot irrigation became popular in the 1960s and 1970s, the trees stood in the path of the swiveling equipment, and so people began chopping them down. So many trees were removed that today only about 3% of the region's croplands are protected by shelterbelts. That could soon be changing, however. As reported in a special section in the May–June 2011 issue of the *Journal of Environmental Quality* (JEQ), agroforestry seems poised for new success.

Although the science is still somewhat nascent, data have been steadily amassing over the past 20 to 30 years on what integrated systems of trees and crops can do for agriculture. In tropical regions, agroforestry is known to halt desertification, reclaim degraded land, and offer food and nutritional security to families. In temperate areas, meanwhile, research has focused on agroforestry's potential to provide environmental services, including soil conservation, biodiversity, carbon storage, and improved water quality.

Just as important, yet much less known, are the economic benefits to U.S. farmers. Nebraska windbreaks, for example, can boost corn and wheat yields by 12 to 15% and soybean yields by slightly more. And by planting trees as shelter for grazing livestock—a practice called silvopasture—farmers can increase their profit on each cow-calf pair by nearly $45, according to University of Missouri research, because cattle expend less energy staying warm in winter and cool in summer.

What this means is that agroforestry—once considered "a practice in search of a science"—is now on firmer scientific footing than ever before, says Shibu Jose, director of the Center for Agroforestry at the University of Missouri. But with adoption rates still low across much of the United States and the rest of the industrialized world, the question now, ironically enough, is whether the research will outpace the practice.

"The science is developing, but how do you transfer that science to landowners? That's a whole different ball game, and we have not done a great job of it," Jose says. "It's happening. But it hasn't happened at a scale or intensity yet that would really make a difference."

Age-Old Practices Bypassed by Green Revolution

That may be true in the United States, but in other parts of the world, growing trees, crops, and livestock together for economic and environmental gain is common practice. Indeed by the time the term agroforestry was coined in the late 1970s, it had been employed for decades or even centuries, says University of Florida distinguished professor and ASA, CSSA, and SSSA Fellow P.K. Nair, especially by poor farmers in tropical and arid regions that suffer frequently from soil infertility and declining productivity.

In Spain, for example, the "dehesa" silvopasture system is reportedly 4,500 years-old. One of Asia's most ancient farming systems is the home garden: a multi-story mixture of fruit trees, nut trees, and crops that provides families with sustenance, aesthetic beauty, and sometimes even cash. More recently, thousands of farmers in eastern and southern Africa have adopted "alley cropping," in which fast-growing, leguminous trees are planted between rows of maize to fix nitrogen for the crop.

The key to each system is that perennial and annual species are cultivated together to fill different niches. Home gardens, for instance, are "like a multi-story building," says Nair, who got started in agroforestry studying multi-level cropping systems in his native India. Leaves of the tallest trees occupy the top "floors," shorter trees and shrubs reside in mid-canopy layers, and annual crops grow on the ground. Likewise, the root systems of various plants penetrate different layers in the soil. "So there is complete coverage of the soil, and the ground and air above it," Nair says—and thus more efficient use of sunlight, water, and nutrients.

Also critical is the idea of "working" trees: those selected and planted not at random or for aesthetics, but strategically, for the landowner's advantage. Early agroforestry research, for example, emphasized "multi-purpose" trees whose many uses allow subsistence farmers to glean all they can from tiny plots of land. By the time Nair began studying the practices in the early 1970s, however, interest in them had declined for an ironic reason: The Green Revolution. The technological innovations of the era did, of course, feed millions of people. But they didn't apply to home gardens and other farmed mixtures of species, focused as they were on maximizing yields of commodity crops such as rice, wheat, and maize.

"So the developments in agriculture sort of bypassed these traditional systems," Nair says. "And that was the genesis of the concept of agroforestry." To support the fledgling science, in 1978 he helped found the International Centre for Research in Agroforestry (ICRAF), now the World Agroforestry Centre, in Nairobi, Kenya. Nair then worked there as a staff scientist before joining the University of Florida in 1987 to launch its agroforestry program.

Pioneering Research Reveals Ecological Benefits

Agroforestry was actually enjoying a surge of interest in the United States at the time, due largely to returning Peace Corps volunteers, who were intrigued by the practices they had seen

Alley cropping is the practice of growing annual crops in the interspaces (alleys) between widely spaced rows of trees and other perennials. This photo shows maize alley-cropped with fast-growing *Eucalyptus* hybrids in commercial farms in Brazil. *Photo by Laércio Couto, Brazil.*

Home gardens that consist of intimate, multi-story combinations of various trees and crops around homesteads provide food and cash security as well as social and aesthetic benefits to millions of farm households in the tropics. This picture shows a homegarden with coconut palms and various fruit- and nut-yielding trees in the background with a rice field in the foreground in India. *Photo by P.K. Nair, University of Florida.*

overseas and wanted to learn more. The 1990 farm bill also created the USDA National Agroforestry Center in Lincoln, NE. A partnership between the U.S. Forest Service and NRCS, its mission is to help accelerate agroforestry development throughout the United States by working with a national network of partners in research and natural resource assistance.

In Missouri, in the meantime, agroforestry was gaining ground through the work of temperate agroforestry pioneer H.E. "Gene" Garrett. Charged with building an applied research program that would help Missouri farmers when he joined the University of Missouri faculty in 1975, Garrett quickly homed in on black walnuts as a lucrative cash crop that was also underutilized. He soon learned why: Getting farmers to plant orchards of slow-growing walnut trees was tough. So, after some discussion, Garrett and his collaborators tried an experiment. They planted walnut trees in rows spaced 40 ft apart and then sowed annual crops such as corn, soybean, and milo in the wide alleys in between.

With the row crops there to provide income until the trees matured, farmers began recognizing the value of the approach and adopting it, Garrett says. He might have stopped there, but other advantages of the new cropping system kept catching his eye. Soybeans in alleyways, for example, actually yielded more than in open fields, especially during drought years—an effect Garrett's team tracked to reduced wind speeds, cooler temperatures, and consequently, less transpiration by crops and evaporation of water among the trees. Sediment loss and runoff also dropped dramatically when trees were present. Before long, Garrett realized the group needed to think more broadly. "There were a lot of ecological benefits that I could see in agroforestry," he says.

Soon alley cropping with chestnut, pecan, and oak began along with studies of silvopasture. In 1998, the Center for Agroforestry was founded, with Garrett at the helm. And the year before, Garrett's group established one of its most important experiments in a trio of adjacent, but separate, agricultural watersheds in northeastern Missouri. One watershed was left as a control, while the other two were each planted with a different "upland buffer": a series of grass strips and an agroforestry system containing both trees and herbaceous vegetation.

Like riparian buffers, upland buffers are designed to trap sediments, nutrients, and pesticides flowing from pastures and croplands; however, they aren't planted streamside, but directly in fields along the contours of the slope. "We see them as the first line of defense against contaminants getting into our waterways," Garrett says. "The final line of defense is the riparian buffer."

At first, a team of researchers at the Center for Agroforestry and USDA-ARS examined the buffers' ability to curb the movement of well-studied non-point sources of pollution, such as sediments, nitrogen, and phosphorus. A few years later, they added research on atrazine, a major herbicide in corn production. That's when the program really began to take off, Garrett says. In a series of new stud-

Agroforestry Strategic Framework

Agroforestry has been an active, although small, part of the USDA for at least two decades, ever since the USDA National Agroforestry Center (NAC) was authorized in the 1990 farm bill. Agroforestry could soon play a much bigger role across the USDA, however, thanks to the department's Agroforestry Strategic Framework, announced in June.

Aimed at boosting adoption of agroforestry practices, advancing the science, and integrating agroforestry into programs across USDA, the strategic plan has come about largely through the leadership of the U.S. Forest Service's Andy Mason, director of the NAC, and Bruce Wight, national forester for the NRCS. The pair began working on the strategy in 2009, after seeing signs that "maybe the time was right" to expand agroforestry's presence, Mason says. USDA had just released its latest strategic plan, for one, which contained goals clearly suited to agroforestry, including rural development, sustainable agricultural production, and improved water quality.

Then in August 2009, USDA Secretary Tom Vilsack gave a speech during which he presented his "all lands" vision for managing America's forests and other working lands. In the approach, problems such as water quality are addressed at the landscape or watershed level—across all land uses, land types, and forms of ownership—rather than on individual parcels, as mainly happens today. Although Vilsack didn't specifically mention agroforestry in his speech, Mason says, it had agroforestry written all over it.

Buoyed by these developments, Mason and Wight created an interagency agroforestry team in early 2010, which then worked with dozens of stakeholders to develop the framework. The team included the USDA's Farm Service Agency, ARS, and the National Institute for Food and Agriculture along with two key partners, the National Association of State Foresters and the National Association of State Conservation Districts.

Involving so many groups certainly complicates things, but it's also vital to achieving the plan's objectives. On the science front, knowing what agroforestry research different agencies are already doing means that efforts can be coordinated and top research priorities more readily identified. Better communication and cooperation should also foster wider implementation of agroforestry practices. "Part of the adoption goal is increasing the awareness and building the skill set of natural resources professionals whether they're in extension, NRCS people in a field office, or state forestry personnel—all the people who work with landowners and producers out there," Mason says.

Because NAC has traditionally focused on agroforestry's environmental advantages, bringing diverse agencies on board should also help meet economic development goals, Wight adds. This is why USDA's Agricultural Marketing Service and Rural Development agencies recently joined the team. "Engaging other members of the USDA family lets us look at other benefits, whether it's jobs in the rural sector or new products that landowners can use to diversify their operations," Wight says.

Besides, how better to support an integrated land management practice than with an integrated, interagency approach? "Agroforestry is a blending of trees and crops and forages and livestock. There's no single discipline that carries the whole weight," Wight says. "So, we have to work together."

For more information on NAC and the strategic framework, visit www.unl.edu/nac.

Upland buffers are planted directly in fields along the contours of the slope and are designed to trap sediments, nutrients, and pesticides flowing from pastures and croplands; *Photo by Ranjith Udawatta, Center for Agroforestry, University of Missouri.*

Riparian vegetative buffers and filter strips help reduce non-point source pollution of water bodies and soil erosion. This photo shows riparian buffers along Bear Creek in central Iowa. *Photo courtesy of the Iowa State University NREM Riparian Buffer Team.*

ies, the group has now found that upland buffers can cut surface runoff of other common pesticides and veterinary antibiotics by 60 to 75%, depending on vegetation, buffer width, and other factors.

Their goals and findings over the past decade were reviewed in two papers in the May–June 2011 issue of JEQ, but Garrett can sum things up even more succinctly: "Overall, what we're doing is building a better vegetative environmental buffer—a VEB is what we call it," he says. "We actually spend a great deal of our time working on that."

Bottom Line for Farmers: Does it Pay?

Garrett has spent a lot of time on something else, too: As he found with black walnut, convincing farmers to plant VEBs takes some doing because they remove land from production and thus potentially reduce profits. "That's the secret right there: Landowners don't want to give up a lot of land to buffers and trees and what have you," he says. "So somehow you have to try to create another opportunity."

Jose agrees, noting that the Center for Agroforestry, which he started directing in 2009 when Garrett retired, has been able to push the practice only so far by highlighting the ecological benefits. "What landowners need to see is that agroforestry is an economically viable option for them," says the forest ecologist. "It has to be market driven."

Fortunately, several markets appear to be emerging. Growing biomass for biofuel feedstocks is an obvious one to which agroforestry is well suited, Jose says, especially on sensitive, marginal lands that can be harmed by sowing traditional row crops. There are also the well-documented yield bumps that come when row crops are protected by trees. Another promising development is the burgeoning of markets for local foods, which in Missouri includes agroforestry crops like walnut, pecan, elderberry, and mushroom.

Alley cropping with pecan trees, for example, can return up to $3,000 per acre starting in the sixth or seventh year, Jose says, while farmers in the meantime get income from row crops planted underneath. Plus, pecan is extremely tolerant of flooding and does well on swampy lands, meaning that if a bad year of flooding destroys the agronomic crop, farmers will still have pecans to harvest. "So, [the system] is also insurance against natural calamities," Jose says.

Still, for adoption to expand, more research is needed on the economic bottom line, Garrett says. "It's one thing to say, 'You're going to increase your yield by this much.' It's something entirely different to be able to say, 'You're going to increase the rate of return on your investment by 5 or 10%.'" The economic opportunities to be found in certain tropical agroforestry systems, such as shade-grown coffee or cacao, could also help the practice spread in developing countries, adds Nair.

Agroforestry also needs more skilled practitioners, Jose says. To this end, the University of Missouri recently started an online master's program in agroforestry that has been well received. And the USDA National Agroforestry Center has been partnering with land grant universities, the National Institute of Food and Agriculture, and oth-

For more on this topic, check out the agroforestry symposium in the May–June 2011 issue of JEQ at: www.agronomy.org/publications/jeq/tocs/40/3

ers to strengthen agroforestry education and outreach, reports the center's director Andy Mason.

But for now, few trained professionals are available to help landowners establish agroforestry systems. In this regard, Garrett is well pleased with the USDA's new agroforestry "strategic framework" (see sidebar on page 8). Announced this June by USDA Deputy Secretary Kathleen Merrigan as a new roadmap to sustainable agriculture, the five-year initiative seeks not only to further agroforestry research and national policies that support the practice, but also to educate employees across USDA about agroforestry's advantages—so that they, in turn, can educate landowners and natural resource managers.

It's just the leadership that agroforestry advocates have been waiting for, Garrett says. "In my opinion, this is the single most important step that has been taken to get the benefits of agroforestry acknowledged and the practices implemented—to actually get these systems on the landscape."

Carbon Storage Potential

Another force that could put more agroforestry practices on the landscape is climate change, specifically the push to mitigate it by storing carbon long term in plant biomass and soil. "Everyone without exception acknowledges that agroforestry is one of the best ways to sequester carbon," Nair says. The Intergovernmental Panel on Climate Change (IPCC), for example, states that natural forests hold the greatest carbon storage potential. But among *managed* systems, agroforestry systems top the list, followed by managed forests, and agricultural lands.

How much carbon can be stored is an open question, however, which is why Nair has devoted the last several years to studying it. In a set of experiments around the world, including Brazil, sub-Saharan Africa, northern Spain, and Florida, he and his colleagues have been examining the soil properties that promote sequestration in different agroforestry systems. They've also been measuring how much trees and grasses each contribute to carbon storage in soil, using isotopic fractionation techniques that can trace the source of the carbon.

Jim Brandle, meanwhile, has been examining similar questions in some of the Great Plains windbreaks that remain. A University of Nebraska–Lincoln professor and ASA, CSSA, and SSSA member,

Brandle has taken a path in agroforestry much like Garrett's: He focused initially on yields and economics, but couldn't help noticing the conservation benefits. And, like Garrett, it led him and his collaborators to ask eventually what those benefits might be worth. Payments to farmers for storing carbon could be one answer some day, and so Brandle has devoted a lot of time to understanding how much carbon can potentially be sequestered in shelterbelts (one of his latest papers also appears in the May–June 2011 JEQ issue).

But storing carbon is just one side of the coin; the other is preventing CO_2 emissions in the first place, he says. Say, for example, that a shelterbelt takes 5% of a farmer's land out of production. "Now we're not running a tractor over that 5% of the land, we're not using fuel for that 5% of the land, and therefore we're not releasing emissions from that land," he says. Add it all up, and the carbon that's saved can exceed the amount stored in wood.

There are also the windbreaks around farmsteads, which have survived in much greater numbers than their counterparts along section lines. Brandle's group has examined them also, specifically the amount of emissions, energy, and dollars they save. Research has shown, he explains, that protecting homes from wind reduces the exchange rate between outside and inside air, cutting the need for heating and cooling, and producing energy savings of 15 to 30%, depending on location. Brandle's studies are older, but he recently received U.S. Forest Service funding from the National Agroforestry Center to revisit the work and do the accounting in 2011 dollars. It's likely the only effort of its kind in the country, he thinks, outside of urban areas. And it wouldn't be possible without the foresight of those who maintained the windbreaks in the decades since the Dust Bowl.

There's a lesson here for our modern world, one that reaping the rewards of agroforestry absolutely requires: We need to take a longer view. "Anything to do with trees is long term," Brandle says. "That's almost a prerequisite."

M. Fisher, lead writer for CSA News *magazine*