Cultivating Biodiversity

Reaping the Benefits of Eco-friendly Farming

by Nancy Maddox

Ask Sam Rose about bees, and he will tell you they aren’t all equal. “In my opinion,” he says, “honeybees are just not the best bees for pollinating blueberries.” Rose would know. Since 1982, he has been cultivating 200 acres of highbush blueberries on the North Carolina coastal plain. The plants thrive in the acidic, sharp-draining soil at Rose’s Lake Creek Farm in Ivanhoe. But they need bees to grow berries.

“I had used bumble bees in the past, but they were so expensive I didn’t feel I was getting value for what I was spending,” Rose says. “I tried the orchard mason bee, but it wouldn’t wake up after the winter.”

As it turns out, some of the world’s best blueberry pollinators were already in the area: an assortment of native bees, including Habropoda labriosa, the aptly-named southeastern blueberry bee.

Says Rose, “Normally, blueberries are one of the very first things to bloom in the spring. That’s why the southeastern blueberry bee is so interesting because it hatches right on time when the blueberries bloom. And it does a very good job of pollinating blueberries.”

Rose values his native bees so much that he has gone out of his way to make them happy: “The more I can get bees to forage close by, the more I’ll have the following spring.”

He puts out boxes to shelter over-wintering native bumble bees and limits insecticide use when bee activity is high. He tried moving bee-pleasing weeds, like Maryland meadow beauty, from fields to fallow areas.

And he flattened eight large mounds of soil, excavated to create irrigation ponds, and planted the resulting half-acre plots with buckwheat.

“So the blueberry blooms,” says Rose, “and then the [wild] gallberry, and then the buckwheat comes into bloom right behind the gallberry.” Not only do the bees feast on a succession of nectar-rich flowers, but the buckwheat foliage and seeds feed wild turkeys and deer—which Rose hunts—and quail, an elusive delicacy in these parts.

As an added bonus, he says, the fast-growing buckwheat “helps keep some of those animals out of my blueberry fields. It gives them something else to eat other than my blueberries.”

Rose discovered empirically what researchers are now beginning to document scientifically: managing farmland to promote biodiversity and to maximize ecosystem services can yield big benefits.

How big?
da laboriosa, and a collection of species they termed small native bees.

Shelley Rogers, a NCSU master’s student (now graduated), Burrack, and other collaborators surveyed local bee populations and measured the pollination of blueberry flowers visited by multiple bees (i.e., “open-pollinated”) and flowers pollinated via a single bee visit. They found that bee richness—the number of species present—was a better predictor of pollination than bee abundance.

“What we’ve been able to demonstrate, Burrack says, is that different bees do different things; that’s the core of how biodiversity benefits yield.”

So, for example, while honeybees prefer calm, sunny weather before they venture into the fields, native species are more tolerant of the cool, cloudy, windy days likely to prevail in early spring when blueberry plants bloom.

Some species groups are more efficient pollinators than others, producing, on a single-visit basis, a greater number of seeds—the “ultimate measure of pollination because that’s what will make a bigger blueberry,” Burrack says. Some species visit more flowers or have greater flower fidelity, preferring one type of blossom above all others. And some are simply more plentiful. And although Burrack says it is difficult to prove, some species may also be more resistant to common bee stressors, such as the parasitic varroa mite, viruses, or pesticide exposure.

Says Burrack, “No bee is perfect in all categories—forages under any weather conditions, visits lots of flowers really quickly, is abundant, or pollinates a lot of seed.” However, large, multi-species bee communities can, “get to that perfect bee level” in aggregate.

Since the USDA figures that bees pollinate 75% of all fruits, nuts, and vegetables grown in the United States—a harvest worth $20 to 30 billion annually—there is vast potential to recruit the services of the country’s 4,000 native bee species.

Value in Abandoned Fields, Wooded Lots

While the value of pollination may be obvious to a fruit farmer, diverse, interconnected communities of flora and fauna can provide other ecosystem services as well. J. Franklin Egan, an agroecologist and postdoc at the USDA-ARS, for example, points out a host of things native plants can do for farmers.

On Sam Rose’s farm, bees feed on buckwheat flowers (top) while wild turkeys (left) feed on the foliage and seeds. Top image courtesy of Flickr/Nomadic Lass, and bottom image courtesy of Flickr/Kimon Berlin.
“Wild plants serve as the basis for insect services,” he says, including natural pest control. “Hedgerows and buffer strips can be enormously important in providing windbreaks, halting erosion, and filtering water. Natural or semi-natural plant communities sequester carbon and filter air.” They also provide habitat for wildlife of cultural, recreational, and economic value.

Far-sighted farmers with a broad systems perspective can reap the benefits of these services at minimal or no cost. Moreover, oftentimes measures to boost one ecosystem service will boost others as well.

Doug Landis, a Michigan State University scientist focused on insects and landscape ecology, says the easiest thing farmers can do to cultivate biodiversity and attendant ecosystem services is simply not to remove certain habitats.

“If they have lands that are not being actively managed—these could be wooded areas, abandoned fields, early successional habitat—rather than converting them into farmland, they may want to consider the value of retaining them.”

These lands, Landis says, “do have value, and many are providing resources for beneficial insects.”

The true armyworm, for example, is a common pest of cereal grains and corn. Fortunately, however, the armyworm (the larva of the whitespoeck moth, Mythimna unipuncta) is parasitized by a series of beneficial insects. More than a dozen species of wasps insert their eggs—up to 60 at a time—into the armyworm’s body. And tachinid flies lay eggs on the outside of the armyworm, and their offspring then hatch and tunnel in.

These useful parasitoids require access to floral resources for energy, overwintering habitat, and alternate hosts to complete their life cycle at points in the season when primary hosts may be unavailable. Fallow farmland can fulfill all of these needs.

The next step up from simply preserving fallow land is actively managing farmed and unfarmed areas to fulfill a particular need, as Rose does with his nectar-rich stands of buckwheat at Lake Creek Farm.

For pest control, the precise enhancements will depend upon the biology of the natural enemy a farmer wishes to flourish. For instance, predacious carabid ground beetles—which prey upon aphids, caterpillars, insect eggs, and seeds of common weeds like foxtail and lamb’s quarters—generally walk wherever they go. “Because they don’t move very far on their own,” says Landis, “they require little grass strips within the field or habitat on the edge of the field.”

Some California lettuce growers intersperse their fields with flowering plants that attract syrphid flies. Also known as flower flies or hover flies, many syrphid species require a pollen meal as a source of protein before they can lay their eggs. Importantly for farmers, once those eggs hatch, hover fly larvae gorge themselves on aphids and other soft-bodied lettuce pests. But, says Landis, to exploit this dietary preference, the floral resources for adult hover flies must be available “right in the field.”

For natural enemies and pollinators with greater dispersal abilities, the habitat surrounding farm fields becomes more important. Landis and colleagues have found that the amount of non-crop habitat within a one-mile radius of a soybean field is the best predictor of good suppression of the soybean aphid, a favorite food of the highly mobile ladybird beetle.

Managing for Biodiversity

Careful within-field management practices can safeguard critical natural areas near farmland from unintentional degradation. Herbicide drift, for example, can adversely impact habitat adjoining agricultural fields but can be limited using a range of tactics.

If herbicide is used, Egan says, it is critical to pay attention to weather conditions: “Don’t apply it if winds are above 10 miles/hour; that’s an important threshold.”

But first and foremost, he says, farmers should adopt integrated weed management strategies so that they have less need to resort to herbicides.
Crop rotation “can have enormous benefits for switching up which weeds are prevalent in which year and can delay herbicide resistance and break up weed and pest cycles and have benefits for the soil. Crop rotation has big benefits for pest management across the board.”

Other herbicide-reducing IWM strategies include weed-suppressing cover crops (which also have substantial soil benefits) and mechanical weed management and soil disturbance to displace unwanted flora.

Overuse of the herbicide Roundup has made integrated weed management all the more important to protect natural areas in farmscapes. Economically significant outbreaks of Roundup–resistant weeds, says Egan, have left farmers “scrambling for alternatives.” This situation, in turn, has prompted the creation of a new generation of crops—including varieties of corn, soybean, and cotton—resistant to two Roundup replacement herbicides, Monsanto’s dicamba and Dow Agrosciences’s 2,4-D (each sold in various brand name formulations.)

“That technology will enable farmers to use a heckuva lot more—two, three, or four times as much over a national scale than we see today—of those two herbicides,” Egan says.

The potential problem for native plant communities is that both 2,4-D and dicamba effect a wide range of broadleaf plants and can be selectively damaging to wildflowers under certain circumstances. Egan and collaborators have found that, in some application scenarios, exposure to 2,4-D and dicamba increases the proportion of grasses in native landscapes at the expense of wildflowers. Moreover, the chemicals can be active on some plants at the very low doses typical of herbicide drift.

“I haven’t seen a smoking gun that there’s an imminent ecological danger,” Egan says, “but we certainly need to be cautious about how we use these chemicals and do more research.”

A second wildlife-friendly management practice deals with cropping systems themselves. Simply replacing agricultural monocultures with a mix of crops can attract and sustain more diverse populations of beneficial insects. In the Midwest, Landis says, supplementing the typical corn and soybean crops with wheat and alfalfa provides resources for pollinators and natural enemies: “Wheat and alfalfa

Some California lettuce growers intersperse their fields with flowering plants (left) that attract syrphid flies (above), which are also known as flower flies or hover flies. The flies eat aphids and other soft-bodied lettuce pests. Left photo courtesy of Stephen R. Ausmus (USDA-ARS). Top photo courtesy of Flickr/Paul Albertella.
are fall-planted and grow early in the spring; they’re providing habitat before corn and soybeans are even planted.”

Similarly, as high energy prices incentivize farmers to plant marginal lands with biofuel crops, they are faced with the choice of which crop to sow. Landis and a group of fellow Midwest-based researchers have found that choosing switchgrass or perennial prairie plants over maize or other annual grain crops increases biodiversity and can even “[feed] back to benefit commodity production on prime agricultural land,” although the biofuel biomass from the native plants is less. Consistent with other research, they have found that proximity of farm fields to natural or quasi-natural habitat boosts ecosystem services further. For example, their study predicted a 30% increase in pest egg predation as the amount of pastures, hayfields, and other grasslands within 1.5 km of a focal field doubled from about 30 to 60%.

So-called Bt crops—bioengineered to produce Bt toxicants—have been available since 1996 and now include 75% of all U.S.-grown cotton, 76% of U.S.-grown corn, and an estimated 15 to 20% of U.S.-grown sweet corn. Yet, after nearly two decades of use, and 70 million hectares of Bt crops in 2012, there are surprisingly few cases of resistance to the plant-made insecticides.

“It’s always been intriguing to me,” Shelton says. “With Bt crops, there’s a constant expression of Bt protein that really is challenging the insect on a continuous basis to evolve resistance. So, why haven’t we found more cases of resistance to Bt crops?”

Part of the answer, he says, comes back to biodiversity: “Natural enemies are eating the pests that are evolving resistance, so resistance in the population is slowed.”

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A High-Tech/Low-Tech Solution: Bt Genes + Natural Enemies

Cultivating biodiversity can have unanticipated benefits. Anthony (“Tony”) Shelton, an entomologist at Cornell University’s New York State Agricultural Experiment Station in Geneva, NY, has been involved in research showing that an abundance of natural enemies can actually retard a pest’s ability to evolve resistance to at least one class of toxicants—the insecticidal proteins produced by the soil bacterium Bacillus thuringiensis (Bt) and by a variety of crops that have been genetically modified to contain Bt genes.

Because Bt proteins don’t harm predators or parasites, they conserve natural enemies in a way broad-spectrum insecticides do not. Those beneficial insects are then eliminating the pests that are evolving resistance and are thus surviving on a Bt crop.

“Mathematical modelers predicted Bt resistance evolving in five years, but none took into account the contribution of natural enemies,” Shelton says.

The benefit of delayed Bt resistance can be substantial. About 25% of all insecticides are sprayed on vegetable crops intended for human consumption (for which appearance is important). The synergistic combination of a Bt gene and natural enemies can replace much of that insecticide, reducing costs, unwanted agricultural pollution, and human health risks.

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Paying for Nature

Although farmers may manage their land to favor specific insects, they may also be interested in boosting overall species richness. If that is the goal, setting aside uncultivated land—that is, land sparing—is likely a better strategy than simply changing cultivation practices to enhance diversity within farmed fields—so-called land sharing.

According to a 2012 study by Egan, the estimated richness of plant species in a 314.5-ha landscape in Lancaster County, PA, varied inversely with the relative land area of different habitat types. Thus, the fewest species, 89, were found in the dominant habitat—arable fields (66.5% of total land area). And the most species, 213, were found in the smallest habitat within
A recent study in Lancaster County, PA by J. Franklin Egan, an agroecologist and postdoc at the USDA-ARS, concluded that “small amounts of non-crop habitat support far more plant diversity than large areas of arable fields.” This diversity can provide a cost-effective way for farmers to manage pests and diseases. Left photo courtesy of J. Franklin Egan. Top photo by Yuri Kalinin (RU) and courtesy of Bioversity International.