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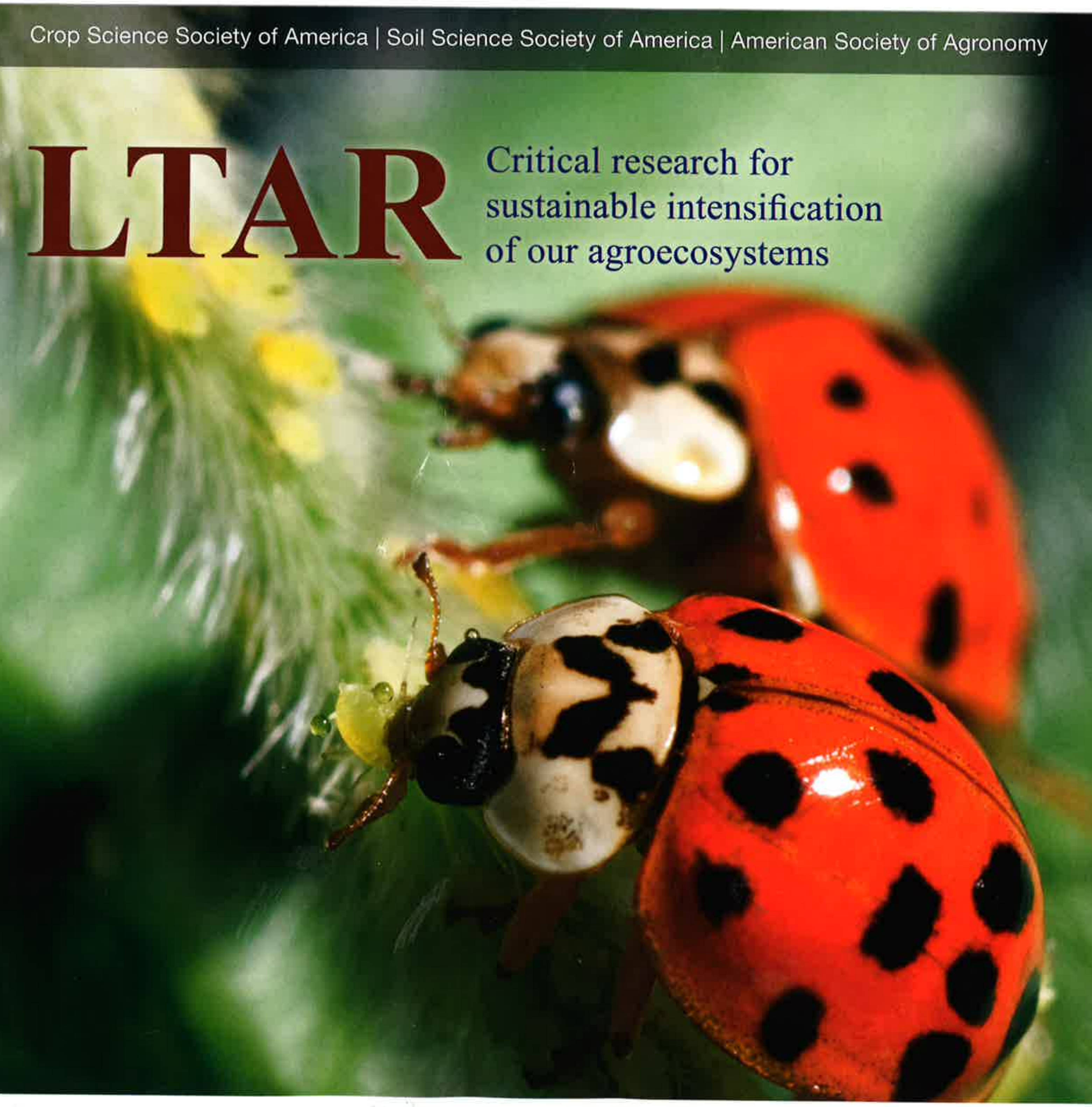

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LTAR

Critical research for sustainable intensification of our agroecosystems

by Nancy Maddox

It arrived unheralded at the turn of the century—soft, yellow, and hungry. *Aphis glycines* Matsumura—the soybean aphid—is no more than 1/16 of an inch in length, but by 2001, the progeny of those first exotic interlopers were sucking enough soybean sap to reduce crop yields by 45% or more in some fields.

Today, this East Asian import has made itself at home in at least 21 states stretching across the U.S. Soybean Belt—a never-ending buffet for an insect that produces up to 18 generations per summer, without ever mating.

Phillip Robertson, a professor of crop and soil sciences at Michigan State University's Kellogg Biological Station (KBS), says KBS entomologists were among the first to detect the uninvited pest. "When the soybean aphid arrived in 2000," he says, "we were able to document that because we were watching; not for aphids necessarily, but watching."

Robertson has been involved in long-term agricultural ecosystem, or *agroecosystem*, research for 20-odd years and is a former chair of the National Science Foundation's Long Term Ecological Research (LTER) Network, which KBS joined in 1987 as the sole agricultural site. "Very often, pest outbreaks are episodic and occur in unpredictable patterns without much warning," he says. "If you're not watching for them, or ready to observe them in a place that has a long-term observation capacity, then you're not likely to find them when they first arrive, only after they become a problem."

That early period is critical, says Robertson, for understanding how the insects become established and how they can be controlled without resorting to costly and potentially hazardous pesticides. "We're always going to be chasing these pests with chemicals, unless we understand their ecology."

Indeed, soybean growers are applying millions of dollars of foliar sprays to control the aphids, at a cost of about $10 to $15 per acre.

Not every farmer knows what KBS entomologists (including Doug Landis and Stuart Gage) discovered early on:

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Backdrop image: Checking insect sticky traps. *Photo by K. Stepnitz.* **Inset images** (l to r): Ladybird beetle eating soybean aphids, collecting a deep soil core, and harvesting native grasses with a plot combine that measures yields (*photos by D.A. Landis and J.E. Doll*). *All images courtesy of Michigan State University's Kellogg Biological Station LTER online photo gallery.*

soybean aphids are themselves food for another insect, the ladybird beetle. "So, the key point," Robertson notes, "is that the ladybird beetles, if they're around, will eat the aphids and can keep them below the economic threshold," which is the population level where crop pests start to reduce yield and spraying becomes economically worthwhile.

In 2000, KBS scientists had already been following ladybird beetles for a decade. "Understanding the different species and the habitats they prefer and tend to feed in gave us a lot of insight into whether any particular species would be useful in keeping the aphids in check," Robertson says. The scientists were able to show that the most zealous soybean aphid predator is an imported beetle, hailing from the aphids' Asian homelands.

But the story doesn't end there. Soybean aphids are active for only six to eight summer weeks when the soybeans are growing, but the beetles are active for six to eight months and need overwintering sites and alternate food sources, such as dandelions in early spring. It turns out the key factor for successful biocontrol of soybean aphids is landscape diversity.

"How mixed does a landscape need to be? Can you just have a strip [of mixed flora] two-feet wide surrounding the field?" Robertson asks rhetorically. "Well, maybe. We don't know yet." It may take years to find the answer.

The continuing saga of the soybean aphid and the ladybird beetle is a textbook example of the value of long-term agroecosystem research. And, considering that the 2011 U.S. soybean crop covered 75 million acres, comprised 56% of world oilseed production, and was worth more than $35 billion, the value of this research is readily apparent.

Facing the Inescapable Facts

Long-term agroecosystem research has been ongoing in the U.S. at a number of experimental sites for decades but is gaining renewed attention with the creation of the USDA's Long Term Agroecosystem Research (LTAR) Network. The network, which grew out of the USDA-ARS ARS Water Availability and Watershed Management Program, was formally announced last September and includes 10 USDA-ARS facilities: six watersheds, three experimental ranges, and one research farm.

Mark Walbridge, national program leader for the watershed management program, helped to start the network. "The LTAR Network is not research *per se*," he says, "but rather infrastructure that supports research."

As the name implies, the network's focus is on *agroecosystems*, ecosystems where agriculture is the predominant land use. An individual field, Walbridge says, would not qualify as an LTAR site since "it doesn't capture the complexity of interactions that can occur at the watershed or landscape scale."

ASA and SSSA Fellow Jean Steiner, director of the USDA-ARS Grazinglands Research Laboratory at Oklahoma's Southern Plains LTAR Network site, says agriculture is really "human management and human-imposed goals overlaid on the ecological system." From the farmer's perspective, she says, the field-scale goals of agroecology include everything from production and profitability—which are "core and essential"—to judicious stewardship of the land to "achieve the quality of life people want to support on their farms and in their communities.

"Ecology is just there," she says. "It imposes inescapable facts. If we don't pay attention to the processes and constraints of the world around us, that usually gets us into trouble."

The primary impetus for starting the LTAR Network was to get at what Walbridge calls "the knotty question of *sustainable intensification*." With the global population expected to reach 9 billion by 2050, he says, "just maintaining our current level of agricultural production is not going to be good enough."

In fact, the United Nations' Food and Agricultural Organization (FAO) estimates that farm production must increase by 70% in the next 35 years or so to avert a serious, global food shortfall. According to the FAO, most of this new production is not going to come from finding and developing additional agricultural lands, but rather from sustainable intensification of agriculture on existing farms and ranches.

A major LTAR goal, Walbridge says, is "to look across regional and continental gradients to really try to get at how do you sustain or enhance agricultural production in a way that maintains ecosystem services, doesn't cause land degradation, doesn't decrease water or air quality, and doesn't exacerbate climate change, but at the same time is both profitable and a desirable way for farmers to make a living.... To really get at these types of questions requires long-term data, cutting across land types."

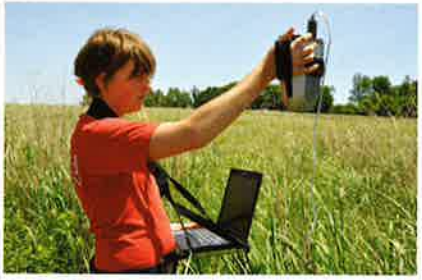
By organizing several existing sites into a network, the USDA-ARS hopes to increase efficiency, create synergy, and ultimately enhance the impact of the research. Walbridge, however, is quick to point out that involvement in the network is not limited to ARS or USDA scientists. The network, he says, is "a research platform that is available for use by the research community at-large." The agency recently solicited a second round of requests from ARS and non-ARS sites wanting to join the network (although membership comes with no new federal funding), and those responses are in review.

The Snow Comes, but it Blows

In the best of all possible worlds, the nation's 922 million acres of farmland—about 40% of the U.S. land area—can be used to provide food and simultaneously boost ecosystem services.

One example of this emerging trend comes from the USDA-ARS Northern Great Plains Research Laboratory (NGPRL) in Mandan, ND. In operation for 101 years, the NGPRL is the oldest member of the LTAR Network, conducting research on 2,400 acres of crop- and rangeland. Over its long history, the NGPRL has amassed 70-plus years of data on grazing management effects on soils and plants, a 90-year-old soils archive, and almost 100 years of long-term weather data that offer myriad opportunities for research.

Matt Sanderson, a research leader at the laboratory, says early NGPRL work focused on simply identifying crops that could survive in the harsh Northern Great Plains environment, with bitter cold winters and hot, dry summers. During the dustbowl years,



Backdrop image: Aerial view of a cellulosic biofuels research experiment of the Great Lakes Bioenergy Research Center Kellogg Biological Station LTER project. **Inset images** (l to r): Taking canopy spectrograph readings in a switchgrass field, collecting wheat samples, and collecting greenhouse gas samples in a corn plot *(photos by K. Stepnitz). All images courtesy of Michigan State University's Kellogg Biological Station LTER online photo gallery.*

the focus shifted to conservation practices, such as using stands of trees and grasses to reduce wind erosion. And for the past 15 to 16 years, the major focus has been integrated crop–livestock systems.

Among other things, Sanderson says, the researchers have found that farmers who produce both grain crops and cattle in an integrated system can "just turn cattle out to graze on crop residues during fall and winter" and save about 25 cents per cow per day in feed cost.

The focus on integrated farming led the NGPRL to pioneer the concept of *dynamic cropping*—adjusting the crop rotation on a fairly short timeline to respond to prevailing weather, plant diseases, soil conditions, and other factors. For example, Sanderson says, "If you plant a crop that uses a lot of soil moisture, and it's a dry year, you might want to follow that with a crop that uses less soil moisture." The NGPRL has even created a crop sequence calculator to help farmers choose crops to minimize management risks.

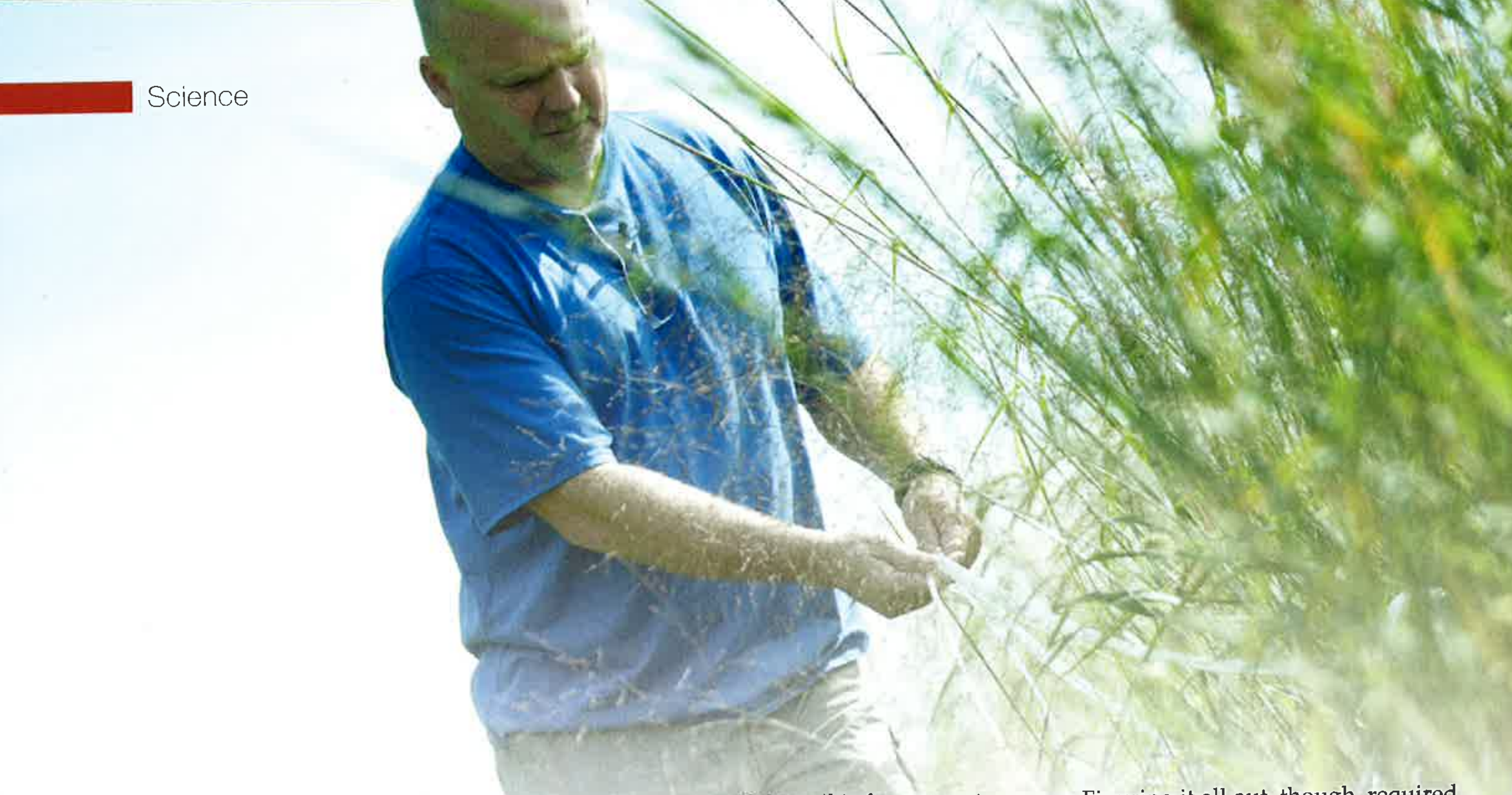
In previous research at the USDA-ARS Upper Chesapeake Bay Experimental Watershed in Pennsylvania (also part of the LTAR Network), Sanderson documented significant economic and ecological benefits from the use of diverse forage mixtures for grazing, including fewer weeds, more diverse bug populations above and below ground, greater drought resistance (from the inclusion of deep rooted species), greater forage yield, greater milk production per acre (for dairy cows), and greater soil carbon sequestration.

Another agroecosystem success story—combining water conservation, greenhouse gas mitigation, and increased farm production—comes from the "baby" of the LTAR Network, the 15-year-old RJ Cook Agronomy Farm (CAF) in the Pacific Northwest Palouse.

The rich, silt-loam earth here—a region of rolling hills, dunes, and shortgrass prairies in eastern Washington and western Idaho—literally blew in over a period of thousands of years when dust storms, volcanoes, and glaciers took turns shaping the land. Not only is the soil fertile, but from a soil science perspective, it has the capacity to store more available water than any other soil type.

ASA, CSSA, and SSSA member David Huggins, a USDA-ARS soil scientist at the CAF—part of Washington State University—says Palouse farmers rely on that stored moisture to grow alternating crops of wheat and legumes.

The Palouse, he explains, receives about 70% of its annual precipita-



tion from November to February. With limited water availability and a Mediterranean-like climate during the growing season, farmers rely on dryland farming techniques and hope the stored soil moisture is enough to produce yield.

In practice, the answer has been *yes* and *no*, with enormous variability across a single field.

Since 1998, Huggins and colleagues have been monitoring crop and soil characteristics at 369 geo-referenced points, spaced 100 ft apart in a grid pattern across 92 acres of the farm. The work is part of a larger effort to demonstrate the feasibility of continuous direct seeding (no-till farming) on the highly varied, large-scale plots typical of the Palouse. Findings have direct applicability to the all-important issue of water.

"One of the things we've found," Huggins says, "is that even though we get, say, on average, 22 inches of precipitation annually, it gets redistributed across the landscape via various mechanisms.... The snow comes, but it blows and tends to accumulate in drifts based on the topography of the landscape. If precipitation comes in the form of rain and hits the surface, it may infiltrate and go into the soil, but it may hit horizons in that soil, and gravity will take it downslope horizontally. If the soil is frozen, water can run off and not infiltrate."

Crop residues left standing in the field under no-till farming regimes insulate the soil from water evaporation and trap it in the field.

Importantly, although water storage can vary over three-fold across a field, it tends to be fairly stable in defined subareas from year to year. "That lends predictability to where we're going to find high- or low-yielding areas in the field," Huggins says.

This information, in turn, enables growers to implement precision farming practices, varying seeding and nitrogen fertilization rates to sync with expected yields. The CAF "farmers" are saving upwards of 15 to 20% in their nitrogen fertilizer bill or roughly \$5 to \$10 per acre. There is less nitrogen leaching into surface water or rising into the atmosphere as nitrous oxide, a potent greenhouse gas. And crop production is actually boosted when lower-yield areas are not overseeded and overfertilized and thereby encouraged to produce excess vegetative biomass before the soil dries out.

"It's a win–win scenario," Huggins says. "Higher yields, higher nitrogen use efficiency, and higher water use efficiency.... "With precision agriculture, we're using the crop to manage the water better."

Figuring it all out, though, required long-term, ecosystem-scale research.

Huggins and colleagues are collaborating with researchers at the University of Idaho to use satellite imagery to identify water-stressed areas of fields. By combining this information with "combine-level" data, they aim to develop decision aids to help farmers create field management zone maps for precision farming.

A Whole New Set of Problems

A half a continent away from the Palouse, at Missouri's Goodwater Creek Experimental Watershed (GCEW), soil and water characteristics also drive agricultural practices. But in this erosive, claypan soil environment in the southern Corn Belt, surface runoff is the paramount concern.

ASA and SSSA Fellow John Sadler, a USDA-ARS research leader at the GCEW's Central Mississippi River Basin site—an LTAR member affiliated with the University of Missouri—has been part of a 15-year study analyzing herbicide transport out of the 28-mi^2 watershed. The study, he says, demonstrates complex ecosystem dynamics.

"If you get an inch of rain on a dry watershed, you may not get much runoff, and the stream may not go up," Sadler says. "But if you get an

Backdrop image: Checking greehouse gas sampling lines. *Photo by K. Stepnitz.* **Inset images** (l to r): Checking CO_2 eddy flux instruments, aerial view of rainout shelters, and collecting soil water samples in a poplar tree plot (*photos by K. Stepnitz*). *All images courtesy of Michigan State University's Kellogg Biological Station LTER online photo gallery.*

inch of rain on a wet watershed, all of that water may go into the stream."

Herbicide runoff at GCEW, he says, is influenced by a number of erratic factors: rainfall, soil dissipation rate, the fraction of the watershed planted with corn or sorghum, when (and how) the chemicals were applied to the ground, and individual chemical characteristics, such as solubility. "Water quality is more variable than runoff, which is more variable than rain," Sadler says. "So that's why you need a lot of data and long-term data" to understand what's happening.

The GCEW study, like much current LTAR Network research, falls under the rubrics of biogeochemistry and ecohydrology, with an emphasis on nutrient dynamics and fluxes of water, gases, or pesticides. Walbridge says he hopes this type of work will continue but also be expanded over time to examine such things as crop–pathogen interactions, crop–insect interactions, and microbial–soil interactions.

One thing, however, is certain. A significant focus for both the LTAR and LTER networks will be climate change.

Robertson says KBS research suggests that almost all of the global warming impact of farming can be mitigated by using no-till cultivation, leguminous cover crops, and other specific management strategies. In fact, he says, not only could row-crop agriculture be carbon-neutral, but it could help to mitigate greenhouse gas production generally.

But a warmer world will pose other challenges, as well, according to Robertson.

"We have potential for a whole new set of pest problems with climate change, not just insects, but weeds. Climate change is going to provide a different set of stressors for cropland and rangeland. And those stressors are, in part, related to plant responses to temperature and precipitation changes, but also pest pressures and changes in soil organic matter and greenhouse gas production and the way water cycles through these landscapes. I think all of these are going to interact in unexpected ways, and it will take long-term, integrated research to reveal those interactions and provide ways to adapt to them."

N. Maddox, contributing writer, CSA News magazine