futures

Michigan State University • AgBioResearch

SPRING/SUMMER 2015 • Volume 33, Nos. 1 & 2

SPARTAN BARLEY:
100-year-old seeds sprout in time for craft beer boom

COVER CROPS:
Interest high, adoption low

2015:
International Year of Soils

UNEARTHING THE IMPORTANCE OF SOIL

2015

International Year of Soils

For more information, visit fao.org/soils-2015

Our writers met with and interviewed close to 20 Michigan State University (MSU) researchers for this issue of the magazine. For me, one fact I learned continues to boggle my mind:

In every handful of soil, there are approximately 7.3 billion living organisms.

That's an astonishing figure — one that oddly mirrors the world's global human population. How can a handful of soil possibly contain the same number of living organisms as there are people on earth? It's fascinating to think that something that appears so simple on the surface could be so complex.

This is our first *Futures* devoted to soils. We initially thought to explore this topic because of the United Nations Food and Agriculture Organization (FAO) dubbing 2015 the International Year of Soils. The campaign aims to increase awareness and understanding of the importance of soil for food security and essential ecosystem functions. What finally cinched the deal for us was when we saw that the Center for Global Connections, part of the College of Agriculture and Natural Resources, was hosting an informal conversation around the UN campaign. Listening to faculty and staff members and students quickly made it clear that soil health is not only a topic that cuts across numerous research disciplines at MSU, but one of utmost importance as society strives to meet the needs — especially those related to food — of a growing population.

I hope you find that these articles help to shed light on the research at MSU that supports the following key messages identified in the UN campaign:

- Healthy soils are the basis for healthy food production.
- Soils are the foundation for vegetation that is cultivated or managed for feed, fiber, fuel and medicinal products.
- Soils support our planet's biodiversity.
- Soils help to combat and adapt to climate change by playing a key role in the carbon cycle.
- Soils store and filter water, improving resilience to floods and drought.
- Soil is a non-renewable resource — its preservation is essential for food security and a sustainable future.

In Michigan alone, there are an estimated 500 types of soil. The glaciers of the Ice Age did a number on the landscape, leaving behind mixtures of soils from sandy shorelines to clay plains. Today the physical properties of soil are well understood, but what's happening biologically within the microbiome remains largely a mystery. MSU researchers are digging for answers and coming up with solutions to improve soil health.

A special thanks to MSU Department of Plant, Soil and Microbial Sciences chair James Kells and soil professor James Crum for their guidance with this issue.

Holly M. Whetstone
Editor

Holly M. Whetstone

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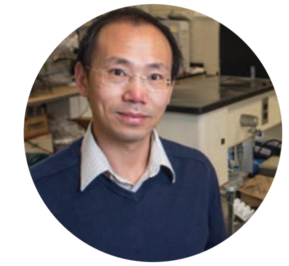

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ON THE COVER: Illustration depicts how soil is directly tied to the production of all different types of foods. Illustration by Iain Bogle, BCP

James Tiedje, the director of the MSU Center for Microbial Ecology and MSU AgBioResearch scientist, examines a miscanthus plant. The perennial grass is being considered for biofuel production and use as an ornamental grass. *Photo by Kurt Stepnitz.*

Getting the scoop on SOIL

Photo by Derrick Turner.

Quality decline causing large scale problems to emerge

While it may seem of little value to the untrained eye, soil is one of the planet's most precious commodities — and it's deteriorating at an alarming rate. Unsustainable agricultural practices have led to the degradation of soil around the world, including erosion, loss of structure, changes in salinity and alterations to the complex ecosystems that live beneath our feet. The World Wildlife Foundation estimates that half of the topsoil on the planet has vanished in the past 150 years.

BY CAMERON RUDOLPH
Writer

Raising awareness of the important roles soil plays in everyday life is one of the goals of the United Nations Food and Agriculture Organization (FAO), which has dubbed 2015 the "International Year of Soils."

The FAO says that more than 805 million people around the world face hunger and malnutrition. Expected growth in global population will require a 60 percent increase in food production just to keep pace.

With one-third of the world's soil declining in quality, large-scale problems emerge. How will growers respond to these looming challenges? What can be done to reverse the trends and improve land management? Researchers at Michigan State University (MSU) are tackling the problem on an international scale to find long-term answers that help preserve this vital resource.

Paving the way

When discussing soil research at MSU, it is impossible to mention the university's immense contributions to the field without recognizing **James Tiedje**, a University Distinguished Professor and the director of the MSU Center for Microbial Ecology. For more than four decades, Tiedje has been unlocking soil's secrets with the development of new technologies and analysis techniques, broadening the scope of understanding for scientists everywhere.

Throughout his career, Tiedje has seen paradigm shifts in soil studies, starting with the advent of personal computers. They allowed researchers to do modeling work much easier and made it simple to scale up mathematical models derived from experiments. Today Tiedje sequences DNA from soil with the same technology used in human medicine. MSU researchers, including Tiedje, led the largest soil DNA sequencing effort to date, collaborating with scientists at the U.S. Department of Energy Joint Genome Institute and Lawrence Berkeley National Laboratory.

"In the '90s, it would take us almost four years to sequence one gene in a microbe," Tiedje said. "Now we can sequence billions of base pairs a day. The sequencing capacity is tremendous, but the hard part is data analysis because storing and examining that amount of data requires high-performance computers. Our team has developed methods of breaking the data into more interpretable components, suitable for computers here at Michigan State."

Tiedje calls soil microbiology the greatest frontier in all of biology because it is the most complex, diverse and unknown. Over nearly 3 billion years, microbial evolution has resulted in extremely high genetic diversity in soils. Sequencing efforts have decoded some of the mysteries, but scientists are just scratching the surface of identifying and understanding soil microbes and their impacts on agricultural production, the environment, biotechnology and medicine.

"No one knows how many species of bacteria there are," Tiedje said. "Any particular gram of soil has about 1 billion bacteria, but no more than 0.1 percent

MSU AgBioResearch soil scientist Lisa Tiemann takes a soil sample from a maize field in Uganda.

OPPOSITE LEFT: MSU AgBioResearch soil scientist Lisa Tiemann talks with young children in Uganda about the importance of soil. *Photos courtesy of Lisa Tiemann.*

OPPOSITE RIGHT: With the same DNA technology used in human medicine, MSU AgBioResearch soil scientist Lisa Tiemann and graduate student Alexia Whitcombe analyze microbial populations in soil by using a Retsch sieve shaker to isolate water stable aggregates in different size fractions. *Photo by Kurt Stepnitz.*

of those microbes would be previously known."

DNA technology is being used in several of Tiedje's current projects, including one that is part of the Great Lakes Bioenergy Research Center. It is one of only three national centers funded by the U.S. Department of Energy that focuses on biofuels research, led by the University of Wisconsin-Madison in partnership with MSU. One of its research groups focuses on the rhizosphere, the area of soil around plant roots, which is home to large microbial communities.

> *"'Soil health' is a general term reflecting the chemical, physical and biological properties that result in efficient food production and optimum ecosystem services…"*
>
> *— James Tiedje*

Just as humans have microbes that live with us and aid our health, plants also have a microbiome that supports their health and productivity. It improves nutrient access, prevents disease and may provide other benefits not yet discovered. Tiedje's group is using new high-capacity DNA sequencing to learn how the plant's microbiome can contribute to cost-effective and sustainable biofuel production.

In addition to pinpointing its effect on promoting healthy vegetation, experts are studying how soil plays a part in climate change. A group of MSU researchers is part of a consortium studying warming sites in Alaska and Oklahoma, looking into the soil microbes' response to an increase in temperature.

"There's so much carbon in the permafrost in the Arctic and some of the permafrost is melting, so the microbes take over and convert that carbon to carbon dioxide and, in wet areas, to methane," Tiedje said. "Our major goals are to learn about the temperature sensitivity of microbes using these DNA approaches, and whether their activity has an amplifying or moderating effect on the projected rate of climate warming."

Soil microbiologists, including those at MSU, have found microbes that can degrade many environmental pollutants. Tiedje's team is well known for the discovery of bacteria that dechlorinate environmental contaminants, important because many environmental pollutants contain chlorine. This microbial dechlorination process is now implemented in the cleanup of some contaminated groundwater and soil. This process, Tiedje said, is one example of the great microbial diversity that resides in soil.

"'Soil health' is a general term reflecting the chemical, physical and biological properties that result in efficient food production and optimum ecosystem services, such as ensuring good water quality and element cycling," Tiedje said. "A very important part of soil health is the microbial community, now often termed the microbiome. The new DNA-based methods allow us much more insight into the unknown world. Plants and microbiomes have been living together ever since the first plants evolved, and it makes sense that they have developed to work in harmony. Keeping soil healthy includes ensuring and improving upon that harmony."

Identifying sustainable solutions

Since her undergraduate days at the University of Colorado, **Lisa Tiemann**, an assistant professor of soil biology at MSU, has been captivated by soil and the complex interactions that take place underground. She also cites the practical applications of soil investigation on daily life.

"I think soil research is important for a couple of reasons, with the first hopefully being obvious but maybe not as obvious as it should be," Tiemann said. "Without healthy soils, we can't survive. We depend on soils for all of the food that we eat. There is some aquaculture, and some people eat fish, but in general we couldn't survive without soil. I also think there's a bit of a disconnect, where young people in school aren't necessarily connected with nature and with the outdoors. I think it's really the purpose behind this 'International Year of Soils.'"

Like much of Tiedje's work, Tiemann's research is largely focused at the microbial level. She is working with her colleagues to gain a firm understanding of soil organic matter and how sustainable land management methods affect nutrients to increase yield and promote soil health. Until recently, researchers did not have a full picture of the diversity of organisms within soil. The technology engineered by Tiedje has revealed a vast ecosystem consisting of thousands of microbial species. One of the keys now, Tiemann said, is to determine the role these species play and the implications they have on humans.

"Over the past 40 years, we've doubled the amount of food that we've had to produce to keep up with human population growth," Tiemann said. "In the next 40 years, we have to double it again. We've gotten to the point now where there's not a whole lot more land that we can actually use for farming, so what we need to do now is be more productive. My research is trying to understand how we can manage soil sustainably. In order to do that, we have to understand how soil organic matter is formed and how it's maintained. Soil organic matter is the cornerstone of fertility."

Through a grant funded by the National Science Foundation's Science, Engineering and Education for Sustainability (SEES) initiative, Tiemann's research has taken her to the central African nation of Uganda, a country on the equator roughly the size of Oregon. Here she is working to understand the causes of soil organic matter decline and soil fertility loss. The project began in 2012, with Tiemann taking her first trip overseas in January 2013. Running through 2016, the research will give her team insight into the land management practices employed by farmers across the country.

A boom in population coupled with a decrease in fertile soil has put significant stress on Uganda's available farmland. In the past, if farmers noticed a decline in productivity, they simply moved and farmed a new area. The Uganda National Environment Management Authority estimates, however, that the remaining land that could be used for agriculture will be converted to farmland by 2020 or 2025. Without the financial means to implement inorganic fertilizers, growers are left to biological farming methods and gaining more knowledge of effective land management.

"That's what we are trying to figure out now," Tiemann said. "Are there things that people are doing elsewhere, cultural practices that would be acceptable for them to adopt that would help to at least maintain the status quo? There have to be some large, wholesale changes to build soil organic matter back up to what it once was, but if we can at least maintain the status quo and keep them fairly productive, that would be a step in the right direction."

Tiemann's team has surveyed local farmers, asking questions that can give researchers a better understanding of how to make recommendations and set feasible goals.

- What do you do with crop residues?
- What crops are you most dependent upon?
- Do you see soil fertility loss as a risk to the future?
- Are you concerned about population growth?

The answers to these questions are

MSU assistant professor of soil fertility and nutrient management Kurt Steinke (left) leads the MSU Soil Fertility Research program. Steinke and graduate student Christopher Bauer count the number of tillers in winter wheat plants to better determine plant response to the impacts of autumn planting date and spring nitrogen applications. *Photo by Kurt Stepnitz.*

OPPOSITE: Graduate student Mike Swoish is working with MSU AgBioResearch scientist Kurt Steinke to determine preliminary data about the impact of land management on microbial communities. *Photo by Cameron Rudolph.*

pivotal and shape the suggestions made to growers. Despite the mounting evidence of population putting increased pressure on soils, Tiemann said farmers do not seem concerned. They are, however, interested in methodologies that can help keep their lands producing at current capacity.

"We've seen a really big shift to a dependence on maize and the profits they receive from selling maize," Tiemann said. "That has a lot to do with the soil organic matter depletion. They've got two growing seasons, so they are harvesting two crops per year. A lot of these fields are seeing maize harvested twice a year with not much else going back in."

Although the project's findings are still in the early stages, the team has made headway through soil testing of a nearby tropical forest conservation park. Analysis of the soil in this undeveloped land provides a picture of the peak of soil fertility in the area. Tiemann said through comparing this ground with the soil used in agriculture, declines in soil organic matter have reached 60 to 80 percent. So what can farmers do to replenish soil organic matter reserves and increase productivity?

Researchers are stressing the importance of cover crops, namely legumes, which will help to increase nitrogen and add other nutrients to the soil. Area farmers have been disposing of crop residues, either burning them or using them as animal feed. Tiemann's team has discussed returning residues to the fields from which they came in an effort to boost soil organic matter. Another suggestion is to increase the frequency of weeding, which may occur only once or twice per year currently, to improve nutrient uptake for crops by removing competition with weeds. Many of these recommendations are currently being implemented, changing the way Ugandans engage in agriculture with an eye on sustainability. But the work is far from over.

"This summer I'm taking a post-doc and my graduate student with me to Uganda," Tiemann said. "I'll be there for probably a month, they'll be there for maybe six weeks, and then we'll go back again next summer."

Hands-on research

One of the only applied soil scientists at MSU, assistant professor of soil fertility and nutrient management **Kurt Steinke** spends much of his time in the field — literally.

In addition to teaching a course on soil fertility and nutrient management to undergraduate and graduate students, Steinke also works with growers across Michigan through a program he leads called MSU Soil Fertility Research, which is partially funded by MSU AgBioResearch and Extension. With the assistance of both graduate and undergraduate students, as well as a research technician, Steinke's program looks to address grower concerns by providing science-based research and extension information that ultimately promotes "greater yield in the field."

His program currently works across five cropping systems — corn, wheat, soybeans, sugar beets and potatoes. Planting season typically begins in early to mid-April and may take roughly two months to complete. Although the focus is on soil fertility strategies, Steinke's team investigates the entire agronomic system and then systematically evaluates individual components, such as planting date, and the impact on plant production.

"One example we are working on is the effect of planting date on wheat production," Steinke said. "We are looking at the effect of planting date in connection with nitrogen rate and nitrogen application timing to increase nutrient use efficiency, improve grower profitability and promote environmental stewardship."

Steinke's nutrient management methods aim to provide farmers with higher yields and sustainability while improving long-term ecological efficiency. This involves using the 4R approach — the right fertilizer source at the right rate, right time and with the right placement — to assist Michigan growers in maximizing their resources while simultaneously giving his students access to industry professionals.

"I advise graduate students to begin to understand grower problems, learn grower solutions and, along the way, learn to see and identify grower issues firsthand in the field," Steinke said. "A lot of graduate students don't have direct interactions with growers or industry personnel, whereas most of mine do. Students can see firsthand that this isn't just a problem in their research project. They can see this problem somewhere in a field from northeast to southwest Michigan."

Health is one component of productive soils, so quality land management to maintain or improve soil health is paramount. Technological advances in recent years have changed soil scientists' understanding of management, forcing researchers such as Steinke to think on a much smaller level. Like Tiemann in Uganda, examining the microbial populations in soil and how management affects them has been a driving force in Steinke's recent work. It is also the focus of one of his graduate students, Mike Swoish.

Receiving data this past winter from 228 soil samples, Swoish found 26 million unique microbes representing more than 600 microbial genera. The next step is to determine which microbes were found where, under which management regime, and attempt to draw some preliminary conclusions about the impact of management on microbial communities.

> *"I advise graduate students to begin to understand grower problems, learn grower solutions, and along the way, learn to see and identify grower issues firsthand in the field,"*
>
> *— Kurt Steinke*

"We've partnered with some of the technology that Jim Tiedje has brought into the realm of extracting DNA from the soil," Steinke said. "Once we extract DNA and see what's present, then it becomes a bigger question: is a more diverse microbial community better for plant production, or is it functionality rather than diversity? We've seen some instances where it may not be about microbial biomass but about getting the right microbes in the right spot at the right time to support a healthy system."

The shift in thinking from simply growing plants to growing two crops, the microbes and the plants, has been a significant change.

"We're attempting to figure out whether we can feed the soil to then naturally feed the plant," Steinke said. "So we then apply fertilizer not based on what a plant needs but rather based more on what a microbial community may need. If the microbes are happy and productive, they may be able to cycle more nutrients for plants to use."

Other technologies have improved accessibility for growers to what were once cost-prohibitive items such as all-in-one nutrient products. When nutrients are applied to a field separately, sizes and densities may vary, and equipment may not evenly distribute the products across the land. A product that contains all of the necessary nutrients in individual prills of fertilizer can be spread consistently.

Slow-release products, a staple of the turfgrass industry for years, have also carved out a spot in agriculture. Housed in a polymer coating, the contents are released over a period of weeks. This allows the nutrients to be available when needed most, rather than immediately and all at once, minimizing losses to rainfall and other environmental factors.

These improvements in affordable technology, in conjunction with his team's research, allow Steinke to provide the most appropriate and sustainable recommendations for Michigan growers.

"We're one of the only unbiased, third-party sources for nutrient response trials and nutrient recommendation," Steinke said. "That's the strength of the land-grant university and the strength of MSU AgBioResearch and Extension. We're trying to make more progressive recommendations that incorporate these newer technologies without forgetting basic agronomic principles and practices. We are there to help growers stay profitable and use long-term management practices that keep their soil productive."

The biochar boon

Interest in ancient soil practice resurfaces

A diorama of ancient rice farming from a soil museum at the Institute of Soil Science of the Chinese Academy of Sciences in Nanjing. Wei Zhang, a Michigan State University (MSU) assistant professor with the Department of Plant, Soil and Microbial Sciences, presented a seminar at the institute in summer 2014 and was particularly interested in learning about the past use of biochar. *Photo courtesy of Wei Zhang.*

BY HOLLY WHETSTONE
Editor

Terra preta is a Portuguese term meaning "black earth" or "black land." It describes the dark, fertile soil of high charcoal content found in the Amazon Basin dating back to 450 B.C. Mixing charred pottery, bone and crop residue is believed to have helped transform the infertile, sandy soil of central South America into a lush, productive region.

Although long discontinued, the ancient practice is captivating the attention of modern-day scientists. They are particularly interested in the char, or biochar, that gives terra preta its darkness. The fine, carbon-rich, porous material is made from organic matter through a heating process that is more akin to smoldering than burning.

Today, biochar is created as a biofuel byproduct and as a result of wildfires. It is also being manufactured from various types of agricultural waste such as corn husks, wood and even manure in low-oxygen chambers at temperatures ranging from 300 to 600 degrees F. Different production techniques equate to different end results, providing an added layer of complexity.

Wei Zhang, a Michigan State University (MSU) assistant professor with the Department of Plant, Soil and Microbial Sciences, specializes in soil remediation and has been studying biochar for more than five years. He is involved in several studies on biochar, from evaluating various production processes to examining contaminant immobilization and even the leaching of biochar particles in soils.

Zhang said there still remains much to learn about biochar, especially about how these particles move through and interact with the soil through chemical, physical and biological processes.

"The reason the people of the Amazon benefited from biochar was not by coincidence," said the MSU AgBioResearch soil physicist. "It was the right place and the right soil for this kind of amendment. That being said, not all biochar is created equal. There have been occasions when people today have applied the wrong biochar at the wrong place with negative outcomes."

Zhang is among a team of scientists led by Johannes Lehmann, a crop and soil scientist from Cornell University, working to develop a production model for biochar. In the article titled "Reverse engineering of biochar" published in Bioresource Technology by lead author Verónica L. Morales (now a soil and environmental scientist at ETH Zurich), researchers stated that the type of starting biomass and the temperature at which the product is made are the two most important production factors.

Although plenty of unknowns remain about why and how it works, biochar sales have tripled since 2008, according to some estimates.

And interest from the agriculture community continues to increase. At the request of growers, MSU horticulture professor **Eric Hanson** gave a presentation on biochar during the 2014 Great Lakes Fruit and Vegetable Expo last December. He told the audience that the subject is a fairly new area of study for him.

"One paper on biochar looked at 23 studies — although none on blueberries — and showed an average benefit of 10 percent yield increase," Hanson said. "The author attributed this benefit to change in soil pH and its water-holding capacity."

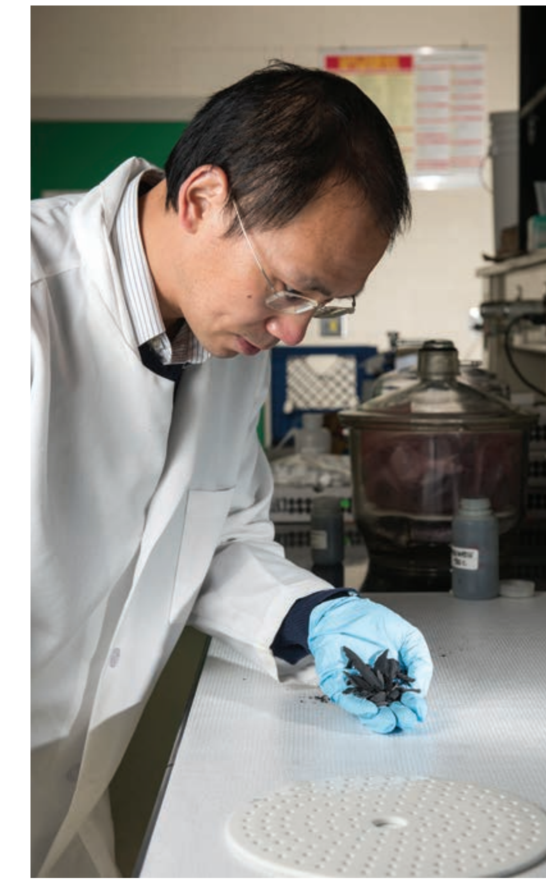
Last fall, Hanson started a biochar trial with Michigan blueberry growers on two farms. He plans to see for himself if there are potential benefits. Blueberry plants are slow-growing and take years to establish, so growers are hesitant to replace old plants with improved types. Hanson said biochar may help shorten the establishment period.

Chemical characteristics of biochar depend on the type of raw material, or parent biomass, used in the production process. Hanson reported that those made from wood tend to have pH levels from 5.0 to 7.0, and are low in salts and nutrient content, relatively high in sorption ability and less prone to leaching than most other biochars. On the other hand, he said biochar from manure tends to have high pH (as high as 11.0) and can contain high levels of total salts, as well as plant nutrients such as potassium, calcium and magnesium.

Zhang said there appears to be some preliminary agreement on biochar from the scientific community.

"Biochar is typically best for acidic soil and also coarse-textured soil such as sandy soils," Zhang said. "The reason is that when you produce biochar at high temperature, like 600 degrees, it typically has an alkaline nature. This creates a liming effect when added to acidic soils. When dealing with coarse, sandy soil, adding biochar can help the water- and nutrient-holding capacities. That's one example of applying the right biochar at the right place."

MSU AgBioResearch soil contaminant remediation experts **Stephen Boyd, Brian Teppen** and **Hui Li** are looking at the use of biochar to help sequester and remove dioxins and other contaminants from hazardous waste sites known as Superfund



MSU assistant professor with the Department of Plant, Soil and Microbial Sciences Wei Zhang examines a sample of biochar in his laboratory. He has been studying biochar production and its use for more than five years. *Photo by Kurt Stepnitz.*

sites across the United States. It is a new phase of an ongoing $18 million project funded by the National Institutes of Health.

"The bottom line is to use chars or some other sorbent amendment to reduce the bioavailability of chemicals that occur as contaminants in soils and sediments," Boyd said. "This reduces risks associated with these contaminants and may let us safely relax clean-up criteria. This might allow, for example, more contaminated sites to be remediated using the limited funds available."

In a separate study, Zhang's graduate student Cheng-Hua Liu is examining biochar made from bull, dairy cattle and poultry manures produced at 600 degrees F for sequestration of antibiotics. The heat destroys any antibiotics in the manure, which, when later applied to the soil, could immobilize antibiotics already present. It is estimated that about 70 percent of antibiotics produced are used in animal

Michigan State University "Black Carbon in the Environment" Core Working Group Members

Jessica Miesel, assistant professor, Department of Forestry. Ecosystem ecology focusing on fire-prone forests and managed conifer stands; black carbon biogeochemistry; biochar application for land management.

Hui Li, associate professor, Department of Plant, Soil and Microbial Sciences. Sorption of pharmaceuticals, persistent organic contaminants and pesticides with biochars; bioavailability of organic compounds in soils amended with biochars.

David Rothstein, associate professor, Department of Forestry. Forest biogeochemistry: response of carbon and nitrogen cycling to stand-replacing wildfire; biological and geochemical controls over dissolved organic matter fluxes through forest soils; soil amino acid cycling and plant amino acid uptake; carbon sequestration in forest ecosystems.

Chris Saffron, assistant professor, Department of Biosystems and Agricultural Engineering. Biomass pyrolysis to produce biochar; modeling of bioenergy systems including life-cycle, supply-chain and technoeconomic analyses.

Laura Schmitt Olabisi, assistant professor, Department of Community Sustainability. System dynamics modeling and participatory modeling; coupled human-natural system dynamics.

Wei Zhang, assistant professor, Department of Plant, Soil and Microbial Sciences. Fate and transport of black carbon in soil and water environments; biochar use as soil amendment; movement of environmental contaminants (e.g., veterinary antibiotics and hormones, colloids, engineered nanoparticles and microbial pathogens) across the interfaces of soil, water and plants.

agriculture.

"We believe this is an innovative approach because you're reducing the antibiotic load to the environment while also dealing with the legacy problems of antibiotics that have been there a while," he said. "If we are able to generate antibiotic-free, manure-derived biochar and place it in the field to alleviate the presence of legacy antibiotics, we could really be onto something." This work is part of a USDA-funded project for Zhang, Boyd, Teppen and Li to study the movement of antibiotics as influenced by biochar soil amendment.

Zhang has also found that biochar can absorb antibiotics from water with very little re-release back into the environment.

"Once you reduce the availability of antibiotics to bacteria in the environment by sequestration, you will decrease the selection process for generating antibiotic resistance in bacteria," he said. "That has huge implications on human health."

In an experiment conducted sheerly out of curiosity, one MSU researcher said he grew soybean plants in various types of soil mixed with biochar, including one that was completely biochar. The plants grew for 60 days in a greenhouse last fall. Afterwards, he weighed the roots of each of the plants and discovered that the one grown in 100 percent biochar outweighed the smallest by 4.5 times.

But despite some positive reports, challenges do remain. Use of biochar has had mixed results on agricultural yields. And there is concern over potential pollutants from the production process.

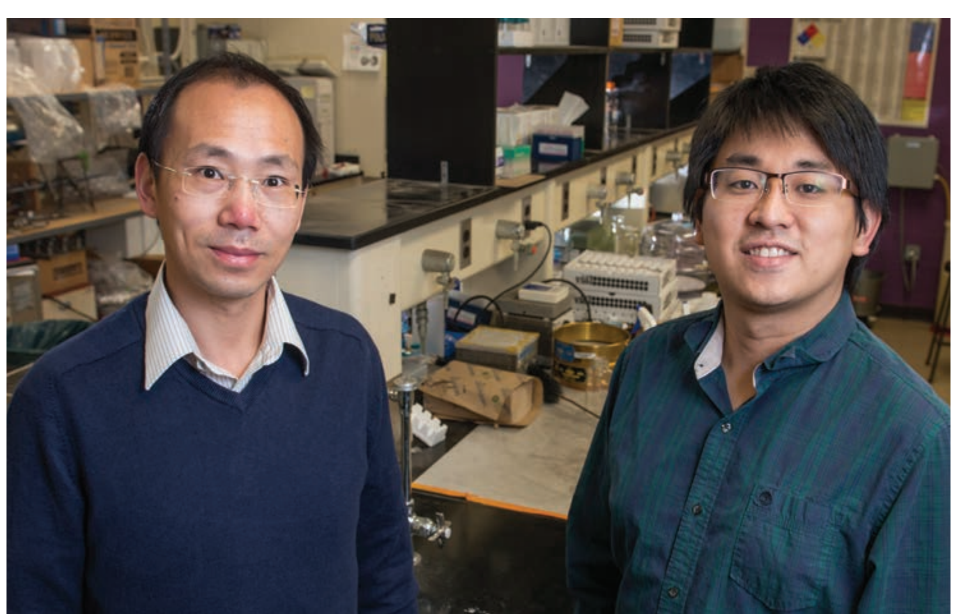
In an effort to learn more about biochar, MSU AgBioResearch and the Environmental Science and Policy Program formed a special team of scientists to study black carbon in the environment. Some studies have shown that about 10 percent of dissolved organic carbon in surface water is from black carbon, and a significant fraction also exists in the soil. In some U.S. regions, burning of crop residue such as sugarcane in the field is still allowed. In many other parts of the world, this is a regular practice, and some concern has been voiced over potential air pollution.

Biochar also comes with high production costs, so benefits must outweigh those.

"We really need to do a better job of protecting our soil resources," Zhang said. "Once they are contaminated, it is really difficult and extremely expensive to clean up. Any society that didn't protect its soils eventually failed. You can look back on history and see many examples of how that happened."

With its natural ability to retain nutrients and water and sequester contaminants, biochar appears to hold promise. But researchers caution there is still much to learn about this practice largely abandoned thousands of years ago.

(From left) MSU assistant professor with the Department of Plant, Soil and Microbial Sciences Wei Zhang and graduate student Cheng-Hua Liu are working together on a project that utilizes biochar made from animal manure. Because the burning process to make the biochar is so hot, it destroys any antibiotics in the manure. The biochar is then used in the field where it can help sequester pharmaceuticals or contaminants, including antibiotics. *Photo by Kurt Stepnitz.*



"100 TIMES MORE SENSITIVE"

New equipment ramps up contaminant research at MSU

BY HOLLY WHETSTONE
Editor

A state-of-the-art liquid chromatography-tandem mass spectrometer (LC-MS/MS) was installed in the laboratory of MSU Plant, Soil and Microbial Science associate professor Hui Li in March. The piece of equipment can detect the presence of pharmaceuticals down to a nanogram. *Photo by Kurt Stepnitz.*

Liquid chromatography-mass spectrometry (LC-MS) may sound daunting to most, but it's music to the ears of scientists — especially those examining pharmaceutical chemicals in water, soil and other natural resources.

This advanced technique is designed to identify, characterize and quantify a vast range of chemicals in the presence of other compounds. As an indispensable tool in the lab, LC-MS has helped advance science by combining the physical separation capability of liquid chromatography with the analysis capability of mass spectrometry.

Earlier this year, a state-of-the-art liquid chromatography-tandem mass spectrometer (LC-MS/MS) was installed in the laboratory of Michigan State University (MSU) Plant Soil and Microbial Sciences associate professor **Hui Li**. It is more sensitive and convenient to use than the instrument it replaced. MSU AgBioResearch contributed funds for the equipment that has been put to full use since its installation.

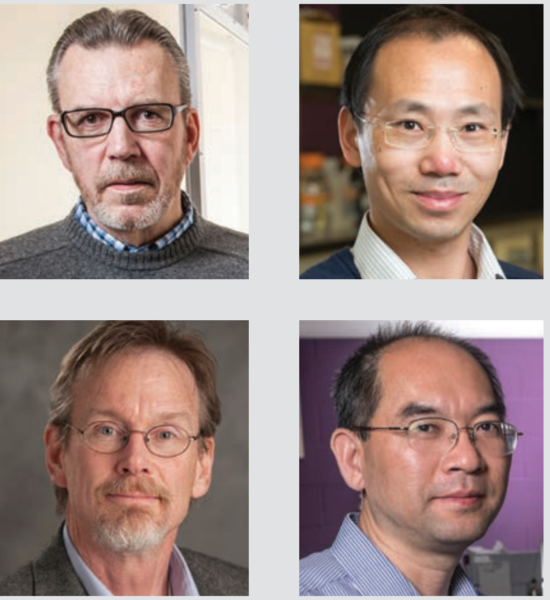
"MSU AgBioResearch has really helped my career development since I started here in 2005," Li said. "They helped with infrastructure fund, along with my and Dr. Irene Xagoraraki's (Environmental Engineering) start-up packages to purchase the first LC-MS/MS equipment. After nine years, AgBioResearch helped pull together funding for this newer state-of-the-art equipment, which is 100 times more sensitive, and has more powerful features compared to the old one in my lab. We have already used this new equipment to measure the trace levels of pharmaceuticals in water, soil, biosolids and vegetables."

Li routinely collaborates with fellow MSU soil chemists **Stephen A. Boyd** and **Brian Teppen**, soil physicist **Wei Zhang** and soil microbiologist **James Tiedje** to study environmental fate and bioavailability of organic contaminants including antibiotics in soil and water. The accurate quantification of antibiotics in soil and water using the LC-MS/MS is essential to evaluating their fate and transport in the environment, and assessing their potential risks to microbial communities and humans.

One of the major challenges in this line of research is to identify and quantify the extremely low concentration of antibiotics, considered as chemicals of emerging concern (CECs), in environmental matrices. Li said the new LC-MS/MS can detect the presence of pharmaceuticals in water down to the levels of nanograms (one billionth of a gram) per liter.

Boyd, a MSU University Distinguished Professor of Plant, Soil and Microbial Sciences, has been studying soil contaminants since coming to MSU in 1980, with research focus on environmental fate and effects of organic contaminants and pesticides in soil.

"We can use engineered bacteria as very sensitive detectors of pharmaceuticals such as tetracyclines, to explore the potential biological effects of antibiotics in the environment. That has been a big step forward," Boyd explained. "On the analytical side, the LC-MS/MS has enabled us to work with more complex mixtures and detect them at lower concentrations, which is important to this line of research on pharmaceuticals in the environment."



MSU AgBioResearch scientists (from top, left to right) Stephen Boyd, Wei Zhang, Brian Teppen, Hui Li.

Through a project funded by the National Science Foundation, the scientists are exploring the issue of antibiotic resistance as it relates to pharmaceuticals in the soil and water.

Li said he was prompted to study CECs after a United State Geological Survey (USGS) report released in 2002 showed that 80 percent of stream samples taken from 30 states, including Michigan, were contaminated by pharmaceuticals, hormones and other organic wastewater contaminants.

The report grabbed the attention of many, including Li who decided then to shift his major research attention from pesticides and organic contaminants to pharmaceuticals, antibiotics and personal hygiene products.

"I did not realize that pharmaceuticals could be persistent in the environment until I saw the USGS report," Li said. "Pharmaceuticals are of particular concern because they have high bioactive potentials. They have different physicochemical properties, and more complicated chemical structures than the conventional organic contaminants. I saw this clearly as an area in need of more scientific information to fill the knowledge gaps, and I wanted to be able to help."

Plant, Soil and Microbial Sciences Department chair **James Kells** said the team, which started with Boyd and Teppen and broadened to include Li and eventually Zhang, is doing an admirable job.

"This highly collaborative team of scientists is conducting research that will help promote sustainable agricultural production and protect our environment," he said. "Their basic work on the sorption and movement of chemical contaminants in soils is very important in the development of effective management strategies. They are developing innovative remediation technologies for clean-up of contaminated sites, with potentially huge savings compared with the conventional practice of disposal in landfills."

The scientists continue to examine the sequestration and transformation of pharmaceuticals in water and soil. These contaminants are found to be persistent for surprisingly long periods of time.

"Pharmaceuticals are designed to stay for a short time, take effect and exit the body," Li said. "So the assumption is that, when these chemicals get into the environment, they will disappear or last a very short time. But that's just not the case."

One concern is that the pharmaceuticals, either in the water system or in land-applied biosolids, can possibly have negative impacts on ecosystems such as enhancing the development and proliferation of antibiotic resistance in bacteria.

"Unfortunately, pharmaceuticals end up in the environment as a mixture of multiple chemicals, and we don't know much about the ecological effects of the mixture," Li said. "The concentrations of these pharmaceuticals are fairly low by themselves, but a mixture of these pharmaceuticals could have potentially dangerous impacts to ecosystem and human health."

The team has conducted studies and showed that 60 to 90 percent of CECs can be removed from wastewater treatment plants. Wastewater treatment plants are designed to treat heavy metals, nutrients — nitrogen and phosphate, or some other organic compounds, but not specifically for pharmaceuticals. A fair amount of CECs are released to the surrounding environments.

Through a project funded by the National Science Foundation, the MSU scientists are exploring the issue of antibiotic resistance as it relates to antibiotics in soil and water. They are mainly focused on tetracyclines — the most commonly used antibiotic in animal feeding operations, accounting for an estimated 40 percent of all antibiotics use in animal agriculture. Their research results indicate that tetracycline specifically the zwitterion species could be the major speciation to exert selective pressure on bacteria such as *E. coli* for development of antibiotic resistance.

The team of soil scientists has reported the existence of pharmaceuticals in surface runoff from agricultural fields could be connected to land-applied animal manure.

"Antibiotic resistance really doesn't recognize any boundaries between humans and animals, it's all interconnected," Zhang said. "It is imperative that we better understand the movement of antibiotics in the environment, as well as their distribution and fate in water and soil to address the antibiotic resistance."

Bioavailability is a concept that describes the movement of an antibiotic substance from an environmental matrix to a living system, and is a key factor linking environmental exposure with the development of antibiotic resistance. Many environmental factors could affect bioavailability, such as wet, dry or moist soils, and water chemistry.

Thanks to the new LC-MS/MS, MSU soil scientists are better able to determine what types of contaminants exist in the environment and how best to get rid of them, or at the very least — reduce their impact to the environment.

Illustration by Iain Bogle, BCP

No matter how you slice it, healthy soil is important

BY JAMES DAU
Writer

It is by no means an accident that human civilization arose from rich agricultural regions characterized by abundant water and fertile soil. The ability to produce large quantities of food enabled people to gather together, build cities and develop culturally. Today, as the global population skyrockets, maintaining and expanding the ability to produce enough food has never been more important. And all of agriculture — field crops, vegetables, fruit and even livestock feeds — still depends on the same soil that it did 6,000 years ago.

> *"I think that sometimes we consider crops more as above-ground organisms than below-ground, but really they inhabit both worlds. They work in tandem with the other organisms and play a significant role in the soil environment."*
>
> *— Phil Robertson*

"Soils are the foundation of crop fertility, and soil fertility is the foundation for healthy and productive crops," said **Phil Robertson**, Michigan State University (MSU) AgBioResearch scientist and University Distinguished Professor in the Department of Plant, Soil and Microbial Sciences. "In order to manage for healthy soil, you have to understand what the soil is providing and how it is providing it."

Soil is a complex medium comprising living organisms, mineral particles and organic matter, along with water and the ions needed for all the organisms that call it home, including crops.

"I think that sometimes we consider crops more as above-ground organisms than below-ground, but really they inhabit both worlds," Robertson said. "They work in tandem with the other organisms and play a significant role in the soil environment."

Long-term research for long-term change

Robertson and his colleagues at the W. K. Kellogg Biological Station (KBS) in Hickory Corners, Michigan, have spent the past 26 years studying long-term change in the ecology of agricultural sites under the auspices of the Long-Term Ecological Research (LTER) program. They observe the interactions between organisms and their environment. The soil environment, one of the key components of the larger ecosystem, is of high priority in Robertson's work.

One of the most important functions of the soil microbial community is to decompose and recycle organic matter left by previous crops. Organic matter accrues in the soil in the form of aggregates, small clumps of material that build up over years into something that can be seen with the naked eye. They comprise tiny ecosystems in and of themselves. As innumerable species of bacteria and fungi consume the organic matter, nutrients are released back into the soil and taken up by the roots of crops. Given the significance of this process to crop nutrition, scientists now widely understand that soil organic matter is the basis of soil fertility.

This vital source of soil nutrients declines following conversion to conventional agriculture, however. The decline can often be attributed to increased microbial activity. As fields are tilled and soils churned, the aggregates are disturbed and exposed to the atmosphere. The sudden exposure to oxygen and the elements causes them to break apart and allows microbes instant access to the organic matter they've contained. Over the course of 40 to 60 years, soil will lose between 40 and 60 percent of its original organic matter.

BELOW: Soil aggregates, like this one held by Phil Robertson, are formed in soil over time and serve as the basis of soil organic matter.

BELOW RIGHT: Phil Robertson, professor of ecosystem science at the Kellogg Biological Station (KBS) and lead scientist for the KBS Long-Term Ecological Research, has spent the last 26 years studying ways to improve soil health on farms without impacting their productivity. *Photos by Derrick Turner.*

Sieg Snapp, a professor in the Department of Plant, Soil and Microbial Sciences, is working to improve soil management practices in Malawi, where soil health has experienced severe degradation. *Photo by Kurt Stepnitz.*

> *"One of the things we learned in Malawi is that there is a minimum amount of soil carbon that you need to have for productive soils."*
>
> *— Sieg Snapp*

Robertson's team is searching for ways to reverse the deterioration scenario.

"More and more farmers are understanding how significant soil organic matter is to their crops and their livelihoods," Robertson said. "Rebuilding soil organic matter to levels closer to that of the natural ecosystem is one of the major goals of sustainable agriculture."

As a general rule, soils are slow-changing. Though some events, such as the outbreak of a pathogen, can generate quick change, most everyday processes take years to produce a noticeable effect. This makes long-term research projects such as those at KBS essential to understanding how soil works and how it can be enhanced.

"Soil can take more than 10 years to change, which by definition is a long-term study," Robertson explained. "It took us 10 years to document the initial changes here at KBS, and we have some studies designed to last 20 or 30 years."

To study soil health change, Robertson's team oversees 2.5-acre research plots with four agricultural management scenarios: conventional, no-till, reduced-input and biological. The conventional system is managed with the standard practices of the agricultural industry; no-till is a system that does not employ plows to disturb the soil. Reduced-input plots are managed with only modest amounts of synthetic fertilizers and other chemicals, and the biological system relies totally on organic sources for soil nutrients.

The team compares the results at these plots with two natural ecosystems on-site: an area formerly used for agriculture that is now returning to a natural state, and an area of old-growth forest that has never been used for anything else. In the years since the experiments began, several means of improving soil organic matter have emerged.

"By comparing these different systems, we gain tremendous insight into the factors that underlie the overall system," Robertson explained. "The experimental plots are our most important asset in understanding the agricultural ecosystem."

For example, eliminating tilling preserves the existing organic matter while providing an environment in which more can form. Robertson's team witnessed firsthand how significant this practice can be during the 2012 drought, when a severe lack of rain made crops wholly reliant on water already in the soil. Though the drought proved devastating to many Michigan farmers, the higher concentrations of soil organic matter in the KBS LTER plots under no-till management allowed the fields to store an extra three inches of water, prolonging the life of their plants. That year, the soybean yield from the no-till fields exceeded that of the conventional ones by 50 percent.

Improving soil organic matter not only has a demonstrable effect on crop yield but also helps protect the larger environment from water pollution and greenhouse gas emission. Nitrogen fixation, by which atmospheric nitrogen is converted into a form usable by plants, is an essential process fulfilled in nature largely by the bacteria that dwell in the soil.

"This is a process that has been ongoing for eons," Robertson said. "All life depends on these bacteria, flat out."

As soil organic matter declines, the nitrogen originally captured by these bacteria similarly declines, leaving many farmers with little recourse but to add nitrogen in the form of chemical fertilizers to fields. Applying too much fertilizer, however, or applying it at the wrong time, can cause it to leach into the groundwater and/or escape into the atmosphere, contributing to both damaging algal blooms in lakes and rivers and to climate change. Nitrous oxide that escapes into the atmosphere is approximately 300 times more effective at trapping heat than the most common greenhouse gas, carbon dioxide.

"As much as possible, we want nitrogen

to originate from and stay in the cropping system," Robertson said. "Creating an environment that encourages nitrogen conservation is beneficial not only to the plants that live there but to the planet as a whole."

Across the pond

The LTER lessons also hold import for regions far removed from Hickory Corners, Michigan. **Sieg Snapp**, MSU AgBioResearch agronomist and associate director of the Center for Global Change, has been working to improve soil health in the African nation of Malawi since before she came to MSU in 1999.

"The issue of sustainability, of whether soils can continue to produce food in the future, is very stark and clear in Malawi," Snapp said. "The need there is very urgent."

In Malawi, a high population density and small land holdings equate to people farming 2-acre plots to feed their families. Decades of intensive use have resulted in a severe decline in soil organic matter.

Over 20 years ago, the Food and Agriculture Organization of the United Nations (FAO) conducted a soil mapping project across the African continent. Soil pits were dug throughout Malawi, and soil samples were taken at each site to record the soil type and its attributes. The FAO scientists carefully georeferenced these pits, so Snapp and her team could revisit the sites decades later to measure changes that took place in the intervening years. Snapp said that what they found was shocking.

"We were wondering if these soils had gotten worse," Snapp explained. "I thought they might have hit a plateau, where they reached a minimal level of quality and remained there, but that did not happen. The long-term data showed they had continued to decline, which is quite worrisome."

Finding ways to restore Malawi's soils and, therefore, its food security became paramount.

As chairwoman of the KBS LTER agronomy committee, Snapp has taken many of the lessons learned at LTER and applied them to the situation in Malawi. The utility of cover crops in the project has taken on particular importance because not only do they improve soil organic matter but the right cover crop can also yield a profit for the farmer.

Snapp's team has explored a number of cover crops with beneficial properties for farmer and soil both. Pigeonpea, a short, leafy shrub native to South Asia but imported to Africa from India around 3,000 years ago, grows for one to two years and produces peas that can be sold or consumed by the family. The plant is also useful as a forage for livestock and is optimal for recycling both soil nitrogen and phosphorus.

"We need cover crops that can be harvested or grazed, something that generates a product farmers can sell," Snapp said. "It offsets the economic impact of not growing a cash crop on their field while helping to remediate soil quality."

Snapp has unearthed important agricultural insights from her work in Malawi and applied them to the rest of the world.

"One of the things we learned in Malawi is that there is a minimum amount of soil carbon that you need to have for productive soils," Snapp said. "We're getting close to finding out what that tipping point is so that we can recommend a basic level at which farmers need to keep their organic matter."

Putting marginal lands to use

One of the greatest concerns about the decline of soil health in places such as Malawi is the subsequent increase in marginal agricultural landscapes, areas where the soil is too poor or the terrain too hostile for healthy crop growth. These lands are far from unique to southeast Africa. Anywhere the land is steep or marshy or the soil is rocky or has poor drainage can be considered marginal, as well as sites with poor soil nutrient availability. Helping farmers make use of these less fertile lands has been a major focus of MSU AgBioResearch forage specialist **Kim Cassida**.

As part of a team alongside fellow MSU AgBioResearch scientists **Jason Rowntree** and **Lisa Tiemann**, Cassida has found that marginal landscapes are particularly useful for grazed livestock forage crops, which remove fewer nutrients from the soil than traditional cash crops.

"We look at a particular plot of land and determine the plants that are best suited for it," Cassida explained. "At the same time, the plants have to have the right nutrient profile for the animals because we're trying to produce the highest quality beef for the market."

The challenge with forage crops stems from the fact that their quality is neither uniform nor static. As a particular shoot ages, its nutrient levels decline, making a compromise between crop yield and nutritional value inevitable. One of the ways to offset this issue is by growing mixtures of pasture species that complement one another in timing of nutritional value and yield. In addition to improving nutritional value, nitrogen-fixing legumes also improve soil fertility.

Working with alfalfa, the most common legume forage crop in Michigan, and other nitrogen-fixing legumes, grasses and annual forages, Cassida's team is pioneering forage mixes that not only provide excellent nutrition for livestock but also provide nitrogen and other nutrients for the entire soil ecosystem.

Wormy business

Soil is home to far more than crops and bacteria. Among its most influential denizens, to both the benefit and detriment of farmers, are nematodes — roundworms. Nematodes have adapted to nearly every ecosystem on the planet, marine and terrestrial, but by far their most important role in human health and nutrition comes from their interactions with plants. Those interactions have been a major focus of MSU AgBioResearch scientist and Department of Horticulture associate professor **Haddish Melakeberhan**.

"Nematodes live in the soil and water and can be either beneficial or not, depending on the species," Melakeberhan said. "About 10 percent of the species are harmful parasites of plants and humans. The rest play an important role in nutrient cycling and the biological control of pests."

Melakeberhan came to MSU as a postdoctoral researcher in 1990 to study

(Continued on page 50.)

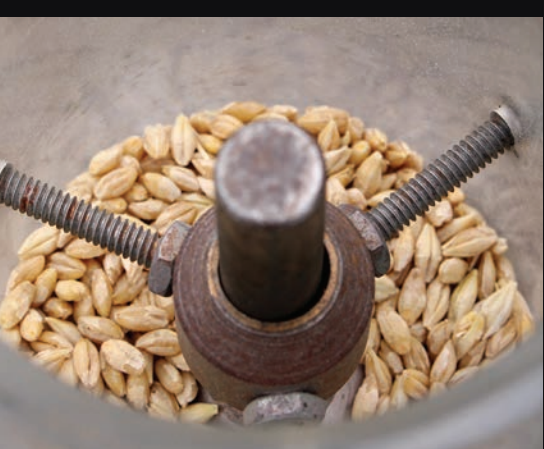
OPPOSITE: Haddish Melakeberhan, (left) associate professor in the Department of Horticulture, came to MSU in 1990 to study the relationship between nematodes and cherry tree decline. He has since been working to help growers find ways to minimize the impact of harmful nematodes and maximize the impact of beneficial ones. He and lab assistant Zinthuz Maung use this device, a semiautomatic elutriator, to extract nematodes from soil samples. *Photo by Kurt Stepnitz.*

BELOW: Kim Cassida, forage Extension specialist in the Department of Plant, Soil and Microbial Sciences, has found that planting perennial grazing crops in marginal agricultural landscapes not only slows soil degradation, but allows farmers to reap financial benefits from otherwise unfruitful land. *Photos by Kurt Stepnitz.*

"We look at a particular plot of land and determine the plants that are best suited for it. At the same time, the plants have to have the right nutrient profile for the animals because we're trying to produce the highest quality beef for the market."

— Kim Cassida

A SPARTAN COMEBACK OF THE SEED KIND



Spartan barley seeds await distribution on a test field in the Upper Peninsula. Barley is one of four essential components of almost any beer. *Photo courtesy of UPREC.*

In 1916, Michigan State University (MSU) plant breeder F.A. Spragg created a new variety of barley fittingly called "Spartan." The cultivar — a cross between Michigan black barbless and Michigan two-row — had higher production capabilities and superior quality compared with other commonly grown barleys. By the late 1950s, Spartan barley was found on farms around the country.

BY JAMES DAU
Writer

The passage of time, however, brought new advances in plant breeding. Eventually, Spartan was surpassed by barleys of even higher quality and yields, and this once-commonplace grain was relegated to the annals of agricultural history. The seeds were locked away in a U.S. Department of Agriculture (USDA) gene bank in Utah, one of a number of facilities established to preserve the genetic diversity of the nation's field crops, for more than 60 years.

Now, a team of MSU researchers in the northern region of the Upper Peninsula have set out to resurrect Spartan barley in light of increased demand for locally brewed beers in Michigan.

Barley has been produced around the world since the foundation of agriculture nearly 12,000 years ago. References to the grain have been found in the writings of ancient Greece and Rome, on 4,000-year-old clay tablets in Iraq and in Egyptian hieroglyphics. Its long global success can be traced to its versatility: barley contains eight essential amino acids and is used in bread, livestock and fish feed, as an algicide and, perhaps most notably, in beer and whiskey production. Barley is a key ingredient in the malting process, in which the starches of cereal grains are converted into sugars by soaking them in water and then drying them in hot air. Combined with hops, yeast and water, it is one of the four essential components of almost any beer.

Since the late 1990s, craft breweries have proliferated rapidly in the United States, driven by consumer demand for beers made with local ingredients. Today, more than 2,300 craft brew businesses are in operation around the nation, representing more than 104,000 jobs and a nearly $20 billion industry. Expansion of operations has invigorated grower interest in producing the necessary crops — hops and barley. A new 400-acre hops farm, MI Local Hops, is planned in Williamsburg, Michigan, that would double the state's hops production. MSU AgBioResearch scientists and MSU Extension specialists are working to help growers meet craft brewers' requirements around the state.

"We've been working with barley for the past 10 years," said **Ashley McFarland**, center coordinator for the MSU Upper Peninsula Research and Extension Center (UPREC) in Chatham. "A lot of craft brewers and distillers want to source their grain here in Michigan, and we're helping farmers produce a crop that has the level of quality that malt houses need."

As researchers investigated the opportunities that malting barley represented for Michigan farmers, one brewer reminded McFarland that MSU had once produced its own barley variety: Spartan barley.

"Everyone gets excited about the prospect of having locally grown barley in their beer, and it doesn't get more local than a variety pioneered by MSU," McFarland said. "We wanted to bring it out to the center to start testing it, to determine if it was something growers could use."

Because Spartan barley was no longer grown and no samples remained in Michigan, McFarland's team reached out to MSU AgBioResearch agronomist and plant breeder **Russ Freed** for help. Freed's long experience in the field of plant breeding, developing varieties of oats and wheat, yielded many contacts in the industry, among them staff members at the USDA gene bank in Utah.

"The gene banks are important repositories of genetic diversity," said Freed, professor of international agronomy in the MSU Department of Plant, Soil and Microbial Sciences. "There are a lot of varieties, like Spartan, that go out of production but might still have characteristics that plant breeders want for new varieties. The USDA banks allow them to go back and search those out."

Freed received five grams of Spartan barley seeds, which he planted and successfully grew in greenhouses on the MSU campus in East Lansing. The seeds of those plants were sent to UPREC this past spring for planting and testing in the field.

"We have made significant progress since Spartan barley was developed into a high-yield crop. The thing with microbreweries is that they make smaller batches of beer, so they don't need the large, standardized quantities of malting barley

Spartan barley, once common throughout the United States, has been resurrected after over six decades for the craft beer industry. *Photo by Natasha Berryman.*

> *"Everyone gets excited about the prospect of having locally grown barley in their beer, and it doesn't get more local than a variety pioneered by MSU. We wanted to bring it out to the center to start testing it, to determine if it was something growers could use."*
>
> *— Ashley McFarland*

that the big brewers do," Freed explained. "Microbrewers like to have something with a local flavor, with local significance. They like the idea of having diversity in their product line."

The staff at UPREC, led by MSU assistant crops researcher **Christian Kapp**, will test Spartan to see if it is a viable crop for microbrewery use.

"When Ashley [McFarland] told me MSU had released a barley variety called Spartan back in the teens, I thought that was really cool," Kapp said. "I'm excited to see how it does in the field."

Kapp has been working with barley at UPREC since 2004, with a specific focus on malting barley since 2011. This year his team planted Spartan during the first week of May. During the intervening months until harvest time near the end of August, they will observe the plants and be on the lookout for the ideal characteristics of a good barley crop.

"The traits we're looking for are ease of harvest, a strong stem and grain heads that stay intact," Kapp explained. "If the heads break, the seeds can scatter and be much more difficult to collect. These are all things we need to investigate because we need to make sure this is a good fit for farmers and brewers."

The initial quantity of seeds is too small to create a comprehensive picture of Spartan's potential, so Kapp's team will collect this year's seeds and use them to plant an even larger plot next year.

> *"The gene banks are important repositories of genetic diversity. There are a lot of varieties, like Spartan, that go out of production but might still have characteristics that plant breeders want for new varieties. The USDA banks allow them to go back and search those out."*
>
> *— Russ Freed*

"It takes time to get a production-sized plot established," McFarland said. "Potentially, we'll be able to start full variety trial work in 2016 or 2017."

Michigan growers and maltsters are eagerly awaiting preliminary results. Carl Wagner III, a lifelong farmer and 2011 MSU graduate, is the founder of C3 Seeds, which supplies farmers with seeds for a variety of crops.

"When Ashley [McFarland] emailed me about revitalizing Spartan barley, I got very excited," Wagner said. "Looking at the history of seed development, anything from Michigan State is right up my alley. There are a lot of questions yet on the agronomic side of this, but there are a lot of opportunities, too."

Brew business takes interest

The Pilot Malt House in Byron Center was founded in 2012 to provide high-quality malt to Michigan craft brewers. McFarland works with the business on a weekly basis, exchanging ideas. She pitched the idea of Spartan barley, and the staff jumped at the possibility.

Ryan Hamilton joined Pilot Malt House as a maltster the year after it was founded and has since seen the company expand its malt production fourfold.

"When Stroh's went out of business, malting barley production in Michigan essentially ceased," Hamilton said. "We lost a lot of the knowledge that was passed down, a lot of that heritage, and Spartan is from that earlier era. As an heirloom variety, it's significant. It would only help our business and our customers to have a barley grown here, and the fact that it's from MSU and the 1910s only adds to its mystique."

Most barley now grown in Michigan originates in North Dakota and central Canada, regions with different climatic and environmental conditions. Hamilton said he hopes that Spartan, with its roots firmly in Michigan soil, will have the genetic fortitude to thrive where other varieties presently struggle.

"The varieties we get from out west perform differently here," he said. "In Michigan, we have more concerns about fungal infections and higher moisture levels than they do, and we get big rainstorms close to the harvest. Even if Spartan doesn't turn out to be viable as a commercial variety, bringing it back will allow us to breed its best attributes, those suited to Michigan's climate and soils, back into our barley crops."

If successful in the trials, Spartan barley stands to help not only Michigan malt houses and craft brewers but also the agricultural industry of the U.P., where growing options are limited by long winters and relatively brief summers.

Under McFarland's coordination, the team identified barley as one of a number of small grains and forages with potential for the northern region. Barley test plots at the center have already shown promising yields. Add the appeal of the barley carrying the MSU name grabs the attention of growers, malt houses and craft breweries.

"We're in the early stages now, but a lot of people are excited to see it," McFarland said. "To be able to have a Spartan beer made with Spartan barley at a Spartan tailgate — that's something worth pursuing."

Spartan barley holds a unique place in the annals of an ancient crop, both for its historical use in barley production on a national scale and now, as it experiences a resurgence, for the potential it holds for Michigan agriculture and craft brewing.

"It's more than just an heirloom variety," Kapp said. "I mean, how cool would it be if we could resurrect Spartan barley and bring it back after over 60 years? From my perspective, that's a major appeal. Let's dust it off and see how it does out in the field."

LEFT: Christian Kapp, MSU assistant crops researcher, plants Spartan barley in a plot at the Upper Peninsula Research and Extension Center in Chatham. Kapp has been working with malting barley since 2011. *Photo courtesy of UPREC.*

RIGHT: Planted in May of 2015, the Spartan barley had sprouted several inches by mid June. *Photo courtesy of UPREC.*

OPPOSITE: Russ Freed, professor of international agronomy in the MSU Department of Plant, Soil and Microbial Sciences, grew the first batch of Spartan barley in more than 60 years in a greenhouse on the MSU campus. *Photo by Natasha Berryman.*


If successful in the trials, Spartan barley stands to help not only Michigan malt houses and craft brewers but also the agricultural industry of the U.P., where growing options are limited by long winters and relatively brief summers.

Groundbreaking moments in soil:

A look back on various advancements

BY JANE L. DEPRIEST
Contributing Writer

Soil research at Michigan State University (MSU) has a long, rich history — some milestones even predate the university's official establishment of a soils department in 1909.

For example, in 1863, R. C. Kedzie with the Department of Agricultural Chemistry at the Michigan Agricultural College (MAC) — the forerunner of Michigan State University— reported on projects closely related to soil science because they involved using fertilizers on corn and potatoes.

And in 1868, MAC's Manley Miles, who six years earlier had become the first professor of scientific agriculture in the United States, reported that soil variability was a significant problem on many plots. He proclaimed that "the results of a single field experiment on the application of manure cannot be relied on to establish any rules of practice." That thought is still valid today.

Members of the MSU Soil Science Department gather in front of the Soil Science Building in the fall of 1968. Those unable to attend were included by way of photo posters. The photo was taken just before the department merged to form the Department of Crop and Soil Sciences. Professor Ray L. Cook, department chair from 1954-69, is pictured in the second row from the bottom, first person on the right. *Photo Courtesy of MSU Archives & Historical Collections.*

The **Soils Department** was formed four decades later as part of the College of Agriculture. Joseph A. Jeffery, a native of Wisconsin who had been appointed an assistant professor of agriculture in 1899, was the first head of the department. Jeffery was the only department member until A. R. Potts, a member of the original Department of Agriculture, was appointed as an Extension field agent for the Soils Department and also the Department of Crops later that year.

The Soils Department remained a separate entity until 1969, when it joined with the crops department to form the **Department of Crop and Soil Sciences**. Dale Harpstead came to the university as the chair of the combined department after serving on the staff of the Rockefeller Foundation as director of its maize improvement program in South America.

In 2012, the Department of Crop and Soil Sciences was merged with the Department of Plant Pathology to form the Department of Plant, Soil and Microbial Sciences. This realignment aimed to increase the focus on strategic platforms and improve administrative efficiency. **James Kells**, professor and former chair of the Department of Crop and Soil Sciences, became the chair of the new department.

The MSU Soils Department, under various monikers, has existed more than 100 years. During that time, faculty members have made numerous historic achievements in key research areas that have helped build the foundation for today's soil science research.

Soil Physics

Soil physics has been a major emphasis for scientists and engineers at MSU going back to the formation of the soils department. C. H. Spurway, who was appointed an instructor of soil physics in 1910, became a recognized authority in the management of greenhouse soils. His major contributions during his 35-year tenure included the development of simplified methods of determining available plant food elements. In 1911, G. J. Bouyoucos was the first Ph.D. hired by the soils department. His best known contributions to soil physics are his widely used gypsum moisture blocks, which bear his name, and the hydrometer method for particle size analyses.

In the 1960s and '70s, A. Earl Erickson, a professor of soil physics, and Clarence M. Hansen of MSU agricultural engineering worked on techniques to retain water in sandy soils. They developed a machine to lay a thin asphalt layer under sandy soils to create a barrier to downward water percolation, which improved crop yields in those soils.

Another area of soil physics is water flow in unsaturated soils, which R. L. Kunze pursued in research. Joe T. Ritchie came to MSU in 1984 to assume the Homer Nowlin Chair in the College of Agriculture and Natural Resources. His groundbreaking research in agricultural physics with emphasis on soil-plant-water-atmosphere relationships led to the development of functional crop models for efficient use of water and fertilizer.

Soil Chemistry

Soil chemistry — how soil is affected by mineral composition, organic matter and environmental factors — has been widely researched at MSU. The growth of research on clay soils at MSU began in the 1950s with Max Mortland, who was at the forefront of identifying the physical and chemical relationships of clay minerals and soil organic matter, which prompted a greater understanding of how to increase and retain organic matter in soils. Mortland's work was a precursor to the research on clay soils being conducted today at the university. Micronutrients in soils, especially the lack of micronutrients and their effect on soil productivity, are another long-standing area of research pursued by professors of soil chemistry including Boyd Ellis and Bernard D. Knezek.

Soil Genesis and Classification

Because of Michigan's diverse soils, research in soil genesis and classification has been important to identify the soil resources of Michigan and determine their best uses. The type of soil often determines what crops grow best, whether home septic systems can be used, what engineering must be done to support roads and buildings, what trees can be successfully grown in agroforests, what plants would be successful to manage wildlife in their natural habitats, and a host of other uses. Over the years, MSU researchers have studied soils throughout Michigan and have helped to identify what soils occur where, what their properties are and why particular soils occur in the places they do.

Identification and characterization of the sandy Spodosol soils that occur throughout northern Michigan was a major undertaking of Eugene Whiteside, who came to MSU in 1949. Whiteside and

(Continued on page 48.)

Alvin Smucker, PhD

(Photo courtesy of MSU Innovation Center)

Alvin J. M. Smucker

2015 Innovator of the Year

Alvin Smucker, professor of soil biophysics in the MSU Department of Plant, Soil and Microbial Sciences, is the 2015 MSU Innovator of the Year for his original work with subsurface water retention technology (SWRT) and his continuing research to develop water retention membranes on a commercial scale. He received the distinction from MSU Technologies during the fifth annual MSU Innovation Celebration in April.

“The 2015 MSU Innovator of the Year Award for SWRT affirms another world-grant focus by MSU,” Smucker said. “This demonstrates how scientists from many disciplines at MSU and supporting industries have successfully developed a revolutionary concept for doubling soil water content in the root zones of sandy soils.”

Agriculture uses approximately 70 percent of the world’s freshwater supply. Smucker and his colleagues developed SWRT after six years of research. It’s an MSU-patented process that retains plant-available water and nutrients in the plant root zone.

“This technology has the potential to change lives and regional landscapes domestically and internationally where highly permeable sandy soils have prohibited sustainable food production,” said Smucker.

In addition to 370 million acres in the United States, more than 5 billion acres of soils have been identified for SWRT improvement globally.

Smucker’s innovation strategically places contoured, engineered films at various depths below a plant’s root zone, doubling natural soil water content. Proper membrane spacing also permits internal drainage during excess rainfall and provides space for limited primary root growth.

Irrigated sandy soils improved by SWRT membranes produced 45 percent more cucumbers, squash and green peppers than did the control fields near Benton Harbor, Michigan. During the past three years, SWRT membranes have been combined with prescription irrigation and the injection of fertilizers, soil amendments and other water-soluble products into an irrigation system. As a result, the system helped produce 239 percent more corn grain and biomass — with a world record of 325 bushels per acre on irrigated sandy soil — during the 2014 growing season.

Smucker sees the advantages of this system in many aspects of agriculture.

“Water retention membranes reduce quantities of supplemental irrigation, protect potable groundwater supplies, and enable more efficient use of reduced quantities of fertilizers and pesticides.”

TITLE: Professor of soil biophysics, MSU Department of Plant, Soil and Microbial Sciences.

JOINED MSU IN: 1971 as assistant professor.

HOMETOWN: A farm between Smithville and Orrville, Ohio. He has lived in Okemos, Michigan, since 1974.

FAMILY: Married to Betty Smucker, MSU instructor emeritus, College of Arts and Letters. They have three married children and nine grandchildren.

MUSES: I am inspired by constant contemplations about new solutions for resolving global poverty, malnutrition and starvation.

FAVORITE FOOD: Peking duck and all of the delicious side dishes that accompany it.

BEST SONG/GROUP: Johann Pachelbel’s Canon in D Major by the Chicago Symphony Orchestra.

BOOKS I’D RECOMMEND: I believe that multidisciplinary minds need daily readings of the Bible, peer-reviewed multidisciplinary journals and Howard Buffett’s *Forty Chances: Finding Hope in a Hungry World.*

COOLEST GADGET: iPad

BEST PERSONAL INVENTION: Hydropneumatic elutriation root washer and global root image processing website: http://rootimage.msu.edu.

WORST GLOBAL INVENTION: Soil disc equipment.

ON MY BUCKET LIST: Travel to countries to visit former graduate students.

PERSON I’D MOST LIKE TO MEET: (living or dead): Dr. Francis Collins, geneticist and director of the National Institutes of Health and the author of *The Language of God.*

BEST TRIP/VACATION: Riverboat cruise in Russia from St. Petersburg to Moscow.

ON A SATURDAY AFTERNOON, YOU’LL LIKELY FIND ME: Catching up with household hobbies and email.

MAJOR RESEARCH BREAKTHROUGH OF THE NEXT DECADE: Permanent, low-maintenance and inexpensive low-energy water desalinization technologies.

ON MY BUCKET LIST: Travel to countries to visit former graduate students.

TURF TRIUMPHS

From Friday nights under the lights to World Cup, MSU research plays vital role on the field

Michigan State University (MSU) turfgrass scientists (from left) Joe Vargas, Kevin Frank, Trey Rogers, James Crum and Emily Merewitz assemble on Spartan Stadium's portable athletic field. The system and soil mixture pioneered for Spartan Stadium is the same that was used for the Athens and Beijing Olympic Games. *Photo by Gregory Kohuth.*

OPPOSITE: A portable athletic field was installed in Spartan Stadium following remodeling in 2001. *Photo courtesy of James Crum.*

BY JAMES DAU
Writer

Since the early days of civilization, humanity has been playing sports.

And for as long as there have been sports, there has been a concurrent need to manage and maintain the spaces that host them. From the ancient tracks and arenas of Olympia to the numerous stadiums, golf courses and athletic fields that dot the cities of the modern world, the expertise, skill and passion of the people dedicated to preserving and improving these important cultural centers have long played a significant, if often unsung, role. Michigan State University (MSU) boasts a long history of assisting these professionals beginning in the 1880s, when MSU botanist W.J. Beal conducted turfgrass species evaluation studies at the Michigan Agricultural Experiment Station, now MSU AgBioResearch. Since then, researchers — especially those of the MSU turfgrass program — have been offering innovative solutions to the ever-changing needs and challenges faced by the sports industry.

Kevin Frank, MSU AgBioResearch and Extension turf specialist and associate professor in the Department of Plant, Soil and Microbial Sciences, said one of the first significant scientists in the field in more recent times was James Beard, who began his career in academia at MSU

LEFT: A portable turfgrass module ready to be installed in the Olympic Stadium in Athens. The portable athletic field system made it possible for the games to begin the day after the opening ceremony which purposely flooded the stadium.

RIGHT: Turfgrass modules are installed at Spartan Stadium. The field was designed with an optimal soil mixture that combined excellent drainage with the strength and durability to withstand prolonged athletic competition. *Photos courtesy of James Crum.*

and is professor emeritus of turfgrass science at Texas A&M. His seminal work, "Turfgrass Science and Culture," laid the foundation upon which many turf managers and scientists around the country were educated.

"Dr. Beard quite literally wrote the textbook on turfgrass in 1973, and we still use that book today," Frank said. "Starting with his early work, MSU has had a reputation for doing research that is very applicable to the industry."

A few years later, in 1979, MSU and the Michigan Turfgrass Foundation broke ground on the Robert Hancock Turfgrass Research Center in East Lansing, which continues as the home for leading-edge turfgrass science.

A little sand goes a long way

One of the most fundamental truths of plant management of any kind, whether in agriculture, landscaping or turfgrass, is plants' need for water. As with so many things, however, too much of a good thing can be disastrous. When a field floods, the soil can eventually be strangled by the substance that brings plants to life. Too much water excludes oxygen from the soil, creating an anaerobic environment in which roots cannot survive. This can be particularly devastating for athletic fields and golf courses, whose function depends entirely on maintenance of a healthy, uniform field of turfgrass.

To promote proper drainage, turf managers often use a significant percentage of sand in the soil mixtures on which their fields grow. Sand particles are larger than those of clay or silt — the other two primary soil ingredients — resulting in a looser structure through which water can escape. Muddy soil compacts under pressure, inhibiting the growth of any plants that call it home; sand does not. In addition to its drainage benefits, sand is also slightly more malleable, reducing the impact on players' bodies and, therefore, decreasing the risk of injury.

Trey Rogers, MSU AgBioResearch turfgrass scientist and professor in the Department of Plant, Soil and Microbial Sciences, said that researchers have known for a long time that sand equates to better athletic performance.

"MSU Spartan Stadium is a great example of that. It can rain 3 inches and players on the field won't have a speck of mud on them," Rogers said. "The beauty of sand is that it drains well and it keeps turf growing."

Building a sand-based field from the ground up, however, comes with a hefty price — starting at $500,000 upwards to $1 million. This presents a serious obstacle to institutions such as middle and high schools, particularly in rural areas. Many fields in Michigan and across the country are saddled with native soils with poor drainage, which can result in extensive damage.

In the early 2000s, some schools began tearing out their fields, covering the topsoil with 6 inches of sand and then returfing them to give the fields a fresh, healthy start for less than the cost of a new all-sand facility. Still, the process remained too expensive for many, and many others lacked the expertise to establish a new field.

"These were all problems that reared their heads every rainy Friday night in October, because the fields would get soaked and torn up by games and would remain in a sort of ruined state for the rest of the year and into the next spring," Rogers explained. "Big high schools could afford to install an artificial field, but the small ones didn't even have that option."

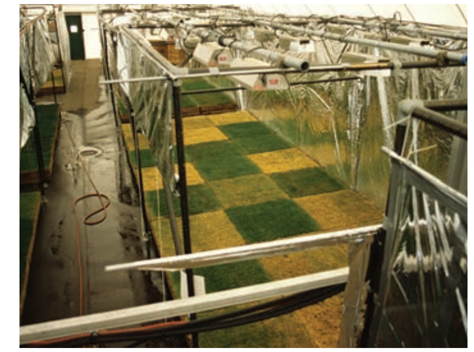
A new, more affordable solution was needed. Rogers and graduate student Alec Kowalewski began developing a way to give schools the stability and drainage advantages of sand fields without exorbitant costs. A former football player from a small high school in Michigan, Kowalewski was the perfect candidate to help Rogers tackle the issue.

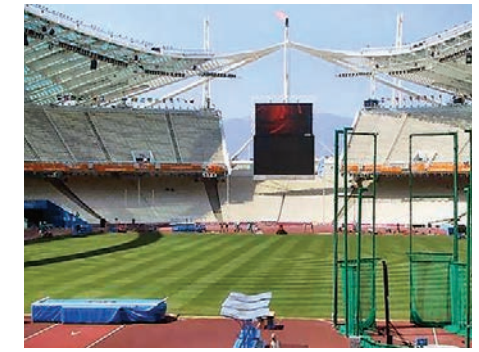
Their solution was as innovative and elegant as it was simple. Called build-up sand capping, this technique involves adding sand little by little across the surface of the field. The blades of grass grow up through the sand, and after multiple treatments, several inches of sand are in place. And it can all be done for about $150,000, a mere fraction of the cost of a new sand-based field.

"The beauty is that there's no difference, from a performance perspective, between a sand-capped field and one that's pure sand," Rogers said. "This is finally a true alternative that's viable for places with a smaller budget, and we still get calls about doing it today."

From Pontiac to Beijing

When the Pontiac Silverdome was chosen as the first indoor stadium to host a World Cup soccer match, its field managers were faced with a problem. The World Cup organizers wanted teams to compete on a field of live, not artificial, turfgrass. The





LEFT: Several turfgrass treatments are tested under low light conditions to determine which would best survive in the Pontiac Silverdome.

RIGHT: The portable athletic field covering the grounds of the Olympic Stadium in Athens, Greece. The field was installed at the stadium less than 36 hours after the opening ceremonies. *Photos courtesy of James Crum.*

issue: the building's reinforced canvas fabric roof allowed only 8 percent of natural sunlight to pass through it and reach the surface below. The problem: without better access to natural light, the field simply would not survive for the duration of the tournament.

"The organizers knew they were going to need help, so they asked us to develop a turf system that could be used indoors," said **James Crum**, MSU AgBioResearch soil scientist and professor in the Department of Plant, Soil and Microbial Sciences. "It was something nobody had ever really tried before at that scale, although there has been much more since."

In the summer of 1992, Rogers and Crum began development of a portable athletic field, one that could spend the majority of its time outdoors, basking in natural sunlight and soaking up rain, be moved inside the stadium for play and then returned outdoors. They didn't want the tenure under the dome to take its toll. On paper, it seemed rather simple, but challenges soon emerged.

Rogers and his team built a research dome similar in structure and material to the Silverdome near the Hancock Turfgrass Research Center on MSU's East Lansing campus. There, they tested various combinations of turfgrass species, fertility practices and irrigation techniques to produce a turf perfectly tailored to the conditions of the World Cup. Few of these factors proved as significant to the novel field's viability as the soil in which it was planted, however.

"This was the most extensive study on indoor turfgrass that had been conducted at that point," Crum explained. "James Beard had done the only related work in New Orleans, but for that project he had simply brought sod indoors and studied it. Our project required a more in-depth focus."

"These were all problems that reared their heads every rainy Friday night in October, because the fields would get soaked and torn up by games and would remain in a sort of ruined state for the rest of the year and into the next spring."

— Trey Rogers

It became apparent early on that the soil requirements of an athletic field were much different than those of other turfgrass areas. The soil of putting greens, for example, has a nearly 100 percent sand composition to allow for rapid drainage in the event of rain, but an athletic field for a sport such as soccer requires greater durability.

Working with Rogers, Crum spent the summer and fall of 1992 developing a soil mixture that struck the necessary balance between drainage and strength. The smaller particles of clay and silt packed together tightly, increasing the overall strength of the soil, while the large proportion of sand still allowed water to drain quickly. Comprising 80 percent sand, 10 percent native soil and 10 percent peat, the new mixture offered excellent drainage while boasting improved durability.

"We realized that a sports field would require a bit more silt and clay to hold water a little better and improve its strength and stability," Crum said. "It's very important you get the right variety of particle sizes in the soil. Finding the right mixture of sand, clay and silt is right at the heart of everything we do in turfgrass research."

While Crum developed the soil, a concurrent effort was under way to develop a system of modular containers to house what would become the new World Cup field. Built at a factory in Pontiac very near the Silverdome, the hexagonal modules were assembled in the stadium's parking lot in the spring of 1993. The field was configured by filling the modules with the tailored soil mixture and covering it with several varieties of Kentucky bluegrass that had been shipped on refrigerated trucks from southern California especially for the occasion. Then came the first true test of the new system.

"They wanted to have a trial run before the World Cup because this had never been tried before and they wanted to make sure it worked," Crum said.

On June 19, 1993, the Silverdome hosted the final game of the U.S. Cup, in which Germany and England competed for the championship. As more than 62,000 fans filled the stands to watch the next installment of a storied soccer rivalry, the world's first portable athletic field system experienced its opening match. This was the first time in the history of professional sports that a field of live turf had been used indoors, but it certainly would not be the last.

Almost exactly one year after its first success, the new field system was brought indoors a second time to fulfill its original purpose: hosting World Cup soccer. Teams from the United States, Switzerland, Romania, Sweden, Russia and Brazil competed in four matches, along with numerous practices, before crowds of more than 70,000 and hundreds of thousands more watching on television.

A company called GreenTech formed to commercialize the technology. With continuing guidance from Rogers and Crum, GreenTech built fields for stadiums around the country, including Giants Stadium in New Jersey and the tennis courts of Wimbledon.

An obvious advantage of a portable field is that it can be established elsewhere and moved into its stadium later. During renovations following the 2001 football season, preparations were made to outfit MSU's own Spartan Stadium with just such a field. It was prebuilt across campus with the modules transported into the stadium in time for the start of the 2002 football season.

"Spartan Stadium had an artificial field for many years prior," Crum said. "The renovations gave us an opportunity to make some changes, and the university administration took advantage of that to have a high-quality live field installed."

The team took the opportunity to reevaluate the soil mixture they had developed to maximize its beneficial attributes. Rogers and Crum, along with then-MSU graduate student Jason Henderson, examined the soil's agronomic properties, such as drainage, and also looked at it from an engineering perspective that took into account the weight it would bear and the stress of athletic competition it would experience. From these intensive observations, the team produced an optimal mixture with slightly more sand and less silt and clay.

The field remains in Spartan Stadium to this day, removed only once for resodding because of damage following a performance by the band U2 in 2011.

The World Cup and subsequent early successes of the portable athletic field were but a foretaste of the innovation's future. As preparations were beginning for the 2004 Olympic Games in Athens, Greece, organizers found themselves facing a new problem. As part of the opening ceremonies, the Olympic stadium would be flooded with water. Such an inundation would surely kill any turfgrass, making it next to impossible for the games to begin the following day.

"They wanted to fill the basin of the stadium with water, drain it and then on the next day be able to play on a mature, well-established, superior-quality athletic field," Crum said. "And that's exactly what our program was able to give them."

> *As preparations were beginning for the 2004 Olympic Games in Athens, Greece, organizers found themselves facing a new problem. As part of the opening ceremonies, the Olympic stadium would be flooded with water. Such an inundation would surely kill any turfgrass, making it next to impossible for the games to begin the following day.*

Like its World Cup predecessor, the field was established in modules several months before the start of the games under Rogers and Crum's supervision using the same optimized soil mixture developed for Spartan Stadium. Less than 36 hours after the opening ceremonies, the new field was moved into the stadium and the games of the 28th Olympiad could begin.

The work of Rogers and Crum did not go unnoticed. When the summer Olympics moved to Beijing for the 2008 games, their expertise was again requested. The challenge this time was that the opening ceremonies would feature so many performers that the field would be left trampled and ruined. As in Athens, the portable athletic field proved to be the answer. The field was held outside the stadium until after the ceremonies, then moved in for the games.

The advent of portable athletic field technology proved to be the answer to a number of significant challenges. The modules themselves, however, would mean little without the right soil inside. The skill and expertise of MSU turfgrass researchers allowed a novel concept to become a true innovation.

"The thing you have to remember about the portable fields is that they are a solution to a problem," Rogers explained. "It allowed events like the Olympics to have these elaborate ceremonies and afterward have a field of a quality nobody could be embarrassed about."

As portable athletic fields have proliferated around the country and the world, the mark of MSU turfgrass research has been unmistakable.

"It's quite exciting to know that something you were dedicated to and worked on has continued to be used, to grow and evolve," Crum said. "The whole experience has been just incredibly rewarding."

The 17-year leach

Like water, nitrogen is one of the must-haves of plants. It promotes rapid, robust growth, and nitrogen fertilizer is one of the staples of management on farms, home lawns, athletic fields and golf courses alike. Plants can only take up this resource at a finite rate, however, and once more turf managers are discovering the dangers of having too much of a good thing.

"Nitrogen is king, in terms of the resources a plant needs," said Frank, who has continued a 17-year-long experiment on the patterns and effects of nitrogen leaching in soil that began two years before his arrival at MSU in 2000. "Mother Nature supplies the light, the water and the oxygen, but we often have to add nitrogen. Especially in home lawns, that's what people see the greatest response to."

When nitrogen is added to soil, it becomes available for plants to take up and use. Excess nitrogen, however, has the potential to leach from the soil into the groundwater and other segments of the ecosystem, where its presence is less beneficial. Frank's long-term study on this subject has yielded important insights into how turfgrass utilizes nitrogen and, by extension, how it can best be applied to maximize its benefits and limit its negative impacts.

The Hancock Turfgrass Research Center has played host to the nitrogen leaching experiment since its inception. There, a series of lysimeters — large, open-topped metal cylinders with a spigot near the base — have been filled with 4 feet of soil covered with a layer of turfgrass. The soil is treated with varying levels of nitrogen, and, as water runs through the lysimeter, sensors in the spigot measure the nutrients flowing out, representing what would be leached into the environment in a real-world scenario. The results are surprising and illustrate the importance of long-term research.

During the initial years of the project, when the turfgrass was newly planted, little to no nitrogen was observed to leach out of the lysimeters — the turfgrass was utilizing virtually all of it as it grew and established itself. As time wore on, however, and the turfgrass matured, Frank's team was surprised to discover that significantly more of the nutrient was leaching through the soil.

"Everything changes as it ages, which was kind of a revelation," Frank explained. "After a decade or so, we saw that nitrogen starts to leach into the water system, which can then contaminate water sources and pose a health risk to people, particularly those living in rural areas."

Frank is now working to develop ways for turf managers and homeowners to limit their nitrogen use without negatively affecting their grass. His team has already reduced their nitrogen use from 5 pounds to 4 pounds per season without seeing a significant change in turfgrass health.

"From a practical standpoint, you build a home in the suburbs, say, and for the first 10 years while the soil is developing and

Joe Vargas, professor in the Michigan State University (MSU) Department of Plant, Soil and Microbial Sciences, led efforts to release Flagstick, the first turfgrass with resistance to dollar spot. *Photo by Derrick Turner.*

MSU hits zinger with new turfgrass

Michigan State University (MSU) researchers have unveiled Flagstick, the first turfgrass cultivar resistant to dollar spot, following a 20-year search. The new turfgrass is expected to drastically reduce pesticide applications and amount to substantial industry savings.

Named for the coin-size spots of dead grass and silvery film left in its wake, dollar spot is the most common turfgrass disease in Michigan and throughout much of the northeast United States. The fungal pathogen is a particular concern for businesses that rely on maintaining excellent turfgrass, such as golf courses.

The only reliable tactics to combat this devastating disease were rolling turf daily and frequent fungicide applications. Now, turf managers have a new tool that promises to control dollar spot, lower disease management costs and reduce the environmental impact of fungicides.

"The importance of the first truly dollar spot-resistant commercial turfgrass is enormous," said **Joe Vargas**, MSU professor of plant, soil and microbial sciences and the lead researcher in developing Flagstick. "Golf courses usually spend about 40 to 50 percent of their fungicide budgets on controlling dollar spot. It's a disease that can't be tolerated, because if you let it go, it will spread and eventually destroy your turf."

The cultivar's arrival has also been well received by the industry.

"It's a tremendous variety," said Gordon LaFontaine, executive director of the Michigan Turfgrass Foundation. "We spend so much on spraying for dollar spot on golf courses, this cultivar will make a world of difference."

Development began about 20 years ago when Vargas's lab technician, Ron Detweiler, discovered patches of grass at the MSU Hancock Turfgrass Research Center devoid of dollar spot in areas otherwise overwhelmed by the disease. Using grants from the Michigan Turfgrass Foundation and Project GREEEN, Vargas and his colleagues sampled the grasses and established small plots of them at the center, where they remain largely free of dollar spot today.

In 2003, Vargas's team partnered with Seed Research of Oregon, a subsidiary of Pickseed USA, to continue testing the cultivar through the National Turfgrass Evaluation Program at various state universities around the country. After 12 years of trials, Flagstick emerged as the first turfgrass cultivar resistant to dollar spot.

"Most of the best discoveries are made through observation," said Vargas. "The best place to look for disease resistance is in the middle of a big outbreak. Developing a dollar spot-resistant cultivar has been a major research focus at a number of universities for the last 20 years. The fact that we at MSU were able to come up with it is very fulfilling."

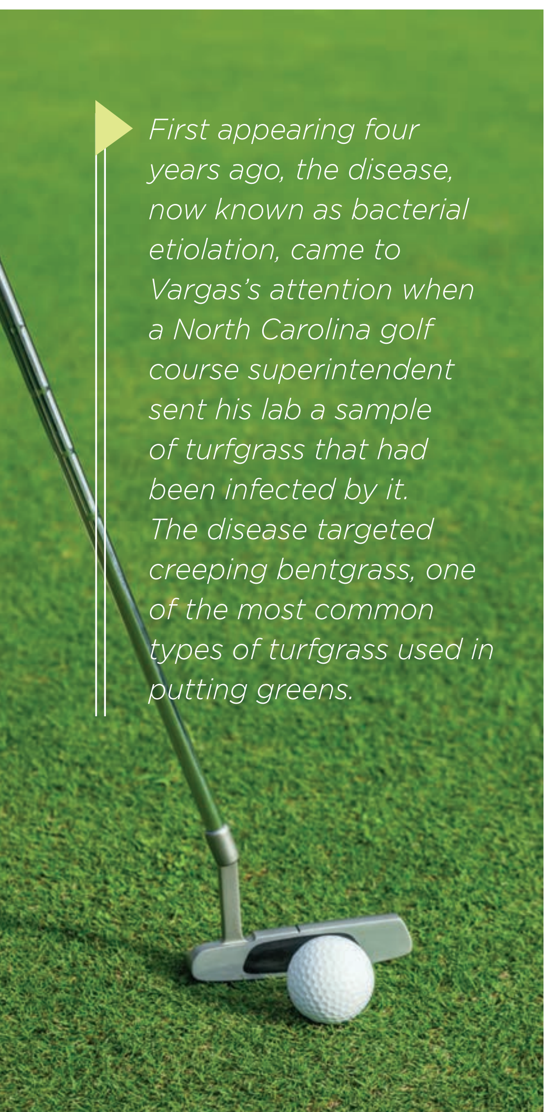
Watch the video on the MSU AgBioResearch YouTube channel.

building up organic matter, you fertilize a lot," Frank said. "Twenty years later, however, your soil has changed and now you don't have to fertilize as much to get the same result. That's what we're exploring now."

Battling soil-borne disease

One of the most persistent concerns in turfgrass management is the ever-present threat of disease. Whether fungal or bacterial, diseases can ruin the pristine look of a playing field or golf course, degrading not only its appearance but also its capability for hosting games.

MSU AgBioResearch plant pathologist **Joe Vargas** recently confronted a new disease that has been taking a toll on golf courses along the East Coast.



First appearing four years ago, the disease, now known as bacterial etiolation, came to Vargas's attention when a North Carolina golf course superintendent sent his lab a sample of turfgrass that had been infected by it. The disease targeted creeping bentgrass, one of the most common types of turfgrass used in putting greens.

First appearing four years ago, the disease, now known as bacterial etiolation, came to Vargas's attention when a North Carolina golf course superintendent sent his lab a sample of turfgrass that had been infected by it. The disease targeted creeping bentgrass, one of the most common types of turfgrass used in putting greens. The North Carolina course was far from the only one affected, however — numerous other golf courses from New England to Texas began replacing their creeping bentgrass greens with other species, such as Bermuda grass, largely because they had no effective means to fight this mysterious pathogen.

Etiolation is a condition in which grasses begin to turn yellow and grow sickly, spindly blades that reach above the normal turf level. Turf managers were concerned that this new wave of etiolation sweeping their courses was being caused by a plant growth regulator, a chemical used to check plant growth and keep golf course putting greens uniformly short and easy to maintain.

"It didn't make sense to me that something that suppresses growth would cause it to spiral out of control," said Vargas, a professor in the Department of Plant, Soil and Microbial Sciences. "So we looked at it more closely to try to isolate the pathogen."

Vargas and graduate student Paul Giordano discovered that the disease was caused not by a chemical or fungus but by a bacterium, *Acidovorax avenae*. Other bacteria in the same genus had been known to attack agricultural crops such as wheat, rice and watermelons, but this was clearly something different.

Using a scanning electron microscope, Vargas and Giordano discovered that the bacterium resided in the soil and moved into the plants' xylem cells, the cells responsible for conducting water from the roots to the foliage, cutting them off from needed water and resulting in their sickly, stringy appearance as they attempted to outgrow the bacterium. Furthermore, they found that, as temperatures and soil acidity rose, the activity of the bacterium worsened.

"It's most devastating in regions with warm temperatures," Vargas explained. "It was also pronounced in areas of New England, where we found they were fertilizing with ammonium sulfate, which is an acidifying fertilizer."

There are no registered turfgrass antibiotics, and none of those used in agriculture were shown to be effective in stopping *Acidovorax avenae*. Vargas has, however, found that simply reducing the use of acidifying fertilizers, either alone or in combination with certain plant growth regulators, can significantly decrease the incidence of the disease.

"We now know how we can at least restrict the environment in which the pathogen thrives," Vargas said. "Golf courses that previously had no recourse other than replacing their greens entirely now have some alternatives at their disposal."

Making sure the grass is always greener

The research conducted by the MSU turfgrass team serves the MSU land-grant tradition by providing the industry with important practical insight and resources. By establishing relationships with turf managers, the team has been able to help them solve problems as they arise.

"Turfgrass has always been a part of my life," Rogers said. "It's a place where a perfectionist can toil and never get bored. You build something, then it gets worn and torn, and you keep working at it. We understand that, and our students understand that."

From a homeowner's lawn to the Olympic Games, the scope and scale of the issues that the turfgrass team tackles are as varied as the people they help. They operate on every level to ensure that turfgrass, and the soil it calls home, is functioning at the highest level.

Water filters through soil samples in the MSU Soil and Plant Nutrient Laboratory. *Photo by Gregory Kohuth.*

IN MOTION:

Improving water quality through better land management

BY CAMERON RUDOLPH
Writer

Safe, clean water is one of the foundational needs of life, but the resource is diminishing as pollution permeates the world. Society has been forced to recycle water of varying quality throughout history, requiring innovative treatment techniques. In the United States during the 19th century, the primary means of dealing with wastewater was to separate it from fresh water using cesspools, dry sewage collection and privy vaults. These methods are ineffective in regions with a high population density, so centralized sewer systems were widely developed across the country. Reuse of these wastewaters without proper handling, however, created health and environmental concerns.

Today much of the nation's wastewater is handled by centralized treatment plants, which can come at a high energy cost and remove water from local systems. With population growth continuing, the need for water is also rising. Researchers are looking at large-scale ways to recycle the wastewater created by human activity.

Steve Safferman, an associate professor of biosystems and agricultural engineering at Michigan State University (MSU), has been working for the past decade to optimize the use of natural resources such as soil to purify water through cost-effective and energy-efficient methods.

"When I came to MSU about 10 years ago, one of my first projects was with several major food processors that were having issues with their wastewater impacting groundwater," Safferman said. "The water was being discharged into the soil, going through the soil, and then entering the groundwater without treatment."

Excessive levels of metals were creating problems in plumbing systems and were on the cusp of being a human health concern. The origin of the contamination was not the wastewater in some cases. It was the soil.

"It's a very complex situation because the metals were not actually in the wastewater," Safferman said. "They were in the soil. When you put a lot of water in the soil, it causes a reaction that makes those metals mobilize. They actually become soluble in water. There was not a good understanding of management strategies to maximize the amount of wastewater that can be successfully treated without impacting groundwater. We've built a research program around these challenges that we are still working on today."

Pinpointing the right amount of wastewater the soil could filter without contaminating groundwater has become the ultimate goal. The group has not found conclusive operational strategies from past projects with scientifically based recommendations.

Conducting laboratory tests, Safferman's team has been trying to identify what he calls a "prescriptive number" using field data. This would allow the researchers to follow a basic outline of how much water and organic material the soil can effectively filter.

Real-time soil monitoring has been implemented as well. In his lab, Safferman set up columns filled with soil, each 18 inches in diameter and fitted with a sensor. This controlled environment proved to be a good predictor of when the soil was not adequately treating wastewater, so the equipment was taken to the field.

Powered by solar panels, the sensors operate via radio transmitters, which then send information to a computer, showing researchers the amount of water, temperature and other soil conditions. Sitting in his MSU office, Safferman can observe conditions at a site hundreds of miles away.

Some food processors have adopted this technique, in addition to the prescriptive number work, and now use a dual method of determining the maximum amount of water that can be added to the soil. This ensures that conditions conducive to groundwater contamination are avoided.

"The problem is that every soil is different," Safferman said. "Wastewater is different. Each area has to be customized depending on the variables. That's why this is so important. I think the bottom line is that we can really use our soil more strategically to be more environmentally conscious, sustainable and economical.

"Strategic management allows the wastewater to become a resource to irrigate an important commodity and replace nutrients that originate from nonrenewable resources. But we have to do it right or we could create bigger problems. When we think about using soil to filter water, it's old technology that we're realizing is very effective if you have the right design."

Conducting laboratory tests, Safferman's team has been trying to identify what he calls a "prescriptive number" using field data. This would allow the researchers to follow a basic outline of how much water and organic material the soil can effectively filter.

MSU associate professor of biosystems and agricultural engineering Steve Safferman places a soil monitoring device in the ground. At several sites across Michigan, Safferman uses this solar-powered technology to check soil conditions and adjust land management accordingly. *Photo by Kurt Stepnitz.*

Improving human health and ecosystem sustainability is the goal of Joan Rose, the Homer Nowlin Chair for Water Research at MSU. Her research focuses largely on treating wastewater for reuse, as well as developing appropriate sanitation methods around the world. *Photo by Derrick Turner.*

"... we need to manage the land better. We know that in some places in the world soil is being depleted of its nutrients. We're not going to have soil that can grow anything if we don't have nutrients and water. It's the idea of thinking holistically about the cycle of humans, waste, energy, water and soil, and how all of it together creates a sustainable future."

— Joan Rose

Better health through clean water

Converging on New York City in September 2000, world leaders met to discuss a global commitment to combating some of the most enduring issues facing their countries. The summit prompted the creation of Millennium Development Goals (MDGs), a list of priorities to be completed by 2015, such as cutting poverty in half and reducing the spread of HIV/AIDS.

Though some of the goals have been reached and even exceeded, a great deal of work on water quality and sanitation remains. For **Joan Rose**, the Homer Nowlin Chair for Water Research at MSU, this is unacceptable.

"Each country was supposed to reduce by half the number of people who did not have access to clean drinking water and sanitation," Rose said. "On the drinking water side, progress was made and MDGs were met. However, with regard to sanitation, very little progress was made. I was recently in India at an institute of public health doing lectures, and right out the window was an open-defecation area. We need to address this issue as quickly as possible. It is now known that without access to sanitation, not only are enteric (gastrointestinal) diseases prevalent, this is linked to malnutrition."

In partnership with the United Nations Educational, Scientific and Cultural Organization, a team of researchers led by Rose is looking to address water safety through the Global Water Pathogens Project (GWPP).

The international initiative is working on a public database with contributions from roughly 150 authors. While the 1983 publication "Sanitation and disease: Health aspects of excreta and wastewater management" has been the gold standard in the field for more than three decades, the new project will offer updated information for the scientific and engineering communities. Rose believes the GWPP, which wraps up in 2017, will provide policymakers with the evidence needed to make risk-based and economically beneficial decisions when drafting future plans.

"In some places around the world, they don't even have sewers," Rose said. "If they do, there may not be wastewater treatment. Now we're starting to talk about what's known as resource recovery, which is getting energy, water and nutrients from wastewater. For instance, we treat water at a very high level and use it for drinking water, which is a growing trend and further shows the need to be resourceful."

Rose cites population growth, coupled with a lack of infrastructure in some areas, as a major factor in the degradation of water, soil and the environment — not only in underdeveloped parts of the world but in Michigan also. Through a project of analyzing sediment core samples taken from two locations in Lake St. Clair, a story of waste mismanagement unfolds.

With funding from the National Science Foundation, researchers have been able to view core samples from more than 100 years ago alongside current conditions. Most of the major industrial milestones between become clearly evident.

Examining the microbial pollutants in each sample, Rose and her colleagues can match them to a point in time when contamination was introduced to the area. Much of the pollution was a result of untreated waste being dumped into waterways. Because of different degrees of industrialization and population density, the two areas from which samples were taken varied greatly.

Whether it involves education and innovation on appropriate sanitation techniques through global collaborations like the GWPP or providing safe drinking and recreational waters in the Great Lakes, Rose insists that understanding how all of the research elements interact is essential to finding answers.

"What we do on the land is the source of contaminants, so we need to manage the land better," Rose said. "We know that in some places in the world soil is being

Using an unmanned aerial vehicle, MSU professor of geological sciences Bruno Basso (right) and programmer analyst Brian Baer measure crop nutrients, temperature and size. Basso is helping large farm operations find balance between resource input and yield. *Photos by Gregory Kohuth.*

depleted of its nutrients. We're not going to have soil that can grow anything if we don't have nutrients and water. It's the idea of thinking holistically about the cycle of humans, waste, energy, water and soil, and how all of it together creates a sustainable future."

Climate-smart agriculture

Seeking to make a splash with the 2012 Global Water Initiative, MSU hired 16 new faculty members identified as leaders who could deliver solutions to some of the planet's chief water challenges.

The first of these staff additions was **Bruno Basso**, a professor in the Department of Geological Sciences, who brings a multifaceted methodology of building resilient natural resources. Trained in crop and soil sciences, he closely monitors the interaction among weather, soil and land management, with a focus on sustainable agriculture. Using leading-edge technology and a $4.9 million grant from the U.S. Department of Agriculture National Institute of Food and Agriculture, Basso and a group of MSU researchers are changing the way large-scale American farms approach operations.

"I have always thought that it was extremely important to look at how plants use water and soil," Basso said. "How can we use the system in a way that we can get the highest yield for the same amount of water and nutrients? Studying the combination of weather, soil and management as it relates to agriculture, it didn't take me long to learn that an integrated approach was necessary. Each of these components is never working alone."

Basso utilizes tools that promote long-term viability, including the System Approach to Land Use Sustainability (SALUS) model. Forged at MSU, the program models conditions of the crop, soil, water and nutrients over space and time. According to the Environmental Protection Agency, more than 400 million acres of U.S. land are used for farming, and there is great diversity in the soils. SALUS allows growers to manage their crops more efficiently by applying appropriate practices to each field area. The model can also simulate situations across multiple years under a variety of weather patterns and predict the impacts on yield, soil and the environment.

An unmanned aerial vehicle (UAV), more commonly called a drone, helps Basso and his team collect data on crops through three attached sensors that observe plant nutrients, temperature and size. Integrating SALUS and data from the UAV, Basso is able to perform what he calls "precision agriculture" — doing the right thing, at the right place and time, and in the right manner.

"One of the big drivers in my research, in the case of water and soil, is to minimize nitrate leaching, which contributes to loss of nutrients from the soil and groundwater contamination," Basso said. "It's all about finding the threshold where revenue of the farm increases without increasing negative environmental impact. Another way of defining it is climate-smart agriculture, where we are building healthy soil and increasing organic matter that makes farming sustainable while using resources like water more efficiently."

Along with his technology-based studies, Basso recognizes the importance of a social component to sustainability and natural resource management. Without the proper education and training of individuals locally operating farms, in the U.S. and abroad, the innovative techniques developed by researchers may be rendered useless.

"When farmers make a decision in this country, they have training and many resources to choose from to make the best decision — the Internet, television, radio and magazines — but it's still difficult for them," Basso said. "In other countries, if you don't get the local people involved through education, you won't have any sustainable impact. There is a strong relationship between social science and biophysical science. We try to always take that into account."

CROPPING UP

Interest in cover crops skyrockets, although adoption remains low

An MSU test plot in Mason shows the winter rye sprouting in a field of harvested corn. Researchers are beginning to gather data to determine the impact of cover crops on soil health and enrichment. *Photo by Derrick Turner.*

BY HOLLY WHETSTONE
Editor

Cover crops are a hot topic in agricultural circles. Ironically, interest isn't due to a major research breakthrough, nor does it stem from cover crops being new on the scene. (They've been grown for generations.) Instead, many attribute the heightened curiosity to a soil health message that's resonating with the right crowd.

Dean Baas, a senior research associate with Michigan State University (MSU) Extension, conducts cover crop and organic agriculture research and education. As a member of the Midwest Cover Crops Council (MCCC) executive committee, Baas advocates for cover crop usage among farmers. Recently he has noticed a substantial change in perception.

"As little as two years ago, if you asked a group of farmers what's the primary benefit from growing a cover crop, a large majority would have said to prevent erosion and keep the soil in place. Now, with recent surveys, they're saying it's to improve soil health," he said. "To have soil health beating out soil erosion indicates to me that there is definite interest in improving soils, and it's high on farmers minds."

MSU Extension educator Dean Baas is conducting cover crop trials at Kellogg Biological Station in Hickory Corners, Michigan. Baas is a member of the Midwest Cover Crops Council executive board that advocates for cover crop usage among farmers. *Photo by Derrick Turner.*

OPPOSITE: MSU AgBioResearch nematologist George Bird stands in a cover crop field on the campus of Michigan State University. Bird, a long-time proponent of cover crop usage, said the benefits span from improved insect and disease control to enhanced soil nutrients. *Photo by Derrick Turner.*

Some of the shift is the result of educational campaigns, including the United States Department of Agriculture (USDA) Natural Resources Conservation Service's "The Science of Soil Health." Started in fall 2013, it encourages landowners to talk with farmers about how they are working to build sustainable soil and productive land. The campaign discusses soil health management practices including diverse rotations, no-till and cover crops.

Planted to provide a protective green blanket when land is normally barren or lifeless, cover crops help create a year-round habitat providing food and shelter for wildlife as well as beneficial organisms in the ground. Cover crops help retain the nutrients from the previous crop and pass them on to the next. They also take in carbon dioxide from the atmosphere and release clean oxygen in exchange.

MSU researchers and Extension educators, like many across the nation, report a rise in requests to speak about the benefits and use of cover crops, largely from growers, commodity organizations, agri-businesses and seed companies.

MSU nematologist **George Bird**, who conducts research in integrated pest management and soil biology, has been studying cover crops since 1968. In the past 18 months, he has received 30 invitations to speak about soil health, a topic that invariably leads to cover crops.

"Cover crops and soil health are the two hottest topics in the north central region in 2015, unless someone wants to throw in colony collapse," Bird said. "Ten years ago, there were very few seed companies interested in cover crops. Today, there are dozens, plus many more in the works. It can even be difficult to get the varieties you want. You may have to find a company halfway across the country to do that."

In addition to various speaking engagements, Bird has organized a 2015 Short Course for Agribusiness that focuses on cover crops and soil health. It is ideal timing — the United Nations declared 2015 "The International Year of Soils."

A project funded by the Environmental Protection Agency from 2010 to 2013, the Great Lakes Cover Crop Initiative, is adding to interest as well. With the catchy slogan "Keeping it green keeps the water clean," the initiative demonstrated the effectiveness of cover crops and conservation tillage systems to decrease agricultural nonpoint source pollution. It also informs producers in the Lake Michigan, Lake Erie and Lake Huron watersheds about implementation of cover crops and conservation tillage systems on nearly 37,000 acres. Baas was co-principal investigator on the project, and MSU Extension educators Paul Gross and Christina Curell contributed significantly.

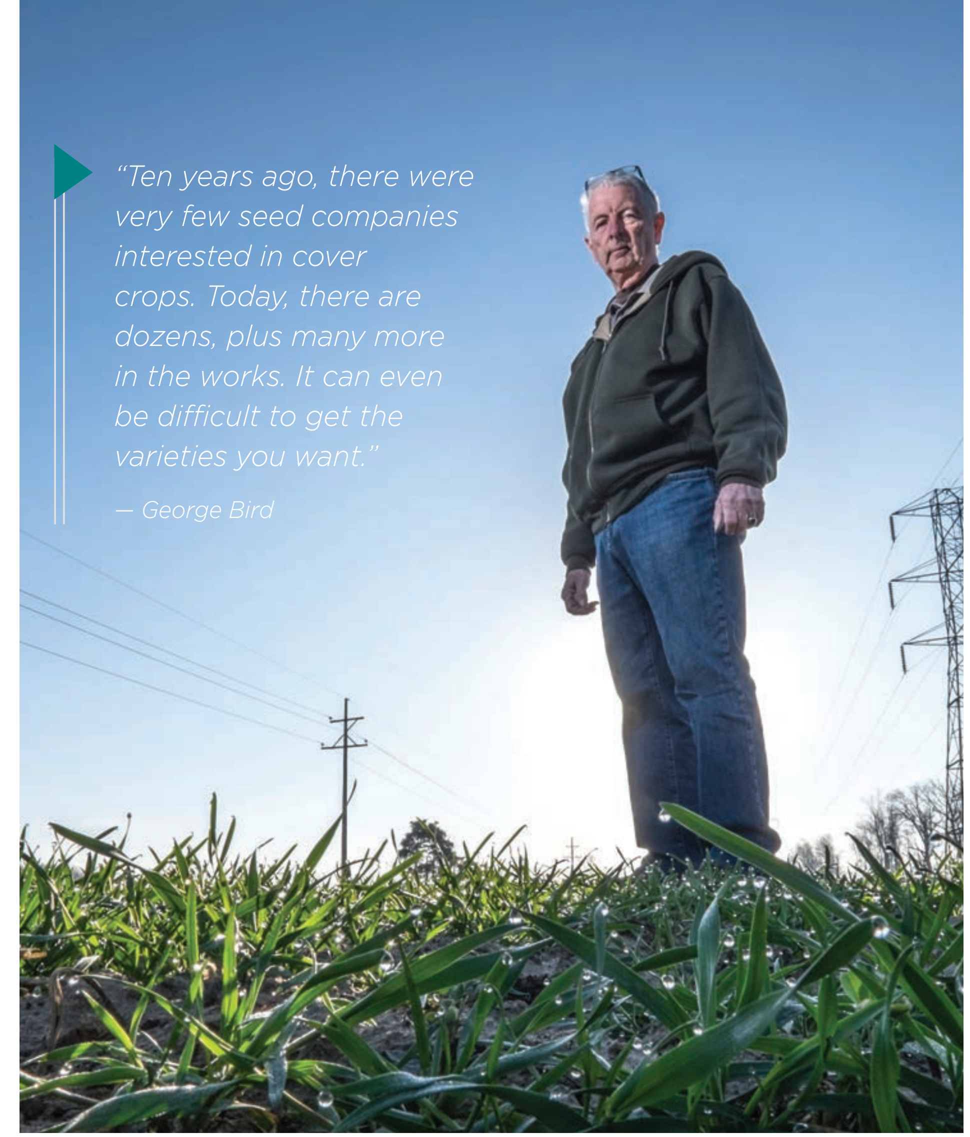
The Conservation Technology Information Center's (CTIC) $1.07 million project, which includes three Michigan farmers, is also garnering attention. It is aimed at examining the economic, agronomic and environmental benefits of cover crops. The ultimate goal is to help the United States reach 20 million acres of cover crops by 2020, an increase of 17 million acres.

Despite considerable publicity, incorporation of cover crops into agricultural systems is nowhere near the norm. The National Agricultural Statistics Service recently started collecting survey data on cover crops. In Michigan, the report revealed that cover crops accounted for 6.5 percent of farmland in the 2012 growing season — fifth in the nation.

"At the end of the day, cover crop use is still at a very low percentage," Baas said. "It is nowhere close to being a common farming practice in Michigan. Word is getting out, the message is being heard and you see pockets of people incorporating them into their systems. But there is still a long road ahead."

Research delves into soil health

Researchers are focusing on ways to use cover crops to bring diversity to the crop system, to reduce reliance on fertilizers, herbicides and pesticides, and to determine the impact of cover crops on overall farm economics. Some of the work is funded by commodity groups to benefit their respective grower members. But cover crops do not have a formal organization advocating on behalf of their usage, a factor that Baas said plays into the lack of adoption and research funding.



MSU researchers, however, are studying the impact of cover crop use on everything from row crops to orchards and carrots to Christmas trees. Field trials are also taking place at MSU AgBioResearch research centers from Traverse City to Frankenmuth and south to Benton Harbor.

Alexandra "Sasha" Kravchenko, professor in the MSU Department of Plant, Soil and Microbial Sciences (PSMS), received both her undergraduate and doctoral degrees in soil science. In addition to soil fertility studies, Kravchenko is looking at ways that cover crops can help mitigate climate variability as part of a large-scale project, Climate and Corn-based Cropping Systems Coordinated Agricultural Project (CSCAP), funded by the USDA.

"To me, there seems to be the beginning of a comeback occurring in soil research," she said. "We came to the realization that while what we do know about soils might be good enough for business as usual, it's not enough to anticipate future impacts of variable climate."

CSCAP encompasses 140 researchers at 10 Midwestern universities, including fellow MSU researchers **Bruno Basso** from the Department of Geological Sciences and **Andrey Guber** from the Department of PSMS who work on modeling; **Martin Chilvers** from the Department of PSMS working on the integrated pest management portion; and **Marilyn Thelen** from MSU Extension on the outreach component.

The group is focused on understanding the mechanisms by which cover crops increase soil carbon sequestration, how they impact greenhouse gas emissions and how they influence corn yields and soil nitrates.

Kravchenko is conducting trials at two experimental sites, one in Mason and the other at Kellogg Biological Station. Each has diverse topography in order to examine cover crop performance and effects in a real life terrain, such as topographically variable landscapes that Michigan farmers face.

This past spring researchers began collecting soil samples from the experimental fields and will begin comparing it to data from 2011 when the project started.

"We're seeing some positive changes in soil organic matter when cover crops are used," she said. "But we're not quite there yet. Cover crops are a tool but they don't work overnight. It takes several years to produce the noticeable, beneficial effects."

CSCAP goals are to safeguard crop production's most basic components — fertile soil and fresh water — maintain crop yields, reduce emissions of atmospheric greenhouse gases that are responsible for climate change, and to train a new generation of scientists.

Like Kravchenko, Baas and Bird agree that continued cover crop research is needed. They are collectively thankful that the soil health message has not fallen on deaf ears.

"We, as researchers, have spent much of the recent past justifying the use of cover crops and quantifying the benefits," Baas said. "So much so that I believe, to a certain extent, that this message has been beaten to death. I no longer run into farmers at meetings who say, 'But why should I plant a cover crop?' Now they say, 'I see the benefits. Now, help me make them work in my production system.'"

No one-size-fits-all solution

A poll of Midwest farmers conducted by the CTIC reveals that one major barrier to cover crop adoption is cost. There is a strong perception among farmers that cover crop seed is expensive. A large

majority — 71 percent — seeded their cover crops at an average cost of $12 per acre. Seed cost is substantially higher — $25 per acre — in the Midwest.

Other challenges cited included time to plant and manage cover crops, terminating the crops and selecting the right varieties. Some also complained of problems with slugs.

The most desired benefits cited were increased soil organic matter, reduced soil erosion, reduced soil compaction, weed control and a natural nitrogen source.

Bird, who started work on cover crops as a graduate student at Cornell University, said he informs farmers of three basic principles he calls "Bird's three laws of cover cropping":

- Decide on your objective.
- Select the proper cultivar.
- Manage the cover crop, with particular emphasis on timing and objective.

"You must know that alfalfa is not just alfalfa. Clover is just not clover. Potatoes are not just potatoes," he said. "There are varieties within each, and they all have different genetic attributes. For instance, oil-seed radish has been bred by Germans as trap crops for sugar beet cyst nematode control. For the past decade or so, Michigan sugar beet growers have been using three specific varieties of oil seed radish as an integral part of soil management. But if you use any other variety, you end up making the entire system worse."

An added layer of complexity is that what works for one farmer doesn't necessarily work for another, not even the neighbor next door. In his studies, Bird has found that some cover crops have shown potential to be conducive to beneficial organisms; others damage them. Some can be highly attractive to beneficial organisms; others attractive to pests. He cautions that each agronomic cover crop variety needs to be evaluated under local conditions by one or more highly respected growers with a significant interest in soil health.

"There is not a one-size-fits-all answer," Baas adds. "But what I point out is that nearby farmers do not necessarily do the same thing to their cash crops. Some fall till, others spring till. There are good years and bad years. Some people say they tried cover crops but quit because they failed miserably. I remind them that this happens with cash crops, but they don't stop growing them."

The researchers agree there is a fairly steep learning curve. Although not all are successful the first few years, Baas said most growers eventually get the hang of it. Having curiosity, tenacity and the ability to learn from mistakes is of utmost importance.

LEFT: (From left) MSU Department of Plant, Soil and Microbial Sciences professor Alexandra "Sasha" Kravchenko and graduate student Jessica Fry examine data from a MSU cover crop testing site located in Mason. Kravchenko is focused on explaining how cover crops increase carbon sequestration among several issues.

RIGHT: Research assistant Richard Price takes a soil sample from a cover crop field in Mason, one of two experimental sites in a Climate and Corn-based Cropping Systems Coordinated Agricultural Project (CSCAP), funded by the USDA and led by MSU Department of Plant, Soil and Microbial Sciences professor Alexandra "Sasha" Kravchenko. *Photos by Derrick Turner.*

On average, it takes three to five years of cover crop use before a farmer begins to see benefits such as increased yield. It also requires added time and labor to plant the crops after harvest, a time when most farmers are in need of a break.

"I remember a survey response years ago that said, 'So what do you want me to do — finish harvesting my crops or plant cover crops?' That's a real battle," Baas said. "A lot of people plant cover crops after harvest. Then you have a year like last year when they're harvesting in November. So there is the time management part of the equation, too."

In general, the researchers say that the farmers finding the most success with cover crops incorporate them into their production plans without stopping to question if they're going to or not.

A reemerging industry of sorts

Cover crops were used several generations ago to manage nutrients in the soil at a time when chemical pesticides and fertilizers were nonexistent. Farmers used cover crops to control weeds, provide nitrogen and keep the soil in place. They also grew them for forage when farms were more diversified, growing both plants and animals.

But as technology advanced, cover crops eventually phased out of many farming systems. Now with interest in soil health and soil productivity surging, perceptions of cover crops are changing.

One of the major differences is transitioning from thinking of something that was once a cash crop in its own right to growing it for purposes other than immediate economic gain. Baas said cover crop breeding is a research area that he believes could be very helpful moving forward.

"The majority of cover crops were never bred or developed as cover crops," he said. "There are many reasons why you breed a crop — high yields, low lodging and short stock, for example. For cover crops, you want a lot of biomass, an early-maturing variety and shade tolerance. If we could do some breeding, we could probably get some better cover crops."

After searching for decades, Bird has found that some varieties of a cover crop called pearl millet help deter the most prevalent root lesion nematode (*Pratylenchus penetrans*) in Michigan. The nematode invades a variety of hosts, including fruit, vegetable and field crops. Bird and his colleagues are also looking at a cover crop called dwarf essex rape to help ward off a tree fruit disease that is particularly devastating to cherries and apples. He says cover crops are gaining popularity because they are a natural way to control insects and diseases, an alternative to using synthetic chemical pesticides and fungicides.

"Today some of the most progressive farmers I know are going one step further beyond soil health and trying to figure out how to develop a bio-based agriculture," Bird said. "They're going to let the biology and the soil provide the things needed for our crops. And so when you go into a system with something designed to kill, you're going to have all kinds of unexpected consequences."

Bird said finding a cover crop that is a trap for soybean cyst nematode, the No. 1 limiting factor of soybean production in the United States, would be a major cover crop discovery. But he said he knows of only two scientists in the world — one in Germany and the other in Denmark — breeding cover crops specifically for nematode control.

While farmers await more research news, researchers are anticipating this summer's release of results from an online national cover crop survey, sponsored by the USDA Sustainable Agriculture Research and Education program, the American Seed Trade Association and Corn+Soybean Digest. The information will provide further information on cover crop usage and research needs. All farmers — whether they use cover crops or not — were invited for the third consecutive year to share their thoughts on this increasingly popular management practice.

Baas, Bird and Kravchenko agree that more work needs to be done to help advise farmers, especially those in regions such as Michigan, where soils can vary tremendously even across short distances.

"Within Michigan, because of its glacial history, soils can vary substantially even in a small space," Kravchenko said. "Whether the soil is stony, sandy or heavy clay, it plays a big role in determining how beneficial or how feasible to manage the cover crops will be. This is a big component of this puzzle we're trying to figure out."

COVER CROP FACTS:

Cover crops are plants seeded into agricultural fields, either within or outside of the regular growing season, with the primary purpose of improving or maintaining ecosystem quality.

ENVIRONMENTAL BENEFITS:

- Enhance biodiversity.
- Increase soil infiltration, leading to less flooding, leaching and runoff.
- Create wildlife habitat.
- Attract honey bees and beneficial insects.

FARMING BENEFITS:

- Reduce erosion.
- Improve soil quality through increases in:
  - Porosity (reduced compaction).
  - Soil organic matter.
  - Water-holding capacity.
  - Beneficial microbes.
  - Micro- and macroinvetebrates.
- Retain nutrients that otherwise would be lost.
- Add nitrogen through fixation.
- Combat weeds.
- Break disease cycles.

FOUR BASIC KINDS OF COVER CROPS:

- Grasses.
- Legumes.
- Brassicas (radishes, mustards, etc.).
- Other non-legume broad-leaf plants (buckwheat, sunflower, etc.).

Source: Midwest Cover Crops Council (mccc.msu.edu)

Potato industry lays important groundwork

Paper spurs innovative research on soil health

Soil health is vital to all types of fruits and vegetables, but potatoes are an obvious standout. These plants prefer a loose, well-drained sandy loam soil. Compared with many other types of produce, they require more care and attention to specific soil requirements and insect and disease control. So it makes perfect sense that the potato industry has been in the driver's seat when it comes to soil management practices in Michigan.

"In the soil health arena, Michigan is a leader because of the Michigan Potato Industry Commission (MPIC)," said **George Bird**, Michigan State University (MSU) nematologist. "Their initiative began on May 16, 2012, when MPIC published a white paper written by Ben Kudwa [then long-time executive director of MPIC]. It has formed the foundation that many other agricultural organizations are building on."

The paper provided details on soil health and has played a critical role in maximizing productivity not only in potatoes, but in many other commodities as well. Today, many of the original goals of the paper have been fulfilled, and research is expanding to new areas.

"The commission was spurred to develop a white paper on soil health by growers who were seeing reduced yields of some potato varieties and were concerned about maintaining and growing the potato industry in Michigan," explained Mike Wenkel, MPIC executive director.

One of the first results of the paper was a survey of high- and low-yield potato fields using the Cornell University Soil Health Assessment model to get a sense of the differences in the soils. Then, with a specialty crop grant from the state of Michigan, MSU researchers, including plant and soil scientists **Kurt Steinke** and **Noah Rosenzweig**, did a more detailed study of the soils on potato farms, looking especially at microbial communities to try to identify specific patterns.

In 2013, Steinke and Rosenzweig began a four-year study at the MSU Montcalm Research Center to look at the impacts of various crop rotations. Another study, led by MSU Extension specialists **Kim Cassida** and **Chris Long**, is looking at forages and crop rotation in the Upper Peninsula. Recently, a group of MSU researchers led by Bird began a long-term study that looks at potatoes in a two-year crop rotation with the goal of potatoes being the only harvested crop.

"Over time, the hope is that growers can build organic matter in the soil with cover crops in the off year," Wenkel explained. "We need to see if we can get a two-year rotation of potatoes that is profitable. However, we hope to move away from fumigation and other conventional practices as part of the study."

The group convened in March at MSU to discuss next steps. Bird said about 20 researchers and industry representatives were invited to:

- Define who Michigan State University is in regards to soil health.
- Draft outlines for an Extension publication and a peer-reviewed research publication.
- Develop the framework for a broad grant proposal to bring external funding to MSU.

A month earlier, Bird had attended a meeting held by the Ontario (Canada) Ministry of Agriculture and Rural Development to discuss soil health initiatives and to determine what soil health indicators should be adopted in Ontario. At the end of the day, there was a unanimous decision that soil health is based on organic matter, water-stable aggregates and nitrogen mineralization potential. Bird said these were the same three principles that the MPIC group agreed upon in March.

Wenkel says growers are pleased to see that MSU recently hired a soil biologist, **Lisa Tiemann**, who is now part of the potato research team, and is considering the addition of a field systems agronomist in the near future.

"We still need someone who can focus on the impact of crop systems and how one crop being present affects the others," Wenkel said.

He credits the white paper as the driver for spurring the current research.

"The paper was cutting-edge at the time from the standpoint of soil health," Wenkel said. "Now about half of MPIC's research dollars are focused on soil health projects."

> *The paper provided details on soil health and has played a critical role in maximizing productivity not only in potatoes, but in many other commodities as well.*

BY JANE L. DEPRIEST
Contributing Writer

CANR alum is lead soil scientist for State of Michigan

Martin Rosek

BY CAMERON RUDOLPH
Writer

On a Tuesday in June, inside his East Lansing office, Martin Rosek initiates the first of several phone calls that consume the afternoon. This may seem normal for someone working in an office. But as Michigan's state soil scientist, an employee of the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS), he faces new challenges and unique agendas daily.

Rosek, 57, is working on the biggest project of his career, one that requires coordination among many entities.

State conservationist Garry Lee has tasked him with managing the implementation of light detection and ranging (LIDAR) technology, which will provide data for Michigan agricultural professionals. LIDAR uses remote laser sensing to generate extremely accurate topographic land maps. Neighboring states are further along in this process, but the Great Lakes State is gaining.

Tomorrow will most likely be spent tending to another duty. The state soil scientist no longer supervises all field operations, but he still sets priorities and must sign off on projects conducted by field scientists.

He's also on the state conservationist management team and provides input on soil-related issues in Michigan. Rosek teaches other NRCS employees at the state and national levels about wetland compliance and soil health.

"I have both office responsibilities and field responsibilities," Rosek said. "I enjoy the dynamic nature of my job in that I'm not doing just one thing."

Growing up in Midland, Michigan, he enjoyed the outdoors and all of the recreational activities that came with it. Although he wasn't raised on a farm, his parents often spoke of their upbringings and how agriculture played a significant role. In high school, Rosek devised a plan to pursue a career in either meteorology or soil science.

"My two loves were and still are weather and soil," Rosek said. "There's so much that goes into soil science with agronomy, environmental sciences, engineering and building, soil health and more. There's a lot of different directions you can go."

Following two years at Delta Community College, he began undergraduate studies at Michigan State University (MSU) in 1978. Piquing his interest was a class on soil landscapes and mapping taught by now retired professor Del Mokma.

As a senior, Rosek joined the soil judging team, undergraduates who square off with other schools in a soil profile description competition. In the regional competition, Rosek took fourth in the individual judging portion.

After graduation, he headed to North Dakota State University (NDSU) in pursuit of a master's degree and also worked as a graduate assistant in the soil characterization lab. Using various tools, Rosek honed his skills and even coached the undergraduates to a Region 5 soil judging championship.

Following his master's program, Rosek became an assistant soil scientist with the Minnesota Agricultural Experiment Station. Among other responsibilities, he was able to participate in the soil mapping process that he first enjoyed. It was then he decided to obtain his doctorate.

James Crum, a 31-year veteran professor in the Department of Plant, Soil and Microbial Sciences at MSU, supervised Rosek's doctoral studies.

"Martin was a wonderful resource for many people because of his field skills and experience," Crum said. "He had mapped and inventoried soils during and after his master's degree. He brought a great perspective on soil from the standpoint of a field soil scientist. He did a lot of work at the Kellogg Biological Station that I thought was just remarkable, and he's been a great friend and colleague since then."

Though Rosek would continue to study soil landscapes, a change in the soil sciences field necessitated a deviation from his original career path. States around the country were beginning to complete soil landscape mapping. Crum switched his primary research focus from soil genesis, morphology and classification to turfgrass. Rosek saw the number of potential academia positions dwindling.

"Although I took a different route than originally planned, the experience at MSU was great," Rosek said. "The more I learned about soil and landscape relationships, soil chemistry, soil biology, the more I knew I wanted to head down this path."

He returned to North Dakota for postdoctoral work before entering the precision agriculture field, which would see yet another trek to the Midwest — specifically, Michigan and Indiana. Tiring of the instability in the precision agriculture arena, Rosek ventured back into field soil science and west to North Dakota and eventually Wyoming.

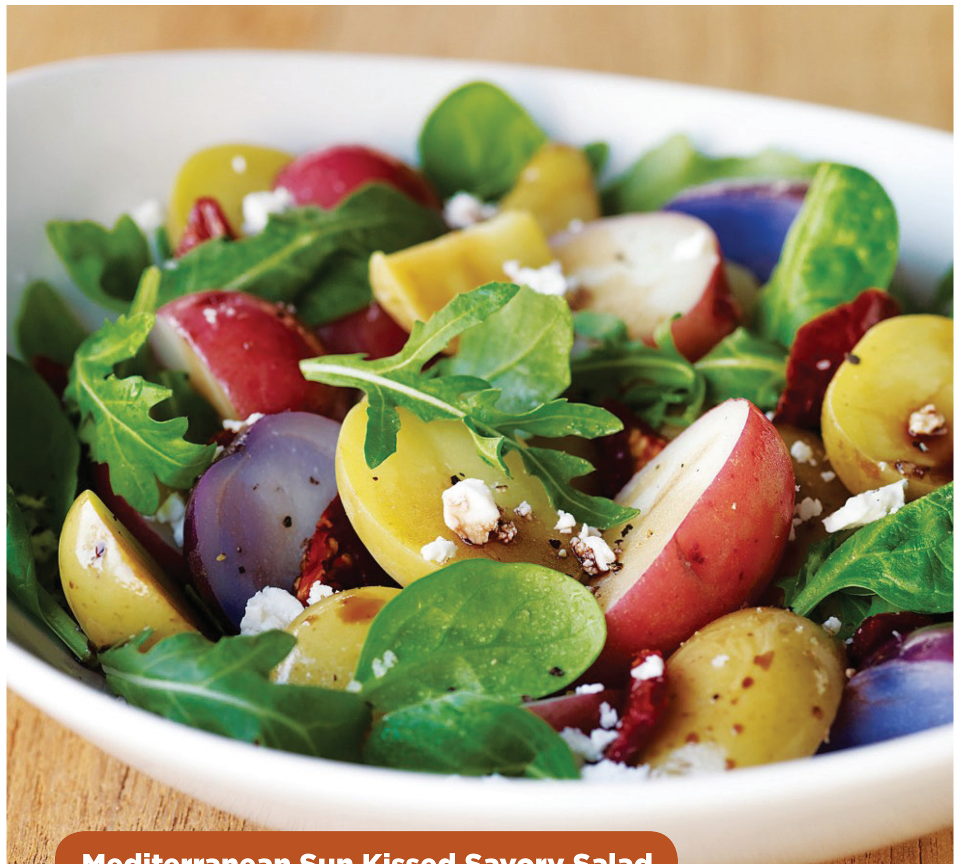
In August 2012, the opportunity arose to come home to Michigan.

"I can see myself doing this state soil scientist role for a long time," he said. "I know this type of work. I enjoy this type of work. Any one day I'm diving off into any number of directions, and that's comfortable for me."

POTATO FAST FACTS

- About 47,000 acres of potatoes are grown on about 80 Michigan farms.
- The average Michigan potato crop is worth $170 million to growers.
- In the United States, Michigan ranks No. 1 in the production of potatoes for potato chips, sixth in the value of potatoes produced and eighth in the volume of potatoes grown.
- The potato, developed from the perennial *Solanum tuberosum*, is the world's fourth largest food crop following rice, wheat and maize. The Inca of Peru were the first to cultivate potatoes around 8000 B.C. to 5000 B.C.
- French fries were introduced to the United States when Thomas Jefferson served them in the White House during his presidency.
- In 1853, railroad magnate Cornelius Vanderbilt complained that his potatoes were cut too thick and sent them back to the kitchen at a fashionable resort in Saratoga Springs, NY. Chef George Crum sliced some potatoes paper-thin, fried them in hot oil, salted and served them. To everyone's surprise, Vanderbilt loved his "Saratoga Crunch Chips," and potato chips have been popular ever since.
- The two newest potato varieties were created specifically for chip processing, and both have long-term storability. Manistee, developed at Michigan State University, has an attractive round shape and shallow eyes. It has a full-sized vine and an early- to midseason maturity with good tolerance to blackspot bruising. Lamoka, developed at Cornell University, has a high level of starch and highly starch potatoes tend not to soak up a lot of oil during frying. It's resistant to golden nematode, a pathogen that attacks potato roots, and potato scab, a disease caused by a soil-borne bacterium or virus.

MICHIGAN POTATOES



Mediterranean Sun Kissed Savory Salad

3 pounds Yukon Gold potatoes or potato of your choice (russet, red, white, fingerling, or purple/blue gems)

4 sun-dried tomatoes in oil, drained and chopped

1/4 cup crumbled feta cheese

5 cups spinach or lettuce

2 tablespoons balsamic vinegar

1/4 cup olive oil

1 teaspoon of salt

Black pepper to taste

Place potatoes in a saucepan. Cover with water to 2 inches above potatoes; bring to a boil. Reduce heat and simmer 20 minutes or until tender. Drain. Or place potatoes in a large microwave-safe bowl and cover. Microwave on high for 10 to 12 minutes or until potatoes are tender. Refrigerate until cool. Cut potatoes into quarters. Place potatoes in a large bowl. Add feta cheese, sun-dried tomatoes and spinach/lettuce. Combine balsamic vinegar, olive oil, salt and pepper; mix well and add to salad mix.

Makes 6 servings.

Photo and recipe courtesy of the United States Potato Board.

Getting real: Team effort aids Michigan potato industry

With an annual crop valued at more than $170 million, growing potatoes is big business in Michigan. To maintain production value and continue the strong history of success requires research and expertise.

MSU potato Extension specialist **Christopher M. Long** is the liaison between growers, researchers and the Michigan Potato Industry Commission, an organization funded by potato growers that supports potato research along with promotion and education. His primary objective is to apply ongoing potato research to real-world agriculture, which he does through on-farm tests, demonstration trials and grower-focused information meetings.

"One of the main things I do is variety evaluation, so I not only work with **Dave Douches**, MSU potato breeder, but I also work with his counterparts around the United States who also are developing new varieties," Long explained. "It's especially important to evaluate new varieties in the various microclimates in Michigan where we grow potatoes."

Michigan's potato claim to fame revolves around the chip industry. Michigan ranks No. 1 in potatoes produced for chip processing, supplying 28 percent of the U.S. market. That ranking is due in part to the ability of growers to store suitable varieties of potatoes until processors need them.

"The state produces about 18 million hundredweight of potatoes annually, and growers store 15.5 million to 17 million hundredweight in specialized storage barns that are designed to maintain temperature and allow for humidity exchange," Long said.

The Burt Cargill Potato Demonstration Storage Facility, which is owned by the Michigan potato industry, is used by MSU researchers to study the commercial potential of new processing potato varieties and perform other postharvest evaluations under simulated commercial conditions. The results of the research are passed along through Long to growers who use the information in the design and use of their storage facilities.

The potato harvest in Michigan runs from the end of July to late October, but because of research at MSU and new varieties, growers can store potatoes into June of the following year. The ability to deliver a quality product for processing is a plus even when freshly harvested potatoes may be available from southern states because of the higher transportation costs for processors of southern-grown potatoes.

An important factor in storing potatoes for the chip market is potatoes that don't convert to sugar easily. Increased sugar content can produce a chip that is too brown.

Long works with a team of MSU researchers, from pathologists to fertility experts to entomologists to soil biologists, involved with various aspects of potato production. A key team member is Douches, who heads up the MSU potato breeding and genetics project. He has developed 15 potato varieties to satisfy the industry's need for pest and disease resistance.

"I am a conduit for information from the university to the potato growers, but I'm also a first responder with growers, getting issues from the growers back to the researchers who may be able to help," Long said. "It takes all of that input, both from researchers and growers, to grow marketable potatoes."

> *"I think not only for the potato industry but for U.S. agriculture in general, soil is our next greatest frontier. A lot of research has been done, but more research is needed."*
>
> *— Chris Long*

Christopher M. Long, MSU potato Extension specialist, was busy this spring planting new varieties of potatoes to evaluate how they perform in Michigan's many micro climates. Here he is planting a russet trial at Walther Farms in St. Joseph County, Michigan. *Photo by Lance Forsburg, research assistant with the Department of Plant, Soil and Microbial Sciences.*

(Groundbreaking moments in soil — continued from page 25.)

his graduate student Don Franzmeier quantified the Spodosol soil order in the Universal Soil Classification System, which was developed in the 1960s. Kalkaska sand is an example of a Spodosol soil. It was first identified in 1927 and occurs in the area surrounding Kalkaska, Michigan. It was declared the state soil of Michigan in 1990. Whiteside also made significant contributions to how soil surveys are done. He developed techniques for updating soil survey work from many years ago that greatly increased the speed and efficiency of that work. After Whiteside retired, Del Mokma continued much of Whiteside's work in soil genesis and classification research. Ivan "Ike" Schneider was responsible for working with the agencies doing the soil surveys throughout Michigan to help in the classification and interpretation of soils.

Research on soil fertility and soil testing began aiding farmers in the 1920s, when a soil fertility train was a cooperative project between the Soils Department and the New York Central Railroad. Samples of both soil and marl (lime-rich mud or mudstone) were tested while farmers waited for the test results. In the 1930s, soil testing was a major Extension project.

Environmental Soil Research

Environmental soil research is another significant area of specialized research. Conservation tillage, or no-till, was supported by MSU along with other universities beginning in the 1920s. Soil management specialists Ray L. Cook and L. S. Robertson, whose careers spanned more than 50 years, strongly supported this idea. Before their work, the principal mode of operation on a farm was turning everything under with a plow, which left the soil susceptible to erosion. Cook and Robertson believed it would be more productive to leave crop residue on the soil surface because the no-till technique conserves water, reduces erosion and uses less fossil fuel and labor to grow crops. It's a practice that is encouraged today by researchers and by the U.S. Department of Agriculture and is becoming more popular with farmers.

Lloyd M. Turk, who came to MSU in 1932 and remained for 32 years, believed that good management of soils was essential to help feed the growing population of the world, and his research centered on that. Richard Harwood, the first holder of the C. S. Mott Sustainable Agriculture Chair, established the Living Field Laboratory at the W. K. Kellogg Biological Station near Gull Lake in 1993. The project was designed as a long-term study of the potential benefits to the soil of including cover crops in the rotation cycle of corn. The first crops were planted in 1994. The field project wrapped up in 2014, though results are still being compiled.

Soil Fertility and Soil Testing

Research on soil fertility and soil testing began aiding farmers in the 1920s, when a soil fertility train was a cooperative project between the Soils Department and the New York Central Railroad. Samples of both soil and marl (lime-rich mud or mudstone) were tested while farmers waited for the test results. In the 1930s, soil testing was a major Extension project. A mobile soil testing laboratory in the back of a stake truck made it possible for farmers to have soil and marl samples tested and brought exhibits on soil test interpretation and soil management that they could study while the samples were being tested.

In the 1940s and '50s, John "Fred" Davis was one of the first to identify the deficiency of zinc in the soil of the Thumb area of Michigan. Eugene Doll, who came to MSU in 1960, worked on soil fertility in northern Michigan and the Upper Peninsula. Professor and Extension specialist Darryl Warncke was the research coordinator for the MSU Muck Soils Research Farm and the supervisor of the MSU Soil Testing and Plant Analysis Lab, a precursor of today's Soil and Plant Nutrient Laboratory. Warncke is widely recognized for his expertise in the soil fertility and plant nutritional requirements of vegetable crops grown on both organic and mineral soils.

MSU also is known for its work with turfgrasses and the work of professors such as Paul Rieke, who joined the faculty in 1963, improved the understanding of effective, safe fertilization of turfgrasses and management of compaction in high-use turfgrass areas.

Education in Soil Science

Numerous achievements in soil research continue today, but many of the faculty members who cut new paths to knowledge are most proud of teaching students about soil science. A number of faculty members wrote textbooks that have been used through many years. One example is Eldor A. Paul, a soil ecologist, who was department chair for 12 years. He was the editor of "Soil Microbiology, Ecology and Biochemistry," a classic textbook that guides students through biochemical and microbial processes in soils and introduces them to microbial processes in water and sediments. Henry D. Foth, a professor of soils and soil geography, wrote the widely used textbook "Fundamentals of Soil Science." The textbook, which is no longer in print, covered important national and international issues such as soil resource conservation, land use, environmental quality and food production. Whiteside excelled at educating and training international students so they could return to their home countries and carry on the soil resource work. Rieke estimates that, in his years at MSU, he taught around 5,000 students about the science of soils, stressing the importance of making good soil management decisions.

"The achievements of the past are inspiration to the faculty and staff members in our department today," said Kells. "Their accomplishments, without the technology and specialized instrumentation available today, are most impressive."

MSU Soil Pioneers 1860s - 1960s

Henry D. Foth, professor of soil geography, is known for his popular textbook, "Fundamentals of Soil Science."

G.J. Bouyoucos, a soil physicist who came to Michigan Agricultural College in 1911, made many contributions to soil science during his 50 year career here.

C. H. Spurway, a soil physicist and authority on greenhouse soils, came to the Michigan Agricultural College in 1910.

L. S. Robertson, soil conservationist and early proponent of conservation tillage or no-till, came to MSU in 1943.

Manly Miles, the first professor of scientific agriculture in the United States, came to the Michigan Agricultural College in 1860.

Ray L. Cook, was a soil management specialist and effective leader of the Soil Science Department for 15 years.

Max Mortland, a soil chemist who came to MSU in 1953, identified the physical and chemical relationships of clay minerals.

Eugene Whiteside, a soil scientist who came to MSU in 1949, quantified the Spodosol soil order.

Photos courtesy of MSU Archives & Historical Collections.

(Healthy Soils — continued from page 19.)

cherry tree decline in western Michigan.

Suspecting bacteria and parasitic nematodes as the culprits, Melakeberhan and his colleagues took samples from the trees back to the greenhouse but were unable to recreate the disease that was killing the trees. That was when he had an epiphany.

"I said, 'I think we need to scrap everything and go back and look at the soil,'" Melakeberhan said.

Returning to the cherry orchards, the MSU team took soil samples across the root zone down to 6 feet below the surface and discovered that the soil pH there was significantly lower than what was normal for the area. They reproduced these conditions in the lab, and, in combination with the nematodes and bacteria, the disease manifested. They traced the low soil pH to the use of ammonium fertilizers instead of nitrate, and when they advised growers to change fertilizers and add lime, the disease was mitigated.

"This stood as a case study for how to do science in the field for many years," Melakeberhan said.

In addition to helping growers fight off detrimental nematodes, Melakeberhan's research also helps them take advantage of the beneficial species. The beneficial nematodes that feed on bacteria, fungi and other nematodes are part of the soil food web, driving nutrient cycling and soil organic matter accumulation. Using community structure analyses models, Melakeberhan's team can help growers evaluate their soil health and identify necessary changes to improve it as habitat for helpful organisms.

Managing harmful and beneficial nematodes in a diverse agricultural state such as Michigan becomes a complex juggling act. Melakeberhan's team has developed a fertilizer use efficiency-based model that separates nutrient deficiency and toxicity from harmful and beneficial nematode suppression, and yield and soil quality benefits.

"You need the kind of biological activity that nematodes provide for nitrogen to be released while suppressing harmful nematodes," Melakeberhan said. "That's where the sustainability of soil health starts. Different soils behave differently, and you need to understand those differences in order to effectively manage them for beneficial organisms."

Conducting a study spanning Michigan's Huron and Saginaw counties, which feature loam and sandy clay loam soils, respectively, Melakeberhan studied soil differences in radish, mustard, sugar beet, soybean and corn fields. His team found that different soils react to cropping systems in different ways. For example, corn crops showed more nitrogen availability in Huron County's loam soil than in the sandy clay loam of Saginaw County. The cause of these disparities is the subject of future research.

"We have to go to the next level to identify the causes and how to adjust the soil," Melakeberhan said. "The way to do that is to find out which organisms are driving the food web in those soils."

In systems dominated by bacteria-feeding nematodes, which have a much shorter life cycle than other species, the soil tends to see nitrogen become available in brief, nutrient-rich bursts. Melakeberhan would like to see growing populations of longer lived nematodes to stabilize nitrogen availability.

"The impact for the grower from this work is that now we can test soil treatments to make these changes," Melakeberhan said. "This is a significant step in managing soil health."

Better soil, better food

Tackling the complex issues surrounding soil health is helping farmers around the world produce food with higher yields more reliably and with reduced impact on the environment.

"The most fulfilling part of this work is answering questions that matter and being able to ask them and search for answers in an environment where everyone else is just as excited about it as you are," Robertson said. "Soils are the key to productive croplands and a healthy environment, and we're working to ensure we have those in the future."

This will only prove more important as time and the human population march on.

"Having soil with richer organic matter means you can get through a longer dry spell and rely less on irrigation and fertilizer, and as we move toward a more weather-inconsistent future, we're going to need more of those buffers," Snapp said. "We're going to have to feed 9 billion people in the future, and we have to know if we can do that."

Source: Food and Agriculture Organization of the United Nations.

FACILITY FOCUS

Soil and Plant Nutrient Laboratory
Plant and Soil Sciences Building
1066 Bogue St., Room A81
East Lansing, MI 48824-1325

Phone: 517-355-0218
Website: soiltesting.msu.edu

In an unassuming lab in the bowels of the Plant and Soil Sciences Building, **Jon Dahl** and his staff are busy running tests and giving recommendations on soil samples from around the state. Dahl manages the Soil and Plant Nutrient Laboratory (SPNL), which offers a variety of analytical services involving soil samples, greenhouse growth media, composts, plant tissue, water and other materials used to grow plants. Samples come from commercial and part-time farmers, greenhouse operations, golf courses, homeowners, consultants, researchers and others. The SPNL, which works closely with MSU Extension, conducts tests on about 10,000 soil samples a year.

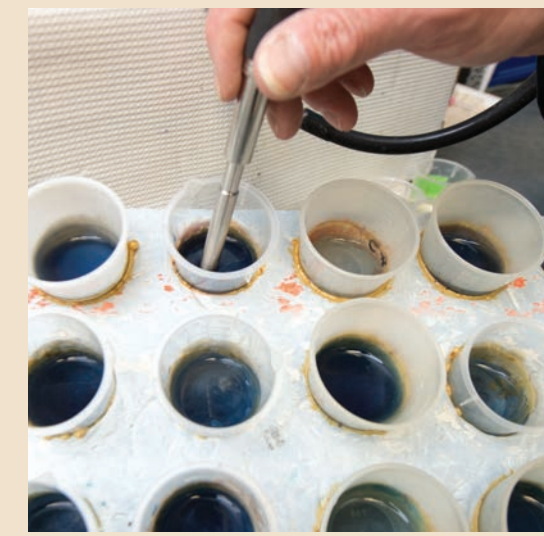
"We analyze whether the soil pH is acidic or basic, and we measure the amounts of basic nutrients such as potassium, phosphorus, calcium and magnesium," Dahl explained. "After the analysis, the lab can provide information on the kinds of fertilizers or lime needed to get the best growth possible for the intended purpose."

Soil testing boxes are available for sale to commercial customers at the lab; homeowners can purchase a self-mailer from University Stores on Service Road or online at www.msusoiltest.com. The mailer gives instructions on how to take the soil sample. Homeowners then drop the prepaid package in the mail, and the results are emailed to the homeowner, usually within two weeks.

"The self-mailer is very popular, and the number of homeowners using this service is growing," said Dahl, who has worked at the lab for more than 30 years. "We currently do about 3,000 homeowner samples per year."

There has been a soil testing lab on the MSU campus since the 1920s. During the first half of the 20th century, Extension specialists took train cars and pickup trucks out to farmers to conduct simple analyses. Today, technology is helping to speed up results and make them more accurate.

"The equipment has definitely gotten better," Dahl explained. "It's more automated, so less labor is involved, and clients get accurate results more quickly."



TOP: Jon Dahl is manager of the MSU Soil and Plant Nutrient Laboratory where about 10,000 samples are examined on an annual basis.

ABOVE: In the colorimetric test, a chemical reacts with the soil phosphorus and produces a blue color. The darker the blue of the extract, the more phosphorus is in the soil. This is an important soil measurement because Michigan soils tend to be generally high in phosphorous. *Photos by Gregory Kohuth.*

MSU AgBioResearch supports a network of campus laboratories and 13 off-campus research centers that provide more than 300 scientists the opportunity to focus their research and outreach activities on the agricultural and natural resource needs of particular regions of the state. The off-campus centers range in location from Chatham in the Upper Peninsula to Benton Harbor in southwestern Michigan. Each is dedicated to high-quality science and innovation that benefit the state and its citizens.

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10 TOP SOILS in Michigan

The predominant soils in key regions of Michigan, along with descriptions of the soil. There are more than 4,000 different soil types, with 500 identified in the state.

To learn more about Michigan's varied soils, visit: nrcs.usda.gov

Did you know? The official soil of Michigan is Kalkaska, a sandy mixture. It was first described in 1927 in Kalkaska County, the source of the series name. It is found in 29 of the state's 83 counties in both the Lower and Upper Peninsula. It was formed in the sandy deposits left by the glaciers that once covered the state. It is used primarily to grow hardwood timber, with some areas used for Christmas tree and specialty crop production. There are 750,000 acres of Kalkaska soil in Michigan.

7-15 4M